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Abstract

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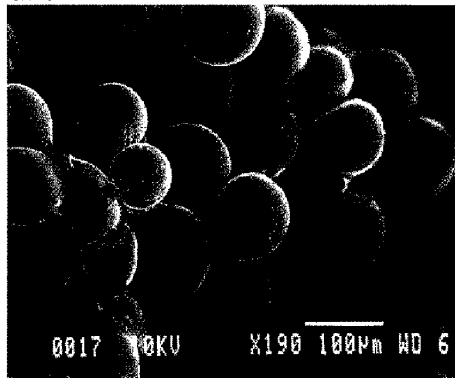


(1 7)

低出力レーザーを使用した脂肪分解装置

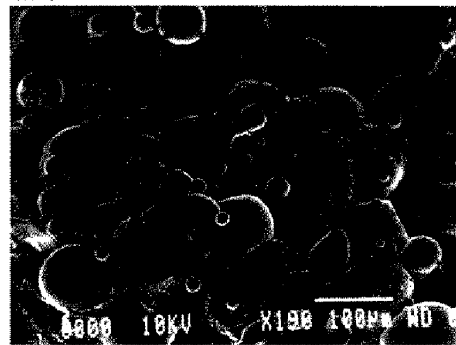
【図1】

【図1】



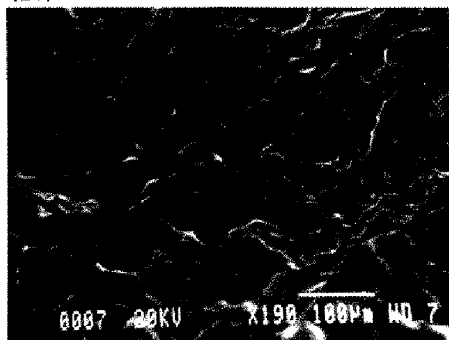
【図2】

【図2】



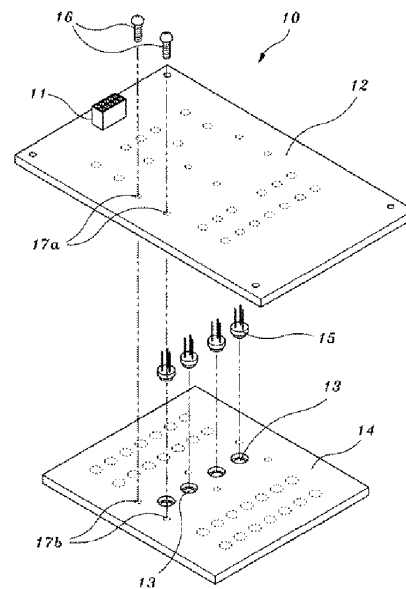
【図3】

【図3】



【図4】

【図4】





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(21) 出願番号	特願2007-537813 (P2007-537813)	(73) 特許権者	507130314
(86) (22) 出願日	平成18年2月28日 (2006.2.28)		メリディアン カンパニー リミテッド
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(87) 国際公開日	平成18年9月8日 (2006.9.8)	(74) 代理人	100102842
審査請求日	平成19年4月19日 (2007.4.19)		弁理士 葛和 清司
(31) 優先権主張番号	10-2005-0017330	(72) 発明者	ミョン、ヒョン セオン
(32) 優先日	平成17年3月2日 (2005.3.2)		大韓民国 ソウル 132-040、ドボ
(33) 優先権主張国	韓国 (KR)		ンーク、チャンードン、815、ヒュンデ
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(54) 【発明の名称】 低出力レーザーを使用した脂肪分解装置

(57) 【特許請求の範囲】

【請求項 1】

低出力レーザーを使用した脂肪分解装置であって、
電源コネクタを具備する PCB (Printed Circuit Board) 12
と、該 PCB 12 に対応する硬性プレートからなり、その一側面に複数の透明窓（または
レンズ）13 が均一に配列された接触板体 14 と、該接触板体 14 に配列された各透明窓
（またはレンズ）13 に挿着され、前記 PCB 12 に電氣的に連結された複数のレーザー
ダイオード 15 とを有するレーザー発生部 10；及び
該レーザー発生部 10 をその内部に収容して皮膚に容易に密着するフレーム 30；
を具備し、低出力レーザーを皮膚に照射して、脂肪を液状化して脂肪細胞から排出させる
ことにより、皮下脂肪を分解することを特徴とする、前記低出力レーザーを使用した脂肪
分解装置。

【請求項 2】

レーザー発生部 10 で生成される各々のレーザーの出力が、10 mW～100 mWであ
ることを特徴とする、請求項 1 に記載の低出力レーザーを使用した脂肪分解装置。

【請求項 3】

接触板体 14 が、レーザーダイオード 15 から発生される熱を放熱するための放熱板体
をさらに含むことを特徴とする、請求項 1 または 2 に記載の低出力レーザーを使用した脂
肪分解装置。

【請求項 4】

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接触板体 1 4 が、皮膚接触に適した楕円曲面に折曲形成され、前記接触板体 1 4 が収容されるフレーム 3 0 が前記接触板体 1 4 に対応した楕円曲面に折曲形成されていることを特徴とする、請求項 1 ～ 3 のいずれかに記載の低出力レーザーを使用した脂肪分解装置。

【請求項 5】

フレーム 3 0 の片側または両側の適所に取っ手 3 1 を具備することを特徴とする、請求項 1 ～ 4 のいずれかに記載の低出力レーザーを使用した脂肪分解装置。

【請求項 6】

フレーム 3 0 の両端部に回動可能に具備されたヒンジ 3 3 に他のフレーム 3 0' が各々連結されていることを特徴とする、請求項 1 ～ 5 のいずれかに記載の低出力レーザーを使用した脂肪分解装置。

【請求項 7】

低出力レーザーを使用した脂肪分解装置であって、電源コネクタを具備した P C B (Printed Circuit Board) 1 2 と、該 P C B 1 2 に対応する硬性プレートからなり、その一側面に複数の透明窓（またはレンズ） 1 3 が均一に配列された接触板体 1 4 と、該接触板体 1 4 に配列された各透明窓（またはレンズ） 1 3 に挿着され、前記 P C B 1 2 に電氣的に連結された複数のレーザーダイオード 1 5 とを有するレーザー発生部 1 0 ；

該レーザー発生部 1 0 をその内部に収容するフレーム 3 0 ；及び、

該フレーム 3 0 の前面に配置され、前記フレーム 3 0 の形状に対応する形状を有し、吸引口 5 1 及び該吸引口 5 1 に真空吸引部 5 4 を通じて連結された真空ライン 5 6 と、該真空ライン 5 6 に連結されて所定圧力の真空を形成する真空ポンプ 5 7 とを備え、皮膚に接触可能に形成された真空吸引手段 5 0 ；

を具備し、皮膚に真空吸着した後、低出力レーザーを皮膚に照射して、脂肪を液状化して脂肪細胞から排出させることにより、皮下脂肪を分解することを特徴とする、前記低出力レーザーを使用した脂肪分解装置。

【請求項 8】

真空吸着手段 5 0 が、フレーム 3 0 に着脱自在に連結されていることを特徴とする、請求項 7 に記載の低出力レーザーを使用した脂肪分解装置。

【請求項 9】

接触板体 1 4 が、可変可能であることを特徴とする、請求項 7 または 8 に記載の低出力レーザーを使用した脂肪分解装置。

【請求項 1 0】

低出力レーザーを使用した脂肪分解装置であって、

吸引口 5 1 と、該吸引口 5 1 に真空吸引部 5 4 を通じて連結される真空ライン 5 6 と、該真空ライン 5 6 に連結されて所定圧力の真空を形成する真空ポンプ 5 7 とを具備し、結合孔 5 2 を有する結合部 5 9 がその上部中央に突出形成された真空吸引手段 5 0 ；並びに該真空吸引手段 5 0 に結合され、ケーブル 7 1 a によって電源の供給を受ける P C B 7 1 と、該 P C B 7 1 に電氣的に接続するレーザーダイオード 7 2 と、該レーザーダイオード 7 2 の近接して適切に具備された透明窓（またはレンズ） 7 3 と、前記 P C B 7 1、レーザーダイオード 7 2 及び透明窓（またはレンズ） 7 3 を収容して、着脱自在に形成され上部定着口 7 4 及び下部定着口 7 5 と、該上部定着口 7 4 及び下部定着口 7 5 の外側に具備したカバー体 7 6 とを有するレーザー発生モジュール 7 0 ；

を含み、皮膚に真空吸着した後、該当の皮膚に低出力レーザーを照射して、脂肪を液状化して脂肪細胞から排出させることにより、皮下脂肪を分解すると同時に排出を助けて、頭皮を刺激して発毛促進をはかることを特徴とする、前記低出力レーザーを使用した脂肪分解装置。

【請求項 1 1】

上部定着口 7 4 の下部外周縁と下部定着口 7 5 の上部内周縁に、互いにネジ結合するための雄ネジ部 7 4 a と雌ネジ部 7 5 a が各々形成され、前記上部定着口 7 4 の内周縁適所に P C B 7 1 を結合するための係止突起 7 4 b が形成され、前記下部定着口 7 5 の下側内

周縁適所に透明窓（またはレンズ）73を結合するための溝75bが形成されていることを特徴とする、請求項10に記載の低出力レーザーを使用した脂肪分解装置。

【請求項12】

吸引口51の適所に手動で吸引口51内の真空及び陰圧を解除するための手動陰圧解除孔58が形成されていることを特徴とする、請求項10または11に記載の低出力レーザーを使用した脂肪分解装置。

【請求項13】

吸引口51の端部に挿入溝58aが環形に形成されており、前記挿入溝58aにボール58bを回転自在に具備することを特徴とする、請求項10～12のいずれかに記載の低出力レーザーを使用した脂肪分解装置。

【請求項14】

真空吸引部54に一方向弁（One-way valve）55を具備することを特徴とする、請求項10～13のいずれかに記載の低出力レーザーを使用した脂肪分解装置。

【請求項15】

真空吸引部54を通じて吸引口51内の空気を吸引時に前記吸引口51内の空気が所定間隔で繰り返し吸引されるリズムモードと、前記吸引口51内の空気が吸引された状態を継続的に維持する維持モードとが作動するようにし、使用者の設定によって選択可能に構成されていることを特徴とする、請求項10～14のいずれかに記載の低出力レーザーを使用した脂肪分解装置。

【請求項16】

レーザー発生モジュール70を有する真空吸引手段50が、その適所に設けられた真空吸引部93に連結された連結真空ライン91が複数分岐した中継器90を有し、前記各連結真空ライン91が他のレーザー発生モジュール70を有する真空吸引手段50と真空吸引部93によって連結されていることを特徴とする、請求項10～15のいずれかに記載の低出力レーザーを使用した脂肪分解装置。

【請求項17】

中継器90から分岐された連結真空ライン91中のいずれか一つの連結真空ライン91が、真空ポンプ95に連結され、他の一つの連結真空ライン91が他の中継器90に連結されていることを特徴とする、請求項16に記載の低出力レーザーを使用した脂肪分解装置。

【請求項18】

低出力レーザーが、波長635～680nmで出力30mW以上の赤色レーザーと、波長780～980nmで出力50mW以上の赤外線レーザーを混用することを特徴とする、請求項1～17のいずれかに記載の低出力レーザーを使用した脂肪分解装置。

【発明の詳細な説明】

【技術分野】

【0001】

本発明は、低出力レーザーを使用した脂肪分解装置に関するものである。より詳細には、レーザーの透過特性を活用してレーザービームをレンズで集束したり、または透明窓を通じてそのまま皮膚に非侵襲的に照射して、照射されたレーザービームが皮膚と組織を透過して組織内の脂肪細胞に照射されるようにすることによって、レーザー照射治療方法を非侵襲的に変えながらも既存の超音波や低出力レーザーを使用した皮膚切開などを通じて外部に露出した脂肪を分解する場合と同一な効果を得ることができ、真空吸引手段を含むことによって脂肪細胞から排出されて細胞組織の空間に集中する液状化した脂肪をリンパ管が豊富に分布した鼠蹊部を通じて体外に容易に排出させて、人体の皮膚に安定的に接触して脂肪を分解することによって、使用上の便宜性を提供するだけではなく、腹部などに低出力レーザーを照射することによって外科的な脂肪吸引術とは異なり、外科的な施術による皮膚の損傷なしに皮下脂肪を分解できる、腹部肥満に効果的な低出力レーザーを使用した脂肪分解装置に関するものである。

【背景技術】

【0002】

一般的に、低出力レーザーを発生させる装置は、5 mW乃至10 mW範囲の出力と635 nm乃至650 nm程度の波長を有するレーザーを放出するレーザーダイオード及び該レーザーダイオードから放出されるレーザーのビーム量を任意に調節可能にする低出力レーザーダイオード駆動ドライバーを使用している。

【0003】

このような低出力レーザーを使用して人体の経穴（つぼ）や患部に照射することにより、疾病治療効果を得るための装置が多数紹介されている。そのような装置の例を挙げると、低出力レーザーダイオードの均一ビームを具現する電気マット（実用新案登録第20-0302173号）と、身体の腰部位に着用するベルトにレーザーダイオードを内設して580～980 nm波長のレーザー光を発生させて身体腰椎部に対して刺激を加えるようにすることで、常時に指圧と同時にディスク治療がなされるようにしたレーザー発生装置を内設したベルト（実用新案登録第20-0270882号）と、経穴照射はもちろん、慢性関節リュウマチ、五十肩、腰痛、頸椎捻挫、痛風、捻挫、打撲、関節炎、ストレス性胃炎等にもその治療範囲を広げた治療用レーザー／LED蒲団（実用新案登録第20-0274266号）及び本出願人が開発に成功したレーザービーム照射装置で、光学レンズに集束されるレーザービームの距離を血管の位置と厚さによって調節して血管内の血液にレーザービームを非侵襲的に照射することにより、照射されたレーザービームが血液細胞を刺激して細胞の代謝作用を活性化させて、毛細管の形成が増加して血液循環を改善するだけではなく、組織治療過程の速度を増加させて生体活性化を増大させるレーザービーム照射装置（特許登録第10-0457964号）などが知られている。

【0004】

ここで、また他のレーザーの使用事例としては、レーザービームをアレイ（Array）に配列して使用上の便宜性を付与する方式で、椅子、帽子、ベッド、ベルトなどの軟性材質に多様に適用させる方法が提案されたが、非侵襲で脂肪分解を起こす程度（約30 mW以上）の出力が可能な赤色レーザーを使用しなければならない場合には、前記赤色レーザーに別途の放熱構造を追加しなければならないので、軟性材質に脂肪分解を目的とするレーザービームをアレイに配列することは実効性が無く、したがって現在としては非侵襲的な方法で人体にレーザーを照射して脂肪を分解する方法は全くないのが実情である。

【0005】

一方、肥満治療を目的とするレーザーの使用効果においては、2002年頃、ネイラ（Neira）等によって低出力レーザー装置を使用すれば脂肪吸引状態の間、脂肪が液化されることを証明した新しい脂肪吸引術が発表された。{PLASTIC AND RECONSTRUCTIVE SURGERY, 2002年, 9月1日, -Fat Liquefaction: Effect of Low-Level Laser Energy on Adipose Tissue}

【0006】

前記論文は、635 nmの波長と10 mWの出力及び1.2 J/cm²、2.4 J/cm²及び3.6 J/cm²の総エネルギー量を有するレーザーを12人の健康な女性たちから採取した脂肪組織に照射する実験に基づいている。実験の結果、レーザー露出の4分後には80%、6分後には99%の脂肪が脂肪細胞から放出され、放出された脂肪は細胞組織の空間に集められた。

【0007】

図1は、190倍の倍率で撮影された正常な脂肪細胞の電子顕微鏡写真で、図2は低出力レーザーを4分間照射した後の脂肪細胞を190倍の倍率で撮影した電子顕微鏡写真であり、図3は低出力レーザーを6分間照射した後の脂肪細胞を190倍の倍率で撮影した電子顕微鏡写真である。図1でははっきりと確認することができるように正常な脂肪細胞は、その外形が丸くて典型的なぶどう房（grape-cluster）模様を成している。このような正常な脂肪細胞に低出力レーザーを4分間照射すると図2に図示されているように一部脂肪細胞はその内部から液状化した脂肪が排出されて、このような脂肪細胞の

外形は丸い模様を次第に失って行くようになる。図2の矢印で表示された部分は、脂肪細胞の外部に排出された脂肪粒子 (fat particle) を示す。低出力レーザーを6分間照射するとこのような変化はほとんどすべての脂肪細胞で起きるようになって、図3に見られるように円形を維持する脂肪細胞は発見されず、液状化した脂肪だけが観察される。図3で矢印で表示された部分は、脂肪細胞の外部に排出された脂肪を示す。

【0008】

低出力レーザーエネルギーは、脂肪細胞の内側から外側へ脂肪物が出るように細胞膜を開くことにより、脂肪細胞に影響を与えることが報告されている。

【0009】

この実験を基に、低出力赤色レーザーの脂肪液化効果を使用して、人体外部からレーザーを照射して脂肪を分解しながら、その分解された脂肪をカニューレ（微細パイプ）を使用して人体の外に排出させるレーザー脂肪吸引術が提案されて実施されている。

【0010】

そのために人体内部の脂肪細胞に非侵襲的にレーザービームを照射して脂肪細胞の脂肪を分解する目的で、赤色レーザービームを治療対象の脂肪層を覆っている皮膚の上に照射する試みが行われ、短時間に広い面積を照射するために赤色レーザービームをライン (Line) 形態に作って治療部位にスキャン (Scan) する方式が試みられて製品化にまで至ったが、人体内部の脂肪分解に必要なエネルギー強度 (10 mW) とエネルギー量 (3.6 J/cm²) の人体内投入が困難で実効を得られないでいる。

【発明の開示】

【発明が解決しようとする課題】

【0011】

このような根拠に基づいて本発明は、低出力レーザーを使用して脂肪を分解するための装置に関するもので、レーザーの透過特性を活用してレーザービームをレンズで集束したりまたは透明窓を通じてそのまま皮膚に非侵襲的に照射して、照射されたレーザービームが皮膚と組織を透過して組織内の脂肪細胞に照射されることで、レーザー照射治療方法を非侵襲的に変えながらも既存の超音波や低出力レーザーを使用した皮膚切開などを通じて外部に露出した脂肪を分解する場合と同一な効果を得ることが可能な低出力レーザーを使用した脂肪分解装置を提供することをその目的とする。

【0012】

また、本発明は前記のような低出力レーザーを使用した脂肪分解装置を使用して、低出力レーザーを皮膚に照射した際に脂肪細胞から排出されて細胞組織の空間に集まっている液状化された脂肪を、リンパ管が豊富に分布した鼠蹊部を通じて体外に容易に排出されるように誘導することができる、真空吸引手段を含む低出力レーザーを使用した脂肪分解装置を提供することをまた他の目的とする。

【課題を解決するための手段】

【0013】

前記の目的を果たすために本発明は、低出力レーザーを使用した脂肪分解装置であって、電源コネクタを具備したPCB (Printed Circuit Board) と、該PCBに対応する硬性プレートからなり、その一側面に複数の透明窓またはレンズが均一に配列された接触板体と、該接触板体に配列された各透明窓またはレンズに挿着され、前記PCBに電氣的に連結された複数のレーザーダイオードとを有するレーザー発生部、及び前記レーザー発生部をその内部に収容して皮膚に容易に密着するフレームを具備し、低出力レーザーを皮膚に照射して皮下脂肪を分解することを特徴とする。

【0014】

前記レーザー発生部で生成される各々のレーザーの出力が、10 mW～100 mWであることが好ましい。

【0015】

ここで、前記接触板体がレーザーダイオードで発生する熱を放熱するための放熱板体をさらに含む。

【0016】

併せて、前記接触板体が皮膚接触に適した楕円曲面に折曲形成されて、前記接触板体が収容されるフレームが接触板体と対応する楕円曲面に折曲形成される。

【0017】

一方、前記フレームの片側または両側の適所に取っ手が具備する。

【0018】

代案的には、前記フレームの両端部に回動可能に具備されるヒンジにまた他のフレームが各々連結される。

【0019】

一方、低出力レーザーを使用した脂肪分解装置であって、電源コネクタが具備された PCB (Printed Circuit Board) と、前記 PCB に対応する板体形状体で、その一側面に複数の透明窓またはレンズが均一に配列された接触板体と、該接触板体に配列された各透明窓またはレンズに挿着され、前記 PCB に電氣的に連結された複数のレーザーダイオードとを有するレーザー発生部、該レーザー発生部がその内部に収容されたフレーム、及び該フレームの前面に配置され、該フレームの形状に対応する形状を有し、吸引口と該吸引口に真空吸引部を通じて連結された真空ラインと該真空ラインに連結された真空ポンプとを備え、皮膚に接触可能に形成された真空吸引手段を具備し、皮膚に真空吸引した後、低出力レーザーを皮膚に照射して皮下脂肪を分解する。

【0020】

前記真空吸引手段は、前記フレームに着脱自在に連結されることが、好ましい。

【0021】

さらに、前記接触板体の形状は、多様な形状に変形可能である。

【0022】

一方、低出力レーザーを使用した脂肪分解装置において、吸引口と、該吸引口に真空吸引部を通じて連結される真空ラインと、該真空ラインに連結される真空ポンプからなり、その上部中央に結合孔を有する結合部が所定部分突出形成された真空吸引手段、該真空吸引手段に結合されてケーブルによって電源を供給受ける PCB と、該 PCB に電氣的に連結されるレーザーダイオードと、該レーザーダイオードの近接する適所に具備される透明窓またはレンズと、前記 PCB とレーザーダイオードと透明窓またはレンズを収容して、着脱自在に形成された上部定着口、下部定着口と、該上部定着口、下部定着口の外側に具備されるカバー体からなるレーザー発生モジュールとを含み、皮膚に真空吸引した後、該当皮膚に低出力レーザーを照射して皮下脂肪を分解すると同時に排出を助けて、頭皮を刺激して発毛促進をはかる。

【0023】

好ましくは、前記上部定着口の下部外周縁と下部定着口の上部内周縁にネジ結合のための雄ネジ部と雌ネジ部を各々形成し、前記上部定着口の内周縁適所に前記 PCB を結合するための係止突起を形成して、前記下部定着口の下側内周縁適所に前記透明窓（またはレンズ）を結合するための溝を形成する。

【0024】

代案的には、前記吸引口の適所に手動で吸引口内の真空及び陰圧を解除するための手動陰圧解除孔を貫通形成する。

【0025】

併せて、前記吸引口の端部に環形の挿入溝を形成して、該挿入溝にボールを回転可能に具備する。

【0026】

一方、前記真空吸引部に一方向弁 (One-way valve) を具備する。

【0027】

前記真空吸引部を通じて吸引口内の空気を吸引時に吸引口内の空気が所定間隔で反復して吸引されるリズムモードと、吸引口内の空気が吸引された状態を継続的に維持する維持モードが作動するようにして、使用者の設定によって選択的に適用可能にすることが、好

ましい。

【0028】

一方、前記レーザー発生モジュールを有する真空吸引手段の適所に、真空吸引部に連結された連結真空ラインが複数分岐した中継器を具備し、前記各連結真空ラインが、また他のレーザー発生モジュールを有する真空吸引手段と真空吸引部によって連結される。

【0029】

代案的には、前記中継器で分岐される連結真空ライン中のいずれか一つの連結真空ラインを真空ポンプに連結して、他の一つの連結真空ラインはまた他の中継器に連結する。

【発明を実施するための最良の形態】

【0030】

以下、本発明の好ましい実施例を添付した図面によって具体的に説明する。

【0031】

図4は、本発明による低出力レーザーを使用した脂肪分解装置のレーザー発生部を示す分解斜視図で、図5は本発明による低出力レーザーを使用した脂肪分解装置のレーザー照射分布範囲を示す例示図で、図6は本発明による低出力レーザーを使用した脂肪分解装置を示す斜視図である。

【0032】

図面に図示しているように、本発明による低出力レーザーを使用した脂肪分解装置1は、レーザー発生部10とフレーム30を含んでいる。

【0033】

前記レーザー発生部10は、電源の供給受けるための電源コネクタ11が具備されたPCB(Printed Circuit Board、印刷回路基板)12と前記PCB12に対応する板体形状体で、その一側面に透明窓(またはレンズ)13が均一に多数配列される接触板体14と該接触板体14に配列される各透明窓(またはレンズ)13に挿着されて、前記PCB12に電気的に連結される多数個のレーザーダイオード15からなる。

【0034】

前記フレーム30は、前記レーザー発生部10をその内部に収容可能に形成される。ここで、前記レーザー発生部10は、前記フレーム30の前面内側に収容されて使用者の皮膚にレーザーを照射する。

【0035】

一方、前記PCB12と接触板体14の適所に締結ボルト16で締結可能にする多数個の締結孔17a、17bが各々貫通形成される。すなわち、前記PCB12に多数個のレーザーダイオード15を設置するが、前記レーザーダイオード15を接触板体14のレンズ(または透明窓)13に挿着した後、PCB12と接触板体14を結合させるために前記PCB12と接触板体14の適所に多数個の締結孔17a、17bを形成して、該締結孔17a、17bに締結ボルト16を締結することで、PCB12と接触板体14が一体に結合される。

【0036】

そして、前記接触板体14に配列されるレンズ(または透明窓)13は、規則的に多数配列及びアレイ(array)になるようにすることが好ましく、接触板体14に配列されるレンズ(または透明窓)13の数に対応するレーザーダイオード15が挿着されるように形成することが好ましい。

【0037】

本発明の一実施例では、前記接触板体14に配列されるレンズ(または透明窓)13の配列が規則的に多数配列されているが、皮膚に接触した後、レーザーを照射して使用者の皮下脂肪を分解することが容易であれば、前記接触板体14に配列されるレンズ(または透明窓)13の配列を不規則的に多数配列することも可能である。

【0038】

ここで、前記接触板体14の形状は、四角形、円形などからなることも可能であるが、

その他多様な形状に変形可能である。

【0039】

一方、前記レーザー発生部10で生成される各々のレーザーの出力は、10mW～100mWの低出力からなる。すなわち、使用者の皮膚に照射して皮下脂肪を分解するために、前記レーザー発生部10のレーザーダイオード15で生成される各々のレーザーの出力は、人体浸透時の減殺を考慮して各レーザーの出力を強化するが、10mW～100mWの低出力を照射するようにする。

【0040】

前記のように、前記レーザー発生部10で生成される各々のレーザーの出力が、10mW～100mWの低出力からなり、レーザー発生部10が使用者の皮膚に密着する平面アレ

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【0041】

そのために皮下脂肪が集中する腹部など、使用者の皮膚に接触が容易なように前記接触板体14は、楕円曲面に折曲形成することが好ましく、前記接触板体14が収容されるフレーム30の形状も接触板体の形状と対応する楕円曲面に折曲形成することが好ましい。

【0042】

本発明の一実施例では、前記接触板体14が楕円を有する曲面形状に折曲形成されているが、前記接触板体14が接触する使用者の身体部位によって多様な曲面を有するなど、接触板体の形態が多様に変形されることが好ましい。

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【0043】

また、使用者の皮膚に接触する接触板体14は、結合及び設置が容易な硬性プレートからなることが好ましく、それを通じて使用者の皮膚により容易に密着するようになる。

【0044】

一方、前記接触板体14は、レーザーダイオード15で発生する熱を放熱するために放熱板体をさらに含んで成り立つ。すなわち、前記接触板体14に設置されるレーザーダイオード15は、レーザー発生時に相当な熱が発生するのでそれを分散及び冷却させるために、接触板体14が放熱板体をさらに含んで成り立つ。本発明の一実施例では、前記接触板体14に放熱板体をさらに含んでなる構造及び形態で成り立っているが、前記接触板体14が放熱材質からなることも可能である。

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【0045】

ここで、前記フレーム30の片側または両側の中心部の適所に使用者が手で把持するための取っ手31を具備する。本発明の一実施例では、前記フレーム30の片側または両側の中心部の適所に取っ手31を具備しているが、使用者が前記フレーム30を把持した後、使用が容易であれば前記把持部31をフレーム30の上側面または下側面中心の適所に取っ手31を具備することも可能である。

【0046】

一方、前記フレーム30の後面に医師または使用者がフレーム30を上下左右に位置を変更することができる位置移動手段35をさらに含むことも可能であり、その具体的な構造及び説明は省略する。すなわち、医療用施設の中で医師が取っ手31を把持した後、引っ張りながらその位置を自由に移動及び変更することができる装備と同様に人体の皮膚に接触可能に成り立つ接触手段を有するフレーム30を、使用者の便宜によって上下左右に位置を移動及び変更するように報告された位置移動手段35を前記フレーム30の後面に具備することも可能であり、それを通じて使用者が所望する身体部位に前記フレーム30を移動させることが容易になる。

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【0047】

以下、本発明による低出力レーザーを使用した脂肪分解装置の使用方法及び過程を説明する。

【0048】

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まず、医療機関で医術を施術または施行することができる医師が、前記低出力レーザーを使用した脂肪分解装置 1 のフレーム 30 に具備された取っ手 31 を把持した後、皮下脂肪を分解するための使用者の皮膚適所に移動及び位置させて皮膚に密着させる。

【0049】

その次に、レーザー発生部 10 を駆動させてレーザーダイオード 15 を通じてレーザーを発生させると同時にレーザーを皮膚に照射する。

【0050】

ここで、レーザー発生部 10 の各レーザーダイオード 15 を通じて 10 mW～100 mW の低出力でレーザーが発生して、発生したレーザーは透明窓（またはレンズ）13 を通過した後、皮下脂肪を分解させるための皮膚に照射される。

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【0051】

前記のように、腹部などの使用者皮膚に照射されるレーザーによって皮下脂肪が分解されて、分解された皮下脂肪は医師の施術によって体外に排出される。

【0052】

ここで、本発明による低出力レーザーを使用した脂肪分解装置 1 は、赤色レーザーと赤外線レーザーを混用して、赤色レーザーは 635～680 nm で 30 mW 以上の出力を必要とし、赤外線レーザーは 780～980 nm で 50 mW 以上の出力を必要とする。以下では赤色レーザーと赤外線レーザーを区別なしに適用する。

【0053】

前記のように、レーザーダイオード 15 を通じて発生及び照射される低出力レーザーの照射範囲は、図 5 に図示したように、各レーザーダイオード 15 から照射されるレーザーの各照射範囲が楕円形になる。ここで、各レーザーダイオード 15 から照射されるレーザーの照射範囲が楕円形になることで、照射範囲が重なることなしにほとんど該当の接触部位にだけ照射されて皮下脂肪を分解することにより肥満解消作用を有する。

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【0054】

図 7 は、本発明による低出力レーザーを使用した脂肪分解装置の一実施例を示す斜視図で、低出力レーザーを使用した脂肪分解装置の一部構成を変えたものである。

【0055】

図 4、図 5 を参照して説明すると、図面で図示しているように、本実施例による低出力レーザーを使用した脂肪分解装置 1 は、フレーム 30 の両端部に回動可能に成り立つヒンジ 33 を具備し、前記各ヒンジ 33 にまた他のフレーム 30' が各々連結される。

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【0056】

すなわち、前記低出力レーザーを使用した脂肪分解装置 1 のフレーム 30 両端部にヒンジ 33 を設置して、前記ヒンジ 33 にまた他のフレーム 30' を各々連結して使用者の腹部周辺または腰周辺を包む形状に形成する。

【0057】

前記のように、レーザー発生部 10 を有するフレーム 30、30' をヒンジ 33 によって回動可能に多数連続的に連結することで、腹部はもちろん脇腹部など使用者の皮膚に立体的に接触可能になる。

【0058】

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本実施例では、前記フレーム 30 の両側面にヒンジ 33 を具備して、前記ヒンジ 33 によってまた他のフレーム 30' を連結する構造からなっているが、前記のまた他のフレーム 30' にヒンジ 33 を具備して、前記ヒンジ 33 によってまた他のフレーム 30' を連続的に設置することで、皮下脂肪を分解させるための使用者の身体構造にかかわらず使用が可能になる。

【0059】

一方、本実施例では、ヒンジ 33 によって連結される各フレーム 30、30' の前面に設置される接触板体 14 が平面で成り立っているが、使用者の腹部及び脇腹部に接触してレーザーを照射し容易いように楕円曲面またはその他の多様な曲面形状に折曲形成することも可能である。

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【0060】

また、前記接触板体14の形状は、四角形、円形、楕円形などからなることが好ましいが、その他の多様な形状に変形可能である。

【0061】

図8は、本発明による低出力レーザーを使用した脂肪分解装置の他の実施例を概略的に示す図面である。

【0062】

図4、図5を参照して説明すると、図面に図示しているように、本実施例では前記低出力レーザーを使用した脂肪分解装置1のレーザー発生部10と前記レーザー発生部10が収容されるフレーム30に真空吸引手段50がさらに含まれる。

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【0063】

すなわち、電源コネクタ11が具備されたPCB(Printed Circuit Board)12と該PCB12に対応する板体形状体で、その一側面に透明窓(またはレンズ)13が均一に多数配列される接触板体14と該接触板体14に配列される各透明窓(またはレンズ)13に挿着されて、前記PCB12に電氣的に連結される多数個のレーザーダイオード15からなるレーザー発生部10と、前記レーザー発生部10がその内部に収容されるフレーム30に真空吸引手段50がさらに含まれる。

【0064】

ここで、前記接触板体14は、レーザーダイオード15を通じて発生される熱を放熱するための放熱板体をさらに含む構造からなることが好ましいが、前記接触板体14が放熱材質からなることも好ましい。

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【0065】

前記真空吸引手段50は、前記フレーム30の形状(例えば、四角形や円形また楕円形など)と対応する形状を有する空間部をその前面に具備して、前記フレーム30が前記空間部に一体に連結されるようにする。また、前記真空吸引手段50は、皮下脂肪を分解させるための使用者の皮膚適所に接触する吸引口51を前記空間部の反対側に具備して、前記吸引口51に真空吸引部54を通じて連結される真空ライン56と該真空ライン56に連結されて所定圧力の真空を形成する真空ポンプ57からなる。

【0066】

ここで、前記真空ポンプ57は、真空吸引部54を通じて使用者の皮膚に接触された吸引口51内の空気を吸引して所定圧力の真空状態にして、前記真空ポンプ57によって吸引される空気は真空吸引部54及び真空ライン56を通じて移動する。

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【0067】

本実施例では前記真空吸引手段50が、前記低出力レーザーを使用した脂肪分解装置1の接触板体14の前面及びフレーム30と一体に連結される構造になっているが、図9に図示するように、前記真空吸引手段50が前記低出力レーザーを使用した脂肪分解装置1のフレーム30と結合可能に分離した構造であることも可能である。

【0068】

ここで、前記真空吸引手段50が、前記低出力レーザーを使用した脂肪分解装置1のフレーム30と、はめ込み結合またはネジ結合によって結合可能に分離した構造であることが好ましい。

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【0069】

前記のような構造及び形態によって、医師または使用者の必要により低出力レーザーを使用した脂肪分解装置1から真空吸引手段50を結合または分離して使用可能である。

【0070】

一方、前記真空吸引手段50の一側面端に使用者の皮膚に密着容易な形状の段差(図番号未図示)が形成されることが好ましい。

【0071】

以下、本実施例による低出力レーザーを使用した脂肪分解装置の使用方法及び過程を説明する。

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【0072】

まず、医療機関で医療を施術または施行することができる医師が、前記低出力レーザーを使用した脂肪分解装置1の真空吸引手段50を、皮下脂肪を分解するための使用者の腹部などの皮膚に密着させる。すなわち、前記真空吸引手段50の吸引口51を使用者の皮膚適所に密着させる。

【0073】

前記のように、前記真空吸引手段50の吸引口51を使用者の皮膚に密着させた後、真空ポンプ57を使用して吸引口51内に所定圧力の真空を形成させて、皮下脂肪を分解しようとする部分の皮膚を吸引口51の内周縁に密着して接触するように吸引する。

【0074】

そのように皮下脂肪を分解しようとする部分の皮膚を吸引口51の内周縁に密着するように吸引してレーザー発生部10の近接する位置に位置させた後、レーザー発生部10を駆動させてレーザーダイオード15を通じてレーザーを発生させると同時にレーザーを皮膚に照射する。

【0075】

すなわち、真空吸引手段50の吸引口51を腹部に付着させた後、真空ポンプ57で吸引して吸引口51の内側面に密着及び接触するようにして、接触した状態でレーザーを照射して腹部など皮膚の皮下脂肪を分解する。

【0076】

ここで、レーザー発生部10の各レーザーダイオード15を通じて10mW～100mWの低出力でレーザーを発生させ、発生したレーザーは透明窓（またはレンズ）13を通過した後、皮下脂肪を分解させるための皮膚に照射される。

【0077】

前記のように、真空吸引手段50によって吸引または吸着された皮膚に照射されるレーザーによって皮下脂肪が分解された皮下脂肪は、医師の施術によって体外に排出される。

【0078】

ここで、前記レーザーダイオード15から発生するレーザーによって分解された皮下脂肪は、真空吸引手段50の吸引口51内の真空によって吸引口51内に吸引及び吸着された皮膚の内側に位置するので、その内部が真空を成す吸引口51をスキャン形態で移動させると皮膚内で分解された皮下脂肪が移動するようになる。

【0079】

前記のような方法によってレーザーによって分解された皮下脂肪を前記真空吸引手段50の吸引口51を通じて人体の所定位置に移動させた後、鼠蹊部を通じて排出させることも可能である。

【0080】

図10は、本発明による低出力レーザーを使用した脂肪分解装置のまた他の実施例を示す分解図で、図11は本実施例による低出力レーザーを使用した脂肪分解装置の真空吸引手段とレーザー発生モジュールの結合断面図である。

【0081】

図4、図5を参照して説明すると、図面に図示しているように、本実施例では前記低出力レーザーを使用した脂肪分解装置1が、真空吸引手段50とレーザー発生モジュール70とからなる。

【0082】

前記真空吸引手段50は、皮下脂肪を分解させるための使用者の皮膚適所に接触するための吸引口51と該吸引口51に真空吸引部54を通じて連結する真空ライン56と該真空ライン56に連結されて所定圧力の真空を形成する真空ポンプ57とからなる。

【0083】

ここで、前記真空ポンプ57は、真空吸引部54を通じて使用者の皮膚に接触した吸引口51内の空気を吸引して所定圧力の真空状態を作り、前記真空ポンプに57によって吸引された空気は、真空吸引部54及び真空ライン56を通じて移動する。

【 0 0 8 4 】

一方、前記吸引口 5 1 の上部中央には、レーザー発生モジュール 7 0 を設置するために結合孔 5 2 を有する結合部 5 9 を所定部分の上方向に突出形成する。

【 0 0 8 5 】

前記レーザー発生モジュール 7 0 は、電源供給を受けるための P C B 7 1 と該 P C B 7 1 に電氣的に連結するレーザーダイオード 7 2 と該レーザーダイオード 7 2 と近接する適所に具備される透明窓（またはレンズ） 7 3 と前記 P C B 7 1 とレーザーダイオード 7 2 と透明窓（またはレンズ） 7 3 を収容して、着脱自在に成り立つ上部定着口 7 4、下部定着口 7 5 と前記上部定着口 7 4、下部定着口 7 5 の外側に具備されるカバー体 7 6 からなる。

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【 0 0 8 6 】

そして、前記上部定着口 7 4 の下部外周縁と下部定着口 7 5 の上部内周縁には、ネジ結合のための雄ネジ部 7 4 a と雌ネジ部 7 5 a を各々形成して、前記上部定着口 7 4 の内周縁適所には前記 P C B 7 1 が結合するための係止突起 7 4 b を形成して、前記下部定着口 7 5 の下側内周縁適所に前記透明窓（またはレンズ） 7 3 を結合するための溝 7 5 b を形成する。

【 0 0 8 7 】

ここで、前記上部定着口 7 4、下部定着口 7 5 に形成する雄ネジ部 7 4 a と雌ネジ部 7 5 a の締め付けまたは緩めることによって前記レーザーダイオード 7 2 と透明窓（またはレンズ） 7 3 との間の間隔調節が可能である。

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【 0 0 8 8 】

一方、前記 P C B 7 1 は、電源供給を受けるためのケーブル 7 1 a が連結され、前記カバー体 7 6 の上部に前記ケーブル 7 1 a を引入れるための引入孔 7 6 a を貫通形成する。

【 0 0 8 9 】

そして、前記真空吸引手段 5 0 とレーザー発生モジュール 7 0 には、相互に結合するために各々に具備される吸引口 5 1 の結合孔内周縁上側とカバー体 7 6 の外周縁にネジ結合のための雌ねじ部 5 3、雄ネジ部 7 6 b を形成して、前記上部定着口 7 4、下部定着口 7 5 には、レーザー発生モジュール 7 0 のレーザーダイオード 7 2 から発生する熱を放熱するための放熱材料が適用される。

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【 0 0 9 0 】

一方、前記吸引口 5 1 の適所には、手で吸引口 5 1 内の真空及び陰圧を解除するための手動陰圧解除孔 5 8 を貫通形成する。

【 0 0 9 1 】

すなわち、医師または使用者が吸引口の使用時に指を使用して手で吸引口 5 1 内の真空及び陰圧を解除するための手動陰圧解除孔 5 8 を貫通形成する。

【 0 0 9 2 】

本実施例では、前記吸引口 5 1 の適所に手動陰圧解除孔 5 8 が 1 個貫通形成されているが、吸引口 5 1 内の真空及び陰圧を解除することが容易であれば、前記手動陰圧解除孔 5 8 をそれ以上の数で貫通形成することも可能である。

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【 0 0 9 3 】

また、本実施例では前記吸引口 5 1 の適所に貫通形成される手動陰圧解除孔 5 8 が円形に貫通形成されているが、前記手動陰圧解除孔 5 8 を楕円形または四角形などその他多様な形状で貫通形成することも可能であり、前記手動陰圧解除孔 5 8 の直径または大きさも多様に可変可能である。

【 0 0 9 4 】

ここで、前記吸引口 5 1 の縁部には挿入溝 5 8 a を環形に形成して、前記挿入溝 5 8 a にボール 5 8 b を回転可能に具備する。すなわち、真空及び陰圧が設定された状態を有する吸引口 5 1 の移動を容易にするために、環形に形成された吸引口 5 1 の開放された側の下部面に挿入溝 5 8 a を延長形成して、前記挿入溝 5 8 a にボール 5 8 b を回転可能に具備する。

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【0095】

本実施例では、前記吸引口51の縁部にボール58bを回転可能に有する挿入溝58aを形成する構造によって、吸引口51が移動可能にしているが、前記吸引口51が真空及び陰圧が設定された状態で使用者の皮膚に沿って移動することができれば、前記吸引口51の縁部がその他の多様な構造からなることも可能である。

【0096】

一方、前記吸引口51に連結される真空吸引部54にチェックバルブ（Check valve）等からなる一方向弁（One-way valve）55を具備する。前記のように具備される一方向弁55によって吸引口51内の真空が所定圧力に維持される。

【0097】

そして、前記真空吸引部54を通じて吸引口51内の空気を吸引する場合、吸引口51内の空気を所定間隔で繰り返して吸引するリズムモードと、吸引口51内の空気が吸引された状態を継続的に維持する維持モードとが作動することが好ましく、これは使用者の設定によって選択的に適用可能であることが好ましい。

【0098】

本発明の一実施例では、前記吸引口51がその内部に真空を形成するための所定空間を有する半円形状に形成されているが、前記吸引口51がその内部に真空を形成するための所定空間を有し、真空ポンプ57によって所定圧力の真空を形成することが容易であれば、六面体形状または楕円形状からなることも可能で、その他の多様な形状に形成することも可能である。

【0099】

また、前記吸引口51の真空吸引部54端部の外周縁が使用者の皮膚に密着するように半円形状または楕円曲面に折曲形成することが好ましい。

【0100】

以下、本実施例による低出力レーザーを使用した脂肪分解装置の使用方法及び過程を説明する。

【0101】

まず、医療機関で医療を施術または施行することができる医師が前記低出力レーザーを使用した脂肪分解装置1の真空吸引手段50を、皮下脂肪を分解するための使用者の皮膚適所に密着させる。すなわち、前記真空吸引手段50の吸引口51を顔、首、肩、腋窩等の皮下脂肪を分解するための使用者の皮膚に密着させる。

【0102】

前記のように、前記真空吸引手段50の吸引口51を使用者の皮膚に密着させた後、真空ポンプ57を使用して吸引口51内に所定圧力の真空を形成させて皮下脂肪を分解しようとする部分の皮膚を吸引口51の内周縁に密着接触するように吸引する。

【0103】

前記のように皮下脂肪を分解しようとする部分の皮膚を吸引口51の内周縁に密着するように吸引してレーザー発生モジュール70に近接した位置に位置させた後、レーザー発生モジュール70を駆動させてレーザーダイオード72を通じてレーザーを発生させると同時に、レーザーを皮膚に照射する。

【0104】

すなわち、真空吸引手段50の吸引口51を顔、首、肩、腋窩等の皮下脂肪を分解するための使用者の皮膚に数個付着させた後、真空ポンプ57で吸引して吸引口51の内側面に密着及び接触するようにして、接触した状態でレーザーを照射して皮膚の皮下脂肪を分解する。

【0105】

ここで、レーザー発生部10の各レーザーダイオード72を通じて10mW～100mWの低出力でレーザーを発生させて、発生したレーザーは透明窓（またはレンズ）73を通過した後、皮下脂肪を分解するために皮膚に照射される。

【0106】

一方、前記レーザー発生モジュール70のレーザーダイオード72は、カバー体76を分離した後、上部装着口74、下部装着口75に形成された雄ネジ部74aと雌ネジ部75aを調節してレーザーダイオード72と透明窓（またはレンズ）73の間隔を調節して使用し、レーザーダイオード72と透明窓（またはレンズ）73の間隔は、設置及び施術初期に調節することが好ましい。

【0107】

前記のように、真空吸引手段50によって吸引または吸着された皮膚に照射されるレーザーによって皮下脂肪が分解された皮下脂肪は、医師の施術によって体外に排出される。

【0108】

ここで、前記レーザーダイオード72から発生するレーザーによって分解された皮下脂肪は、真空吸引手段50の吸引口51内の真空及び陰圧によって吸引口51内に吸引及び吸着された皮膚の内側に位置するので、前記吸引口51の縁部に形成された挿入溝58aに具備されたボール58bの回転によって、皮膚内をスキャン形態で移動させてリンパ管が豊富に分布した鼠蹊部を通じて外部に排出させる。

【0109】

前記のような方法によって、レーザーによって分解された皮下脂肪を前記真空吸引手段50の吸引口51を通じて人体の所定位置に移動させた後、外部に排出させることが好ましい。

【0110】

一方、前記真空吸引手段50の吸引口51に貫通形成された手動陰圧解除孔58を医師または使用者が手で開放または閉鎖することにより、吸引口51の真空及び陰圧が手動的に解除可能であり、これによってより容易に医師または使用者が吸引口51内に形成された真空及び陰圧を設定または解除することができる。

【0111】

本実施例による真空吸引手段50を頭に使用する場合、頭の血液循環を助けるだけではなく、頭皮を刺激して発毛を促進させるだけではなく、毛髪の成長を促進させることができる。

【0112】

一方、図12に図示しているように、レーザー発生モジュールを有する真空吸引手段の適所に中継器を具備することも可能である。図10、図11を参照して説明すると、前記レーザー発生モジュール70を有する真空吸引手段50の適所に中継器90を具備するが、前記中継器90は真空吸引部93を有する複数の連結真空ライン91に分岐され、前記真空吸引部93によって真空吸引手段50と連結され、また他の真空吸引部93を有する連結真空ライン91がまた他のレーザー発生モジュール70を有する真空吸引手段50の真空吸引部93に連結される。

【0113】

前記のように、レーザー発生モジュール70を有する各真空吸引手段50が、複数の連結真空ライン91によって中継器90と連結されることにより、使用者が皮下脂肪を分解するための所定皮膚、すなわち所望する部位に真空吸引手段50を接触させて使用可能である。

【0114】

ここで、前記レーザー発生モジュール70を有する真空吸引手段50と中継器90を連結する真空吸引部93を有する連結真空ライン91の長さは、使用者が使いやすいうように多様に加減することができ、前記連結真空ライン91の長さを適切に調節することによって、多数の使用者が使用することも可能である。

【0115】

そのために前記中継器90で分岐される連結真空ライン91中のいずれか一つの連結真空ライン91は、吸引口51内を所定圧力の真空で形成させるための真空ポンプ95に連結し、他の一つの連結真空ライン91は、また他の中継器90に連結することも好ましい。

【0116】

一方、前記のように、前記レーザー発生モジュール70を有する真空吸引手段50を多数個連結する中継器90が、また他の中継器90と連結真空ライン91を通じて連結するようにすることによって、使用者の皮膚に多数個の真空吸引手段50を接触させられるように構成することも好ましい。

【0117】

本発明は、特定の実施例に関して図示及び説明したが、添付の特許請求の範囲によって示された発明の思想及び領域から脱しない限度内で、多様な改造及び変化が可能だということを当業界で通常の知識を有する者なら誰でも容易に理解できるであろう。

【産業上の利用可能性】

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【0118】

以上説明したように、本発明による低出力レーザーを使用した脂肪分解装置は、レーザーの透過特性を活用してレーザービームをレンズまたは透明窓等に集束したりまたはそのまま、レンズまたは透明窓を通じて皮膚に非侵襲的に照射し、照射されたレーザービームが皮膚と組織を透過して組織内の脂肪細胞に照射されるようにすることで、レーザー照射治療方法を非侵襲的に変えながらも既存の低出力レーザーを使用した皮膚切開などを通じて外部に露出した脂肪の分解効果と同一な効果を得ることができ、真空吸引手段を含むことにより、脂肪細胞から排出されて細胞組織の空間に集中する液状化した脂肪を鼠蹊部を通じて体外に容易に排出させ、人体の皮膚に安定的に接触して脂肪を分解することにより使用上の便宜性を提供することができる。

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【0119】

また、低出力レーザーを使用した脂肪分解装置は、従来の医科的な脂肪切除術（吸引術）とは異なり、皮膚の損傷なしに腹部等の脂肪を皮膚外から低出力レーザーを照射させて分解／液状化させて外科的施術なしに皮下脂肪を分解させてそれを脂肪吸引術によって体外に排出することにより、腹部肥満などを円滑に解決できるなどの効果を得ることができる。

【0120】

併せて、本発明は真空吸引手段を含み、脂肪細胞から排出されて細胞組織の空間に集中する液状化した脂肪を体表に引き上げてリンパ管が集中している鼠蹊部などを通じて体外に容易に排出されるように誘導することにより、脂肪吸引術のような侵襲的な排出手段を使用しないで、人体の超過脂肪を自然排出するリンパ排出能力を最大にして、腹部肥満などを円滑に解決できるなどの効果を得ることができる。

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【図面の簡単な説明】

【0121】

【図1】人体から採取した脂肪組織に低出力レーザーを照射して脂肪が分解される様子を段階的に示す図面である。

【図2】人体から採取した脂肪組織に低出力レーザーを照射して脂肪が分解される様子を段階的に示す図面である。

【図3】人体から採取した脂肪組織に低出力レーザーを照射して脂肪が分解される様子を段階的に示す図面である。

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【図4】本発明による低出力レーザーを使用した脂肪分解装置のレーザー発生部を示す分解斜視図である。

【図5】本発明による低出力レーザーを使用した脂肪分解装置のレーザー照射分布範囲を示す例示図である。

【図6】本発明による低出力レーザーを使用した脂肪分解装置を示す斜視図である。

【0122】

【図7】本発明による低出力レーザーを使用した脂肪分解装置の一実施例を示す斜視図である。

【図8】本発明による低出力レーザーを使用した脂肪分解装置の他の実施例を概略的に示す図面である。

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【図 9】本実施例による低出力レーザーを使用した脂肪分解装置の一実施例を概略的に示す図面である。

【図 10】本発明による低出力レーザーを使用した脂肪分解装置また他の実施例を示す分解図である。

【図 11】本実施例による低出力レーザーを使用した脂肪分解装置の真空吸引手段とレーザー発生モジュールの結合断面図である。

【図 12】本発明による低出力レーザーを使用した脂肪分解装置の設備概略図である。

【符号の説明】

【0123】

1：低出力レーザーを使用した脂肪分解装置 10

10：レーザー発生部

11：電源コネクタ

12、71：PCB

13、73：透明窓（またはレンズ）

14：接触端子

15、72：レーザーダイオード

16：締結ボルト

17a、17b：締結孔

30、30'：フレーム

31：取っ手 20

33：ヒンジ

35：位置移動手段

【0124】

50：真空吸引手段

51：吸引口

52：結合孔

53：雌ネジ部

54、93：真空吸引部

55：一方向弁

56：真空ライン 30

57：真空ポンプ

58：手動陰圧解除孔

58a：挿入溝

58b：ボール

59：結合部

【0125】

70：レーザー発生モジュール

71a：ケーブル

74：上部定着口

74a：雄ネジ部 40

74b：係止突起

75：下部定着口

75a：雌ネジ部

75b：溝

76：カバー体

76a：引入孔

76b：雄ネジ部

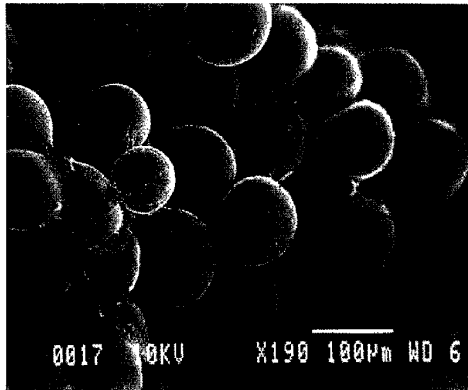
90、90'：中継器

91：連結真空ライン

95：真空ポンプ 50

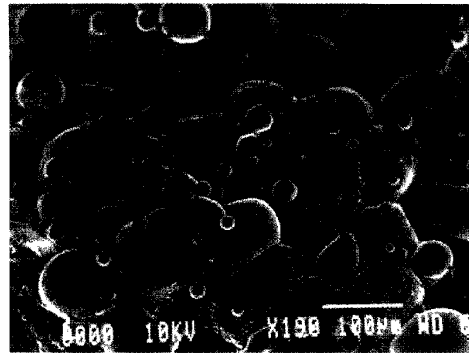
【図 1】

【図 1】



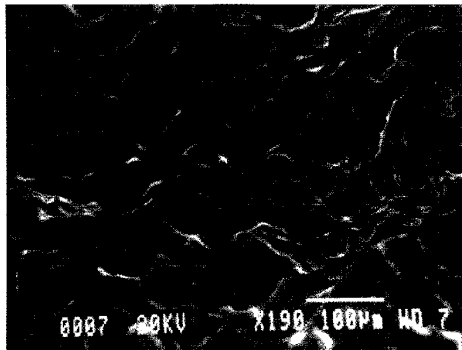
【図 2】

【図 2】



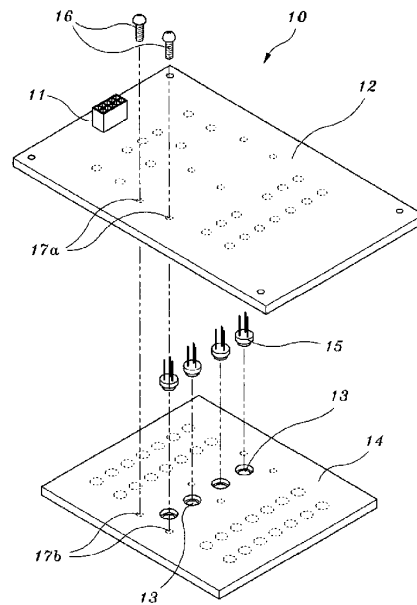
【図 3】

【図 3】



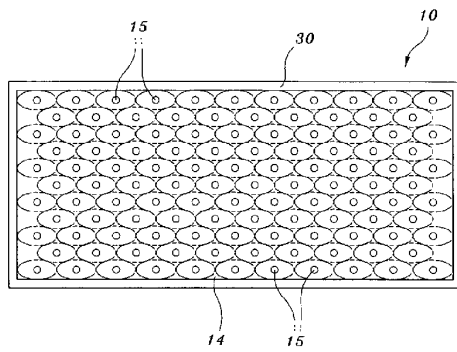
【図 4】

【図 4】



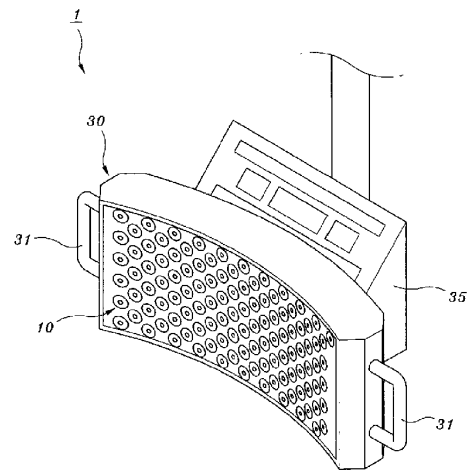
【図 5】

【図 5】



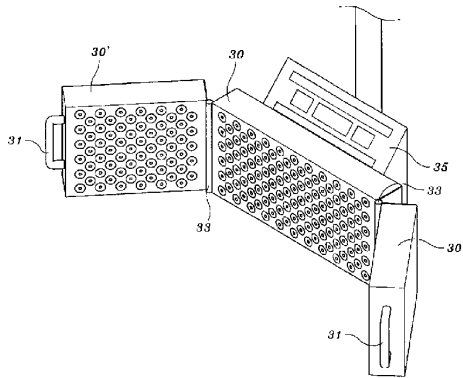
【図 6】

【図 6】



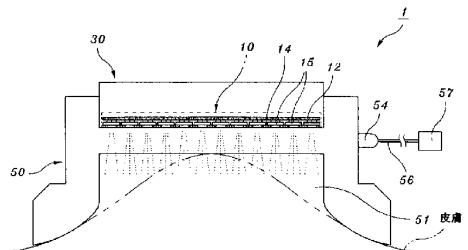
【図 7】

【図 7】



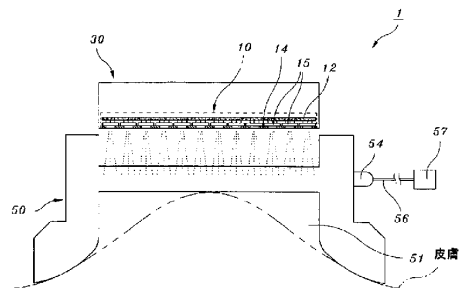
【図 8】

【図 8】



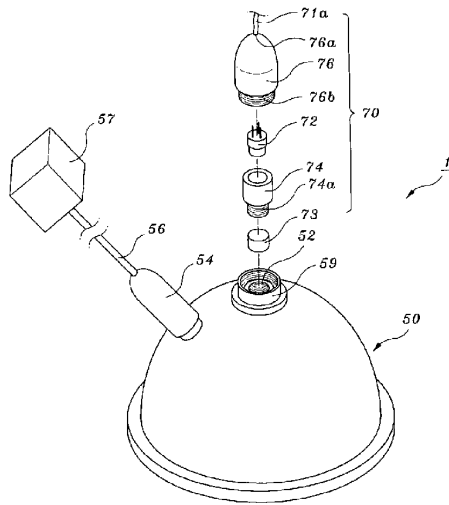
【図 9】

【図 9】



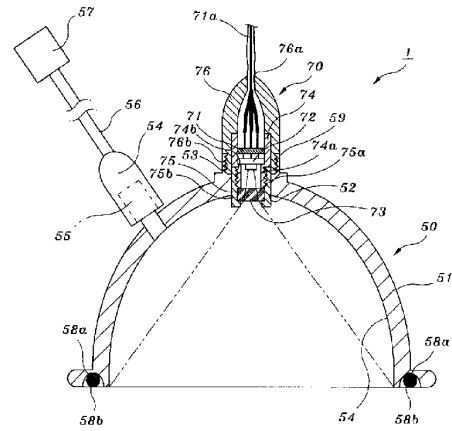
【図 10】

【図 10】



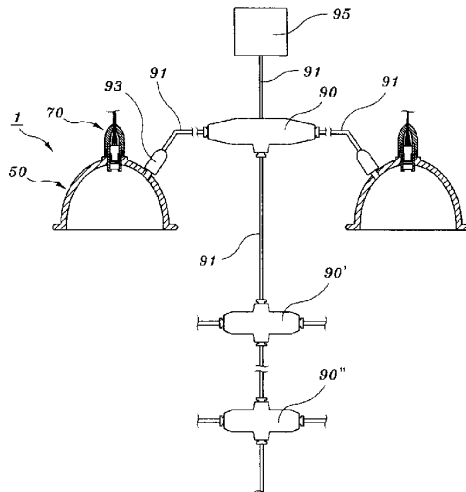
【図 11】

【図 11】



【図 12】

【図 12】



フロントページの続き

(72) 発明者 リー, チュル ギュ

大韓民国 ソウル 138-040、ソンパーク、プンナップードン、509、シティー クック
ドン アpartment #103-707

審査官 川端 修

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• **Elettronica Valseriana S.R.L.**
24020 Casnigo (BG) (IT)

(72) Inventor: **Palmieri, Beniamino**
41100 Modena (MO) (IT)

(74) Representative: **Gatti, Enrico et al**
Giambrocono & C.S.p.a.
3, Via E. Zambianchi
24121 Bergamo (IT)

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(71) Applicants:
• **Palmieri, Beniamino**
I-41100 Modena (IT)

(54) **Apparatus for delivering energy to a patient's body on the basis of the patient's biological parameters**

(57) The apparatus (14) for treating a patient's body by delivering energy, comprises: a device (18) for delivering energy to the body of a patient (10); a series of sensors (S1-S6) for measuring all or part of the essential

physiological integrated biorhythms of the patient (10); a control and command unit (20) enabling the energy delivered to the body of the patient (10) to be varied on the basis of the measurement by the sensors (S1-S6).

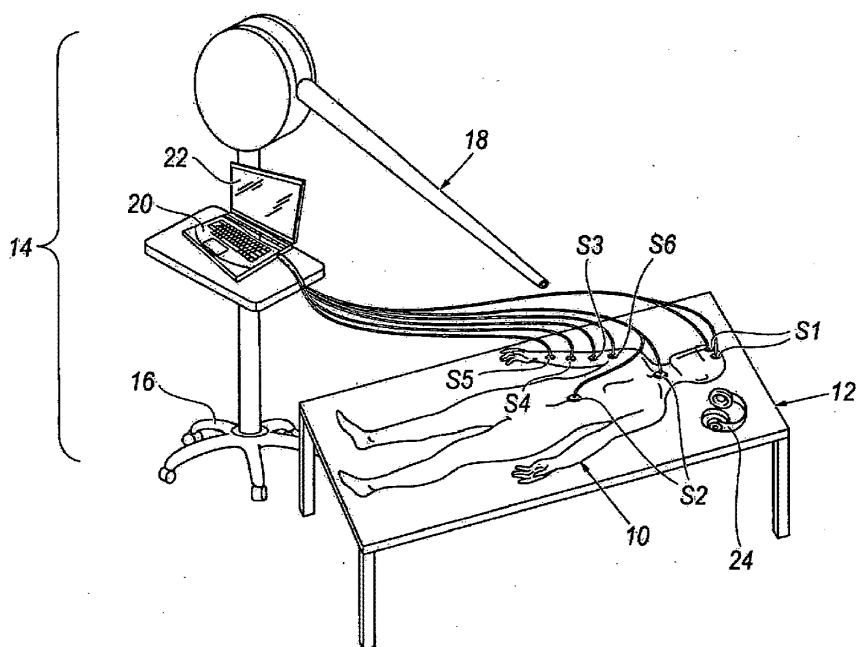


Fig. 1

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Description

[0001] The present invention relates to an apparatus for treating a patient's body by energy delivery.

[0002] Current methods of delivering energy to a patient (in particular ultrasound, electrotherapy or magnetotherapy treatments, laser, radiofrequency, pulsating light, pressotherapy, iontophoresis or ionophoresis treatments) take no account of the conditions of the patient's essential biological parameters. The relative energy is administered to the patient independently of the patient's receptivity conditions at that moment, which in particular determine the rise in cell temperature and entropy, from which it is hoped, by previous experience, that the patient will derive beneficial effects.

[0003] All treatments involving the delivery of energy, in the various aforesaid forms, to a tissue, a limb or a body part (viscera) of a patient suffer from the limitation of not having any relationship with the patient's essential physiological integrated biorhythms, and hence an energy transfer which is neither functionally correlated nor commensurate with the physiopathological unbalance and the specific requirements of that patient for that determined illness at that moment.

[0004] The illnesses for which energy administration is used have as their common essential characteristic the loss of integrated synchronization of the circular, respiratory or neurological biorhythms, so compromising or limiting the relative function diminution in the cellular-subcellular energy required to quickly restore functional integrity. In the most serious cases this absence of reparative energy can result in cellular death and gradual functional stupor or meiopragy of variable duration. In this respect, a traumatized or edematous or contused limb, or one with a hematoma, which is treated with ultrasound or electrotherapy or other types of energy, was found to lose, in that segment the subject of the trauma, its own compliance with the biorhythms always present in physiological conditions in the body; transudate or exudate or hematic liquid can in fact be observed for example by extravasation in tissues as a result of secretion by proinflammatory cells (leucocytes, basophils, eosinophils, monocytes and macrophages) and also adrenergic monoamines which act via the central and peripheral nervous system and the adrenal glands. All these factors cause biorhythm interruption in the seat concerned, creating an inflammatory engorgement with vasoconstriction and/or vasodilation, itself causing stasis and aggravation of liquid and cell blockage.

[0005] From research and experiments carried out, it has been surprisingly found that in delivering the energy relative to a determined treatment, its administration synchronously with the essential physiological integrated biorhythms in order to potentiate them enables maximum effectiveness to be obtained together with maximum restoration of wellbeing and healing of the subject.

[0006] The object of the present invention is therefore to provide an apparatus which enables this latter result

to be obtained.

[0007] Before explaining how this result is achieved by virtue of the present invention, it should be noted that the term "essential physiological integrated biorhythms" (EPIB) comprises:

- CARDIAC AND ARTERIAL PULSATILITY

[0008] Measurable by pulse oximeters, phletismographs, oscillometers.

- RESPIRATORY RHYTHM AND DEPTH

[0009] Measurable by thoracic impedancemetry and correlatable with oxygenation and CO₂ discharge.

- CENTRAL ARTERIAL AND VENOUS PRESSURE

[0010] The first measurable by a pneumatic armband of the type conventionally used for holter pressure examinations and the second by strain gauge transducers.

- GLOBAL CELL AND TISSUE ELECTRICAL ACTIVITY

[0011] Measurable by bioresonance sensors.

- CUTANEOUS ELECTRICAL RESISTANCE AND CONDUCTANCE

[0012] Measurable respectively by ohmmeters and hygrometers (because also related to perspiration).

- FUNCTIONAL RHYTHMS OF THE PERIPHERAL CENTRAL NERVOUS SYSTEM OF ORTHO AND PARASYMPATHETIC VOLUNTARY TYPE

[0013] Measurable by subjective perception of the working noise of the vital organs and in particular of the heart, caused by the flow of blood through the arteries; pulmonary rustling and abdominal rumblings. This object is attained by the apparatus of the present invention, comprising:

- a device for delivering energy to a patient's body;
- a series of sensors for measuring all or part of the patient's essential physiological integrated biorhythms;
- a control and command unit enabling the energy delivered to the patient's body to be varied on the basis of the sensor measurements. During the tests carried out, it was also surprisingly noted that if the patient is able to perceive with his/her senses the variation in the EPIB correlated parameters measured by the sensors, a particular concentration and knowledge of his/her state is generated in that patient, also influenceable by the wish of the subject, which causes variation in the patient's functional parameters and hence of the EPIBs (with a mechanism which

we shall define as interactive biofeedback). Consequently the control and command unit acts to vary the energy delivered to the patient's body on the basis of the variation in said functional parameters.

[0014] Specific neuron paths have recently been identified in the cerebral amygdala structure which give rise to this concentration and knowledge phenomenon.

[0015] It should be noted that said interactive biofeedback has therapeutic mechanisms which are very different from the so-called placebo effect, i.e. from brain endorphin release (which reduce pain perception and increase the subjective wellbeing effect by virtue of the expectation of treatment benefits and the subjective conviction that it will be effective). In this respect the placebo effect is involuntary and unconscious, whereas the interactive feedback is directed to the intentional recruitment of all those forces and resources (endorphin secretion, vasodilation, direct hyperemia of an organ or at a limb, incretion of steroids and monoamines by the adrenal glands) required to implement the therapeutic effectiveness of energy delivered to the patient, for example laser energy, administered extrinsically. It is convenient that the said energy delivery (nearly always invisible, such as infrared laser energy) be concretely represented such that the patient perceives it by relating it to luminous and light effects (for example produced by means such as a screen or obtained by LEDs) which are able to achieve a reinforcement of the therapeutic effect by the induction of that known as chromotherapy; and/or acoustic effects (for example produced by amplifiers such as loudspeakers, headphones or earpieces); and/or effects perceivable through the skin (for example an air current the temperature of which varies as the delivered energy varies, or by cutaneous thermoceptors), and in any event effects perceivable by the patient's sensorial receptors which are able to reflectively evoke biological responses synergic with the therapeutic action of the delivered energy.

[0016] To benefit from this situation, the apparatus of the invention is provided with means which enable the patient to perceive the variation in the parameters measured by the sensors, in particular visually (in particular via said screen) and/or by hearing (in particular via loudspeakers, headphones or earpieces), and possibly also by the other senses, and relative means for patient perception via these senses. It has been verified that this potentiates the therapeutic action of the energy delivered to the patient.

[0017] The invention will be more apparent from the ensuing description of one embodiment thereof, relating in particular to an apparatus for delivering energy to a patient in the form of powerless laser beams, hence not perceptible by the patient's senses. In this description reference will be made to the accompanying drawings, in which Figure 1 is a very schematic representation of a patient subjected to the action of said laser beam apparatus.

[0018] This figure shows a patient 10 lying on a bed

12 or other means for accommodating the patient 10 in the most comfortable manner. The same figure also shows very schematically an apparatus 14 for delivering light of powerless laser type comprising, in addition to a stand 16 carrying a multidiode device 18 (for example with helium neon guide light) able to emit energy in the form of infrared laser beams, this energy in the specific illustrated example being directed onto a particular region of the right arm of the patient 10.

[0019] The apparatus 14 also comprises a control and command unit 20 (in particular a microprocessor and preferably a personal computer) able to vary the energy delivered by the laser device 18 on the basis of the signals from a plurality of sensors able to measure all or part of the patient's essential physiological integrated biorhythms. In particular, in the specific illustrated example the sensors S1 are electroencephalographic transducers, the sensors S2 are ultrasound microamplifiers for perception of vital mechanical noises of the patient (in particular breathing, cardiac and visceral noises), S3 is a hygroscopticity sensor, S4 is an impedance meter, S5 is a pulsometry transducer and S6 is an arterial and/or venous pressure transducer. This latter is in particular of the type comprising a pneumatic armband connected to a transducer, commonly available for holter pressure examinations. The arterial pressure measurement becomes important in the case of patients with hypertension or are treated for cardiovascular problems or are stimulated at the charka points (essential psychophysical energy points according to oriental tradition). In this respect as certain types of hypertension can be modulated by psychophysical relaxation and voluntary breathing control, the final mechanism of which results in peripheral vasodilation, pressure regulation involves a blood flow increase in the peripheral districts and in the treated areas, with potentiated energy absorption.

[0020] The aforelisted sensors are connected by relative cables (although other known types of signal transmission means can be used) to the control and command unit 20 via a suitable decoder (not shown for simplicity). The unit 20 has been previously programmed to vary the emitted energy quantity, and in particular the quality (frequency) and intensity (i.e. the Joule value) of the energy irradiated as the parameters measured by the sensors S1-S6 vary. The variations are controlled such that the energy irradiated is a minimum when there is slow-down in the blood flow (expiratory and diastolic pauses) and progressively increases from the beginning of treatment as the integrated sensors gradually indicate patient relaxation (in particular cardiac slow-down, voluntary breathing slow-down, reduced electrical skin resistance, less surface hygroscopticity).

[0021] The irradiation frequency varies starting from a continuous initial emission stage, then increasing the frequency during the "energy loading" stage of the figured circulating blood elements, such as diastole and inspiration, but also the other parametral variations which enable quicker energy loading.

[0022] The variation in energy emitted by the laser device 18 of multidiode type (i.e. having a plurality of energy emission sources, in practice up to 20 diodes) can be achieved by selecting one or more diodes by a q-switched device.

[0023] The apparatus 14 also comprises a screen 22 on which the patient sees the variation in said parameters represented, for example by polychrome representations (chromotherapeutic).

[0024] As already stated, it is precisely the fact that the patient can observe and follow the variation in said parameters which gives rise to the aforesaid interactive bi-feedback, which is extremely important.

[0025] The variation in delivered energy can also be shown on the same screen such that this variation can be perceived by the patient, this also substantially contributing to said interactive feedback. This energy variation can also be perceived by the patient in other ways, for example by an air current the variable intensity of which stimulates the patient's cutaneous pressure receptors, or by multipoint means which induce a variable pricking sensation, or by small electrical discharges of variable intensity, or an air flow (preferably ionized) at variable temperature, such that the skin, as the receptive sensorial member, sends stimuli to the brain which evoke reflexive neuronal responses aimed at soothing, attenuating, reducing inflammation or deflating the injured part.

[0026] Figure 1 shows, resting on the bed 12, headphones 24 which can be used by the patient to prevent excessive environmental noise contamination, to hence perceive the physiological body noises directly in the headphones.

[0027] As an example of the use of the apparatus 14 to deliver energy in the form of laser light, a patient 10 suffering from scapulo-humeral periarthritis is treated. Having activated the apparatus 14 and in particular the multidiode device 18, we shall assume that the sensors (in particular the sensors S2 and S5) measure a frequency of 78 heartbeats/minute and respiration of 18 breaths/minute, values which are fed to the control and command unit 20. We shall also assume that the control and command unit is programmed for example to cause the laser device 18 to radiate an energy of 15 Joule/m² divided into 20 cycles/second as frequency during the diastole and into 4 cycles/second during the systole, with an initially monodiode intensity which progressively increases to arrive for example at an energy value up to 20 times the initial value as the electrical conductivity of the skin measured by the sensor S4 gradually rises from 3 to 10 kOhm and the brain alpha waves increase from 2 to 8 cycles/second, while the surface hygroscopicity measured by the sensor S3 falls from 6 to 2 (using the commonly used reference values based on the evaluation of the dielectric constant of the skin corneal layer), final values which clearly indicate a state of relaxation of the patient.

[0028] This increase in radiated laser energy is obtained by gradually activating an increasing number of

diodes up to the maximum number available, as a result of the fact that the patient 10 progressively attains the state of maximum relaxation by listening, for example through the headphones 24 (or through other amplifiers with which the apparatus 14 is provided) to the mechanical noises of the patient's own vital activity while at the same time viewing on the screen 22 (preferably in a chromatic scale based on chromatography principles) the patient's own parameters and also, on the same screen, the representation in similar terms of the quantity of laser energy which is gradually radiated onto his/her shoulder. The patient's attention is inevitably concentrated on the relative part of his/her body, which perceives a growing heat sensation due to the radiated laser energy which the (suitably programmed) unit 20 causes to increase as the patient's relaxation increases.

[0029] The apparatus 14 can also be provided with a source of ionized air which during radiation strikes the patient's shoulder, the temperature of which being made to increase by the unit 20 as relaxation increases.

[0030] The programming of the unit 20 can comprise a determined treatment duration once the patient has reached relaxation, with a maximum duration which must not be exceeded.

[0031] During the last treatment stage (for example the last three minutes), the delivered laser energy is suitably reduced gradually (such that at the end there is for example only one diode active), so consequently returning the patient into a deconcentration stage and activating active and/or passive articular movements to evaluate the symptomatology improvement by comparing the pre-post treatment situations, for example by the pain scale (such as the Scott-Husskinson visual analogue).

[0032] As already stated, the energy delivered by the apparatus of the present invention can be of mechanical type and in particular can be an apparatus for pressure therapy, which in addition to the aforesaid sensors and to the control and command unit is provided with pneumatic sleeves for the limbs, which can be inflated by a pressure pump. Said sleeves are specifically two leg sleeves, with the apparatus serving to facilitate the return circulation of the lower limbs. The control and command unit is programmed such that inflation occurs in two steps in accordance with the systole: a pre-pulse up to 80-100 mmHg during the diastole and a strong pulse up to 20 mmHg beyond maximum pressure during the systole, with a particular prolonged reinforcement shot lasting 10-20 seconds at high pressure (even 200 mmHg) during the expiratory pause and minisurplus trains of pulsating pressure (with 2.3 cycles/second frequency) during inspiration.

[0033] This apparatus mainly uses the heart-breathing-pressure sensors (S5, S2, S6 respectively), however the other sensors serve to cause the inflation pressure to increase progressively as the patient's relaxation increases, seeing that relaxation causes vasodilation which requires greater pressure, as a larger dilated and hence inert vascular bed must be achieved.

[0034] This articulated passive pneumatic exercise with the integrated biosensors S1-S6 serves to at least partly restore an arteriovenous lymphatic pulsating flow where this has been lost, causing leg swelling.

[0035] Finally it should be noted that the device for delivering energy to the patient can be not only of the laser energy or mechanical energy delivery type but also of a type able to deliver other forms of energy, for example in the form of ultrasound or magnetic field or radiofrequency, or by iontophoresis or ionophoresis or pulsating light.

Claims

1. An apparatus (14) for treating the body of a patient (10) by delivering energy, comprising:

- a device (18) for delivering energy to the body of a patient (10);
- a series of sensors (S1-S6) for measuring all or part of the essential physiological integrated biorhythms of the patient (10);
- a control and command unit (20) enabling the energy delivered to the body of the patient (10) to be varied on the basis of the measurement by the sensors (S1-S6).

2. An apparatus (14) as claimed in claim 1, wherein the unit (20) provides for increasing the delivered energy as a result of the measurement by the sensors (S1-S6) of values which indicate the attainment of a relaxation state by the patient (10).

3. An apparatus (14) as claimed in claim 1, wherein means (22, 24) are provided which enable the patient (10) to perceive the variations in the parameters measured by the sensors (S1-S6).

4. An apparatus (14) as claimed in claim 3, wherein means (22) are provided which enable the patient (10) to perceive the variations in the energy delivered by the delivery device (18).

5. An apparatus (14) as claimed in claim 3, wherein means which enable the patient (10) to perceive the variations in the parameters measured by the sensors (S1-S6) comprise visual means (22) and/or acoustic means (24) and/or means which act on the cutaneous perception of the patient (10).

6. An apparatus (14) as claimed in claim 1, wherein the sensors are electroencephalographic transducers (S1), ultrasound microamplifiers (S2) for perception of the vital mechanical noises of the patient (10), hygroscopticity sensors (S3) for the skin of the patient (10), impedance meters (S5) applied to the skin of the patient (10), pulsometry transducers (S5) and

arterial and/or venous pressure transducers (S6).

7. An apparatus (14) as claimed in claim 1, wherein the energy delivery device (18) is of the type for delivering infrared laser light.

8. An apparatus (14) as claimed in claim 7, wherein the infrared laser light device (18) is multidiode.

9. An apparatus (14) as claimed in claim 1, wherein the control and command unit is a personal computer (20).

10. An apparatus (14) as claimed in claim 5, wherein the visual means comprise a screen (22) on which the parameters measured by the sensors (S1-S6) are polychrome representations.

11. An apparatus (14) as claimed in claim 10, wherein the variation in the energy delivered to the patient (10) is also represented on the screen (22).

12. An apparatus (14) as claimed in claim 5, wherein cutaneous perception means are also provided, enabling the patient (10) to perceive the variation in delivered energy.

13. An apparatus (14) as claimed in claim 12, wherein the cutaneous perception means comprise an air current which strikes that part of the body of the patient (10) under treatment, the temperature of which increases as the energy delivered increases.

14. An apparatus (14) as claimed in any one of claims 1 to 6, wherein the device for delivering energy to the patient (10) is of the type for delivering mechanical energy.

15. An apparatus (14) as claimed in claim 14, wherein the mechanical energy delivery device is a device for pressotherapy provided with inflatable sleeves for the limbs, and wherein the control and command unit (20) is programmed such that the inflation is in accordance with the systole.

16. An apparatus (14) as claimed in any one of claims 1 to 6, wherein the device for delivering energy to the patient (10) is of the type for delivering energy in the form of ultrasound or of electric current or of magnetic field or of radiofrequency or of iontophoresis or ionophoresis.

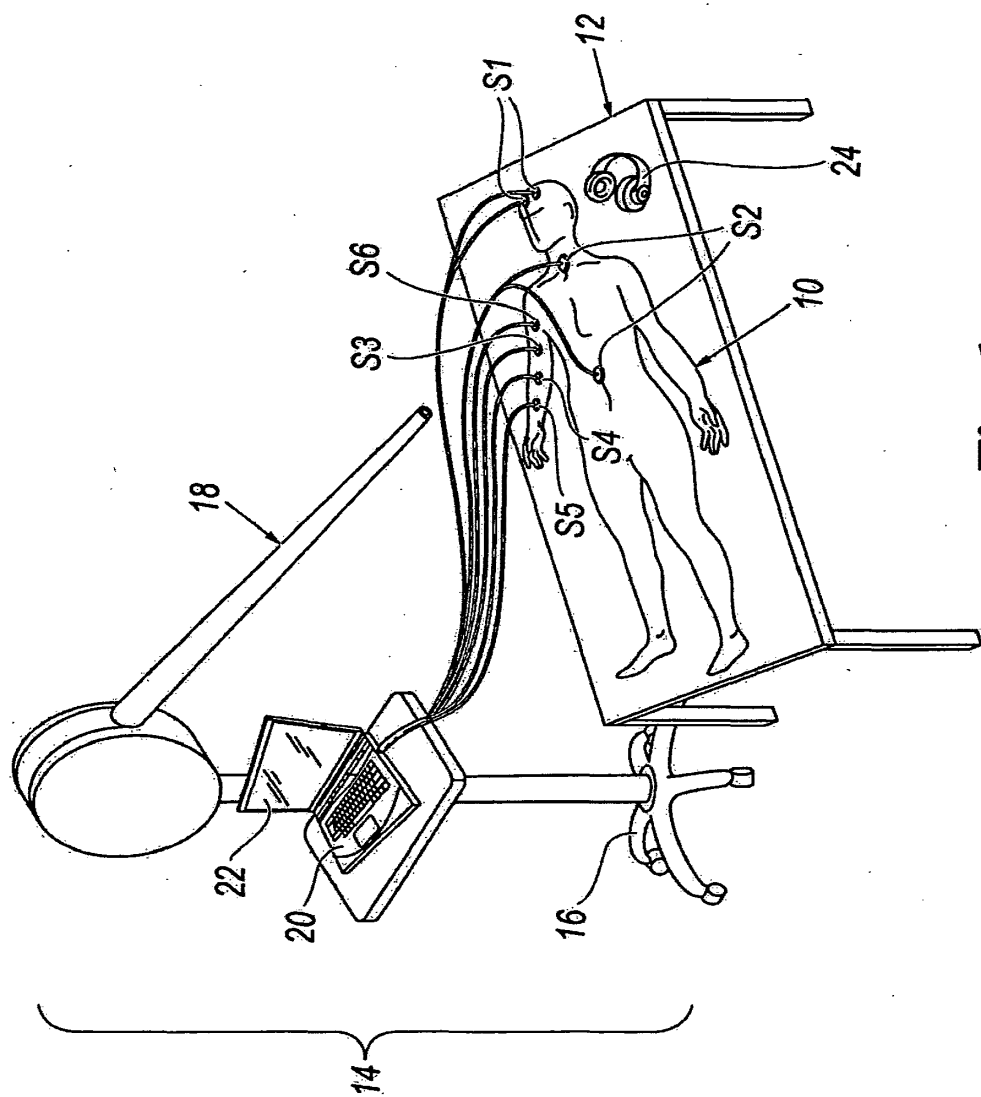


Fig. 1



EUROPEAN SEARCH REPORT

Application Number
EP 11 00 8614

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2008/269629 A1 (REINER ROBERT HOWARD [US]) 30 October 2008 (2008-10-30) * the whole document *	1-11, 13-15	INV. A61M21/00 A61N5/06 A61N1/36
X	US 2007/225769 A1 (SMITH TIMOTHY B [US] ET AL SMITH TIMOTHY BROOKS [US] ET AL) 27 September 2007 (2007-09-27) * paragraph [0005] * * paragraphs [0017] - [0027] * * paragraphs [0034] - [0036] *	1-11,16	
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The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 9 March 2012	Examiner Loveniers, Kris
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**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 11 00 8614

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

JP6652164B2 SOUND OUTPUT DEVICE

Data originating from sources other than the EPO may not be accurate, complete, or up to date.

The wording below is an initial machine translation of the original publication. To generate a version using the latest translation technology, go to the original language text and use Patent Translate.

[0001] The technology disclosed in this specification relates to an acoustic output device that is used by being worn on a listener's ear.

[0002] 2. Description of the Related Art A small acoustic converter that converts an electric signal output from a reproducing apparatus or a receiver into an acoustic signal by a speaker close to an ear or an eardrum, that is, an earphone, is widely used. This type of sound reproducing device emits sound so that it can be heard only by the wearer himself / herself, and is therefore used in various environments.

[0003] Many of the earphones currently in wide use are shaped to be inserted into the listener's ear. For example, an earbud type earphone is shaped to be hooked on the auricle of a listener. Further, the canal type earphone has a shape that is used by being inserted deeply into an ear hole (ear canal), and has many hermetically sealed types, and has relatively good sound insulation performance. It has the advantage of enjoying music.

[0004] A canal type earphone generally includes a speaker unit for converting an electric signal into an acoustic signal and a substantially cylindrical housing (housing) also serving as an acoustic tube, and the speaker unit is provided at one end of the housing (Outside the ear canal). The housing is provided with a radiation outlet for radiating air vibration generated by the speaker unit to the ear canal and transmitting the vibration to the eardrum. In addition, an earpiece (detachable part) having a shape conforming to the ear canal when the listener wears it is attached to the other end of the housing (the insertion part of the ear canal). For example, by arranging an acoustic tube obliquely from a position deviated from the center of the housing, the housing can be housed in the concha of the concha and the acoustic tube can be arranged up to the entrance of the ear canal. A proposal has been made (for example, see Patent Document 1).

[0005] Even while the listener wears the earphones and listens to the presented sound, it is necessary to listen to the surrounding sounds at the same time, for example, when surrounding people talk. However, it is extremely difficult for a listener to hear ambient sounds in most of the conventional earphones such as a canal type in a wearing state. This is because the ear hole is almost completely closed from the viewpoint of improving the reproduction sound quality and preventing the reproduction sound from leaking outside. For example, it is dangerous to be unable to hear ambient sounds when performing sports outdoors or indoors, such as walking, jogging, cycling, mountain climbing, skiing, snowboarding, and when driving or navigating. . Also, if the ambient sound cannot be heard during communication or presentation, the service will be degraded.

[0006] In addition, conventional earphones give the impression that it is difficult for the people around them to talk to the earphone wearer because the listener wearing the earphones appears to be blocking their ear holes. It will also inhibit.

[0007] Japanese Patent No. 4709017

[0008] The purpose of the technology disclosed in the present specification is to be used while being worn on the listener's ear, and to realize good acoustic information at the same time as realizing a listening characteristic of an ambient sound even in a worn state in a worn state and to output good acoustic information at the same time. An object of the present invention is to provide an excellent sound output device and an excellent sound guide device.

[0009] The technology disclosed in the present specification has been made in view of the above-described problem, and the technology according to the first aspect is a sound generation unit disposed on the back of a listener's ear, and one end of the sound generation unit. A sound conducting unit having a hollow structure, wherein the sound conducting unit is connected to the generating unit and the other end is disposed near the ear canal entrance of the listener, and takes in the sound generated by the sound generating unit from the one end and propagates the sound to the other end. And a sound output device comprising:

[0010] According to a second aspect of the technology disclosed in the present specification, the sound output device according to the first aspect further includes a holding unit that holds the other end of the sound guide unit near an ear canal entrance of the listener. Have.

[0011] According to a third aspect of the technology disclosed in the present specification, the holding portion of the audio output device according to the second aspect is configured to engage with a bead notch of the listener.

[0012] According to a fourth aspect of the technology disclosed in the present specification, the audio output device according to the first aspect further includes a pinch portion that holds the earlobe of the listener and attaches the audio output device to an ear. ing.

[0013] According to a fifth aspect of the technology disclosed in the present specification, the sound guide unit of the sound output device according to the first aspect is disposed at a position where the sound guide unit is turned from the back side to the front side of the auricle of the listener. And a pinch portion having an opened / closed structure. The pinch portion is configured to pinch the earlobe by using a pinch force for returning to the closed position.

[0014] According to a sixth aspect of the technology disclosed in the present specification, the sound output device according to the first aspect holds the listener's ear lobe together with the sound generator, and attaches the sound generator to the ear. Further, a pinch portion is provided.

[0015] According to a seventh aspect of the technology disclosed in the present specification, the acoustic output device according to the first aspect prevents the other end of the sound conductor from being inserted deeply into the ear canal of the listener. A guard portion is further provided.

[0016] According to an eighth aspect of the technology disclosed in the present specification, the holding unit of the acoustic output device according to the second aspect engages with the vicinity of the ear canal entrance (intertracheal notch) of the listener, and The sound guide is fixed near the other end so as not to be inserted deeply into the ear canal.

[0017] According to a ninth aspect of the technology disclosed in the present specification, the sound output device according to the first aspect is deformed in response to the action of an external force, and the other end of the sound guide unit is connected to the listener. It further includes a deformable portion that prevents the ear canal from being inserted deeply.

[0018] According to a tenth aspect of the technology disclosed in the present specification, the sound guide portion of the acoustic output device according to the fifth aspect deforms between the other end and the pinch portion in response to an external force. It has a deformable part.

[0019] According to an eleventh aspect of the technology disclosed in the present specification, the deformable portion of the sound output device according to the tenth aspect is broken when an external force of not less than a predetermined value is applied, and the other end of the sound guide portion is cut off. It is configured to prevent the listener from being inserted deeply into the ear canal.

[0020] According to a twelfth aspect of the technology disclosed in the present specification, the deformable portion of the sound output device according to the tenth aspect is cut off when an external force of not less than a predetermined value is applied, and the other end of the sound guide portion is cut off. Re-connection is possible while preventing the listener from being inserted deeply into the ear canal.

[0021] According to a thirteenth aspect of the technology disclosed in the present specification, the deformable portion of the sound output device according to the tenth aspect bends when an external force is applied, and the other end of the sound guide portion is provided by the listener. It is configured such that it is prevented from being inserted deeply into the ear canal, and restores its original shape when released from external force.

[0022] According to a fourteenth aspect of the technology disclosed in this specification, the acoustic output device according to the first aspect further includes an earwax intrusion prevention unit at the other end of the sound guide unit.

[0023] According to a fifteenth aspect of the technology disclosed herein, the sound output device according to the first aspect includes a sound volume output from the other end to an ear canal in response to a change in the inner diameter of the sound conducting unit. Is further provided.

[0024] According to a sixteenth aspect of the technology disclosed in the present specification, the sound volume control unit of the sound output device according to the fifteenth aspect includes a mute unit that appears and disappears in the sound guide unit when a surface is pressed. Is switched between the mute-on state and the mute-off state by the toggle operation of.

[0025] According to a seventeenth aspect of the technology disclosed in the specification, the sound volume control unit of the sound output device according to the fifteenth aspect includes a mute unit that appears in the sound guide unit in response to a surface being pressed. Then, when the surface is released from the pressing, the mute section is retracted from the inside of the sound guide section to be in the mute off state.

[0026] According to an eighteenth aspect of the technology disclosed in the present specification, the sound volume control unit of the sound output device according to the fifteenth aspect includes: a soft tube having a tapered structure inserted into the sound guide unit; The sound volume is continuously set by continuously changing the inner diameter of the soft tube in accordance with the position inserted into the volume adjustment unit. .

[0027] According to a nineteenth aspect of the technology disclosed in the present specification, the volume control unit of the sound output device according to a fifteenth aspect includes: an elastic deformation unit that forms a part of a side surface of the sound guide unit; A cam rotatably disposed so as to be in contact with the elastically deformable portion, wherein the elastically deformable portion is protruded into the sound guide portion in accordance with a change in the rotation angle of the cam so as to continuously set the volume. Is configured.

[0028] According to a twentieth aspect of the technology disclosed in this specification, one end is connected to the sound generation unit and the other end is disposed near the entrance of the ear canal of the listener, and the sound generated by the sound generation unit is generated. A sound guide device including a sound guide unit having a hollow structure, which takes in from one end and propagates to the other end, and a holding unit that holds the other end of the sound guide unit near the ear canal entrance of the listener. is there.

[0029] According to the technology disclosed in the present specification, it is used while being worn on the listener's ear, and in the mounted state, while achieving the same listening characteristics of ambient sound as in the non-mounted state, simultaneously outputs good acoustic information. It is possible to provide an excellent sound output device and an excellent sound guide device.

[0030] It should be noted that the effects described in this specification are merely examples, and the effects of the present invention are not limited thereto. In addition, the present invention may exhibit additional effects other than the above effects.

[0031] Still other objects, features, and advantages of the technology disclosed in the present specification will become apparent from the following embodiments and the more detailed description based on the accompanying drawings.

[0032] FIG. 1 is a front view of an acoustic output device 100 (for wearing on the left ear) according to an embodiment of the technology disclosed in this specification. FIG. 2 is a perspective view of an acoustic output device 100 (for wearing on the left ear) according to an embodiment of the technology disclosed in this specification. FIG. 3 is a diagram illustrating a state in which the open-ear acoustic output device 100 outputs sound waves to the listener's ear. FIG. 4 is a diagram (front view) showing a modification of the sound output device 100 shown in FIGS. 1 and 2. FIG. 5 is a diagram (perspective view) showing a modification of the sound output device 100 shown in FIGS. 1 and 2. FIG. 6 is a diagram (perspective view) showing a modification of the sound output device 100 shown in FIGS. 1 and 2. FIG. 7 is a diagram illustrating a closed state of the pinch portion 123 of the sound guide unit 120. FIG. 8 is a diagram showing an open state of the pinch portion 123 of the sound guide portion 120. FIG. 9 is a diagram showing a state where the sound output device 100 is mounted on the left ear of the listener. FIG. 10 is a diagram illustrating a state where the sound generation unit 110 is viewed from the front. FIG. 11 is a diagram illustrating an AA cross section of the sound generation unit 110. FIG. 12 is a diagram exemplifying the appearance of the sound output device 100 including the sound generator 110 having an elliptical shape. FIG. 13 is a diagram exemplifying the appearance of the sound output device 100

including the half-moon-shaped sound generator 110. FIG. 14 is a diagram exemplifying the appearance of the sound output device 100 provided with the sound generator 110 having a shape whose side edges conform to the shape of the back of the human ear. FIG. 15 is a diagram showing a state in which the sound output device 100 shown in FIG. 14 is worn on the left ear of the corresponding listener. FIG. 16 is a diagram showing a state in which sound 1600 radiated from the other end 122 of the sound guide unit 120 propagates in the external auditory meatus 1601 and reaches the eardrum 1602. FIG. 17 is a diagram showing five portions defined in the length direction of the sound guide portion 120. FIG. 18 is a diagram exemplifying a tubular shape applicable to the sound guide unit 120. FIG. 19 is a diagram exemplifying a state in which the sound guide unit 120 is mounted on the left ear of the listener by passing through a part other than the lower edge of the earlobe. FIG. 20 is a diagram exemplifying a state in which the sound guide section 120 is attached to the left ear of the listener by passing through a portion other than the lower edge of the earlobe. FIG. 21 is a diagram exemplifying a state in which the sound guide unit 120 is mounted on the left ear of the listener by passing through a portion other than the lower end edge of the earlobe. FIG. 22 is a diagram illustrating a state in which the holding unit 130 fixes the other end 122 of the sound guide unit 120 near the entrance of the ear canal. FIG. 23 is a diagram illustrating a state in which the holding unit 130 fixes the other end 122 of the sound guide unit 120 near the entrance of the ear canal. FIG. 24 is a diagram illustrating a configuration example in which the ring-shaped holding unit 130 supports the other end 122 of the sound guide unit 120. FIG. 25 is a diagram showing an example of the configuration of a holding unit 130 having a hollow structure capable of taking in ambient sounds and having a shape other than a ring. FIG. 26 is a diagram illustrating a configuration example of the egg-shaped holding unit 130 made of a flexible material. FIG. 27 is a diagram illustrating a state where the holding unit 130 illustrated in FIG. 26 is attached to the left ear of the listener. FIG. 28 is a diagram illustrating a front view of the holding unit 130 configured to have a shape that conforms to the shape surface of the individual's ear in the interbead notch space. FIG. 29 is a diagram illustrating a state where the holding unit 130 illustrated in FIG. 28 is attached to the left ear of the listener. FIG. 30 is a diagram illustrating an example of the internal configuration of the holding unit 130 that maintains a shape and has an appropriate elasticity. FIG. 31 is a diagram showing a state in which the holding unit 130 also having a role of guarding the eardrum is attached to the listener's ear. FIG. 32 is a diagram showing a state in which the holding unit 130 having a role of guarding the eardrum is attached to the listener's ear. FIG. 33 is a diagram illustrating a configuration example of a holding unit 130 having a shape other than a ring, which can play a role of guarding the eardrum. FIG. 34 is a diagram showing a configuration example of the pinch portion 123 which is configured as a separate component and has a spring property and can be opened and closed. FIG. 35 is a diagram illustrating a configuration example of the pinch portion 123 which is configured as a separate component and has a spring property and can be opened and closed. FIG. 36 is a diagram illustrating another configuration example of the pinch portion 123 which is configured as a separate component and has a spring property and can be opened and closed. FIG. 37 is a diagram showing another configuration example of the pinch portion 123 which is configured as a separate component and has a spring property and can be opened and closed. FIG. 38 is a diagram showing a detailed internal structure of the pinch portion 123 shown in FIGS. 36 and 37. FIG. 39 is a diagram illustrating a pinch force generated by the torsion of the portion A of the sound guide portion 120. FIG. 40 is a diagram illustrating a pinch force generated by the torsion of the portion A of the sound guide portion 120. FIG. 41 is a diagram illustrating a state in which pinch forces 4101 and 4102 are generated by the torsion of the portion A of the sound guide unit 120 in the acoustic output device 100 mounted on the left ear of the listener. FIG. 42 is a diagram showing a structure for generating a pinch force in the portion A of the sound guide section 120. FIG. 43 is a diagram illustrating a configuration example of a mechanism for attaching the sound generating unit 110 to the earlobe. FIG. 44 is a diagram illustrating another configuration example of the mechanism for attaching the sound generating unit 110 to the earlobe. FIG. 45 is a diagram illustrating a configuration example of the deformation unit 124. FIG. 46 is a diagram illustrating a configuration example of the deformation unit 124. FIG. 47 is a diagram illustrating a configuration example of the deformation unit 124. FIG. 48 is a diagram showing a state in which a removable earwax intrusion prevention unit 4801 is attached to the other end 122 of the sound guide unit 120. FIG. 49 is a diagram illustrating a configuration example of the earwax intrusion prevention 4801. FIG. 50 is a diagram illustrating an external configuration of the sound output device 100 in which the sound volume control unit 5000 is provided in the C portion of the sound guide unit 120. FIG. 51 is a diagram illustrating a cross-sectional configuration example (mute-off state) of the volume control unit 5000 that realizes the mute function. FIG. 52 is a diagram illustrating a cross-sectional configuration example (mute-on state) of the volume control unit 5000 that realizes the mute function. FIG. 53 is a diagram illustrating an example of a cross-sectional configuration of a volume control unit 5000 that realizes a mute function (with a mute volume adjustment function). FIG. 54 is a diagram showing another example of the cross-sectional configuration (mute-off state) of the volume control unit 5000 that realizes the mute function. FIG. 55 is a diagram showing another example of the cross-sectional configuration (mute-on state) of the volume control unit 5000 that realizes the mute function. FIG. 56 is a diagram showing another example of the cross-sectional configuration of the volume control unit 5000 that realizes the mute function (with the mute volume adjustment

function). FIG. 57 is a diagram illustrating a cross-sectional configuration example of a volume control unit 5000 that realizes continuous volume adjustment by continuously changing the inner diameter of the sound guide unit 120. FIG. 58 is a diagram illustrating an example of a cross-sectional configuration of a volume control unit 5000 that realizes continuous volume adjustment by continuously changing the inner diameter of the sound guide unit 120. FIG. 59 is a diagram illustrating a cross-sectional configuration example of a volume control unit 5000 that realizes continuous volume adjustment by continuously changing the inner diameter of the sound guide unit 120. FIG. 60 is a diagram showing another example of a cross-sectional configuration of the sound volume control unit 5000 that achieves continuous sound volume adjustment by continuously changing the inner diameter of the sound guide unit 120. FIG. 61 is a diagram illustrating another example of a cross-sectional configuration of the volume control unit 5000 that achieves continuous volume adjustment by continuously changing the inner diameter of the sound guide unit 120. FIG. 62 is a diagram illustrating another example of a cross-sectional configuration example of the volume control unit 5000 that achieves continuous volume adjustment by continuously changing the inner diameter of the sound guide unit 120. FIG. 63 is a diagram illustrating the acoustic characteristics of the acoustic output device 100 when the acoustic generator 110 is configured by a dynamic speaker. FIG. 64 is a diagram illustrating frequency characteristics of signal processing applied to an input signal to the sound output device 100. FIG. 65 is a diagram illustrating acoustic characteristics (frequency level characteristics) of the acoustic output device 100 improved by the signal processing illustrated in FIG. 64. FIG. 66 is a diagram illustrating the one-side open resonance operation (quarter wavelength resonance) of the sound guide unit 110. FIG. 67 is a diagram illustrating the one-side open resonance action (1+による wavelength resonance) of the sound guide unit 110. FIG. 68 is a diagram exemplifying a one-side open resonance action (2 + 4 wavelength resonance) by the sound guide unit 110. FIG. 69 is a diagram exemplifying acoustic characteristics (frequency level characteristics) of the sound guide unit 120 affected by the resonance effect of one-sided opening. FIG. 70 is a diagram illustrating a configuration example of the sound guide unit 120 that suppresses a peak characteristic of a sound pressure frequency due to resonance. FIG. 71 is a diagram illustrating a configuration example of the sound guide unit 120 that suppresses a peak characteristic of a sound pressure frequency due to resonance. FIG. 72 is a diagram illustrating a configuration example of an acoustic element including a sound hole 7201. FIG. 73 is a diagram illustrating a configuration example of an acoustic element including the air chamber 7301. FIG. 74 is a diagram exemplifying acoustic characteristics (frequency level characteristics) in the case where the sound conducting unit 120 that suppresses the peak characteristics of the sound pressure frequency due to resonance is used. FIG. 75 is a diagram showing a state of contact of the acoustic output device 100 shown in FIG. 9 with the ear (the bottom surface of the concha of the concha), the back surface of the ear. FIG. 76 is a diagram showing a state in which the sound output device 100 in which the holding unit 130 conforming to the bottom shape of the concha of the concha and the sound generating unit 110 conforming to the shape of the back of the ear are combined with the left ear of the listener. It is. FIG. 77 is a diagram illustrating a state in which the holding unit 130 and the sound generating unit 110 are viewed from the front of the wearer in the wearing state illustrated in FIG. 76.

[0033] Hereinafter, embodiments of the technology disclosed in this specification will be described in detail with reference to the drawings.

[0034] A. Basic Structure FIGS. 1 and 2 show a configuration of an acoustic output device 100 used by being attached to a listener's ear according to an embodiment of the technology disclosed in this specification. 1 is a front view of the sound output device 100, and FIG. 2 is a perspective view of the sound output device 100 as viewed from the left. Although the sound output device 100 shown in FIGS. 1 and 2 is configured to be worn on the left ear, the sound output device for the right ear (not shown) is configured symmetrically with respect to this. Want to be understood.

[0035] The sound output device 100 shown in FIGS. 1 and 2 includes a sound generation unit 110 that generates sound, a sound conduction unit 120 that takes in sound generated from the sound generation unit 110 from one end 121, and a sound conduction unit 120 that has the other end. A holding section 130 for holding near 122 is provided. The sound guide 120 is made of a hollow tube having an inner diameter of 1 to 5 mm, and both ends are open ends. One end 121 of the sound guide 120 is a sound input hole for a sound generated from the sound generator 110, and the other end 122 is a sound output hole thereof. Therefore, when the one end 121 is attached to the sound generating unit 110, the sound conducting unit 120 is in a one-side open state.

[0036] As described later, the holding portion 130 is engaged with the vicinity of the entrance of the ear canal (for example, a bead notch) so that the sound output hole of the other end 122 of the sound conducting portion 120 faces the back side of the ear canal. The guide 120 is supported near the other end 122. The outer diameter of at least the vicinity of the other end 122 of the sound guide section 120 is formed to be much smaller than the inner diameter of the ear hole. Therefore, even if the other end 122 of the sound guide unit 120 is held near the

entrance of the external auditory meatus by the holding unit 130, the ear hole of the listener is not closed. That is, the ear hole is open. Unlike the conventional earphone, the sound output device 100 can be said to be "open-ear type".

[0037] In addition, the holding unit 130 includes an opening 131 that opens the ear canal entrance (ear hole) to the outside even when the sound guide unit 120 is held. In the example shown in FIGS. 1 and 2, the holding portion 130 is a ring-shaped structure, and is connected to the vicinity of the other end 122 of the sound guide portion 120 only by the rod-shaped support member 132. All the other portions of the window become openings 131. In addition, as described later, the holding unit 130 is not limited to the ring-shaped structure, and may have any shape that can support the other end 122 of the sound conducting unit 120 as long as the holding unit 130 has a hollow structure.

[0038] When the sound generated by the sound generator 110 is taken into the tube from one end 121 of the tubular sound guide 120, the tubular sound guide 120 propagates the air vibration, and the other end 122 held near the entrance of the ear canal by the holder 130. Radiate from the ear to the ear canal and transmit it to the eardrum.

[0039] As described above, the holding unit 130 that holds the vicinity of the other end 122 of the sound guide unit 120 includes the opening 131 that opens the entrance (ear hole) of the ear canal to the outside. Therefore, even when the sound output device 100 is worn, the ear hole of the listener is not closed. The listener can sufficiently listen to the ambient sound via the opening 131 while wearing the sound output device 100 and listening to the sound output from the sound generator 110.

[0040] Further, although the sound output device 100 according to the present embodiment has the ear holes opened, it is possible to prevent the sound generated from the sound generator 110 (reproduced sound) from leaking to the outside. This is because the other end 122 of the sound conducting portion 120 is attached so as to face the back near the entrance of the ear canal and radiates the air vibration of the generated sound near the eardrum, so that the output of the sound output portion 100 is reduced. Even so, sufficient sound quality can be obtained.

[0041] The directivity of the air vibration radiated from the other end 122 of the sound guide 120 also contributes to the prevention of sound leakage. FIG. 3 shows a state in which the open-ear acoustic output device 100 outputs sound waves to the listener's ear. Air vibration is radiated from the other end 122 of the sound guide 120 toward the inside of the ear canal. The ear canal 300 is a hole that starts at the ear canal entrance 301 and ends inside the eardrum 302, and is typically about 25-30 millimeters in length. The external auditory meatus 300 is a cylindrical closed space. For this reason, the air vibration radiated from the other end 122 of the sound guide unit 120 toward the back of the ear canal 300 propagates to the eardrum 302 with directivity as indicated by reference numeral 311. In addition, since the sound pressure of the air vibration increases in the external auditory canal 300, the sensitivity (gain) particularly in the low range is improved. On the other hand, the outside of the ear canal 300, that is, the outside world is an open space. For this reason, the air vibration radiated from the other end 122 of the sound guide section 120 to the outside of the ear canal 300 has no directivity in the outside as shown by reference numeral 312, and attenuates sharply.

[0042] Description will be made with reference to FIGS. 1 and 2 again. The tubular sound-guiding part 120 has a bent shape in the middle part, which is folded from the back side to the front side of the pinna. The bent portion is a pinch portion 123 having an open / close structure, which can pinch the ear lobe by generating a pinch force, but details thereof will be described later.

[0043] The sound guide section 120 further includes a deformable section 124 between the other end 122 disposed near the entrance of the ear canal and the bent pinch section 123. The deformable portion 124 is deformed when an excessive external force is applied, so that the other end 122 of the sound guide portion 120 does not enter the inner ear canal more than necessary. The details will be described later.

[0044] 4 to 6 show modified examples of the sound output device 100 shown in FIGS. 1 and 2. 4 is a front view of the sound output device 100, and FIG. 5 is a perspective view of the sound output device 100 as viewed from the left side. FIG. 6 is a perspective view as seen from the direction in which the back side of the sound generator 110 can be seen. The same components as those of the sound output device 100 shown in FIGS. 1 and 2 are denoted by the same reference numerals.

[0045] In the sound output device 100 shown in FIGS. 1 and 2, the sound guide unit 120 is formed of a rectangular tube. On the other hand, the sound guide 120 of the sound output device 100 shown in FIGS. 4 to 6 is formed of a cylindrical tube. The shape of the member used for the sound guide unit 120 is arbitrary as long as it is tubular, that is, a hollow structure capable of transmitting air vibration.

[0046] As will be described later, since the sound generating unit 110 uses a sound-generating element such as a speaker that generates a change in sound pressure, a pressure change occurs in the housing of the sound generating unit 110 when sound is generated. As shown in FIG. 6, one or more exhaust holes 601 for the case where high pressure is generated in the housing are formed in the rear side of the housing. Also, a code for inputting an audio signal from a sound player (not shown) such as a music player, a smartphone, or a tablet terminal or a receiver (not shown) for receiving a wireless signal from the sound player is provided in the sound generator 110. 602 are connected.

[0047] B. The ear-attaching mechanism sound output device 100 has a bent shape at an intermediate portion of the sound guide portion 120 so as to be folded from the back side to the front side of the pinna. The bent portion is a pinch portion 123 having an opening / closing structure, and the pinch force generated by the pinch portion 123 is used to pinch the auricle of the listener with the sound guide portion 120, so that the acoustic output device 100 can be worn on the listener's ear.

[0048] FIG. 7 shows a closed state of the pinch portion 123, and FIG. 8 shows an opened state of the pinch portion 123. FIG. 9 shows a state where the sound output device 100 according to the present embodiment is mounted on the left ear of the listener.

[0049] As can be seen from FIGS. 7 and 8, the tubular sound guide 120 has an opening and closing structure that is bent at the pinch 123. Then, the pinch portion 123 in the open position as shown in FIG. 8 generates a pinch force for returning to the closed position shown in FIG. 7.

[0050] As shown in FIG. 9, the holding unit 130 that supports the sound guide unit 120 near the other end 122 preferably abuts against the bottom surface of the concha of the concha and engages with the intertrabecular notch 901 to form the external auditory canal. It is installed near the entrance. In addition, the sound generation unit 110 coupled to one end 121 of the sound guide unit 120 is disposed behind the pinna 902. Then, as indicated by reference numerals 903 and 904, a pinch force is generated by the pinch portion 123 to return the opened sound conducting portion 120 to the closed position, and the sound generating portion 110 is pressed against the back surface of the pinna. Then, the sound output device 100 is attached to the left ear such that the sound guide portion 120 that bends as shown in the figure to pinch the pinna (earlobe) 902.

[0051] In order to attach the sound output device 100 to the ear, the sound guide unit 120 may hold any part of the pinna 902. However, it is preferable to hold a flat and simple shape of the lower half of the pinna under the pinna, because the contact area at the time of closing is large and a small pinch force can be firmly held. If the pinch force is small, the listener does not feel pain when wearing the device, and can withstand long use.

[0052] In addition, since the earlobe is relatively small, the distance from the sound generation unit 110 installed behind the pinna to the end of the earlobe after passing through the end of the earlobe and reaching the entrance of the external auditory canal is short. The length can be short. By turning back and passing the shortest place from the entrance of the ear canal, the length of the sound guide section 120 can be made the shortest distance. The length of the sound guide 120 is, for example, about 40 mm. If the sound propagation length is short, the attenuation until the sound taken in from one end 121 of the sound generation unit 110 is output from the other end 122 becomes small, so that the output of the sound generation unit 110 can be kept small. .

[0053] On the other hand, if the upper half of the pinna is to be sandwiched by the sound guide 120 having the opening and closing structure (not shown), the sound conduit 120 having the other end 122 fixed near the entrance of the external auditory canal is directed toward the outside of the pinna. It must pass over the complex irregularities created by the shape of the pinna cartilage in the order of the concha, the annulus, the scaphoid, and the helix. That is, the contact area between the sound conduit 120 and the surface of the pinna at the time of closing is extremely small, and becomes unstable even when the sound conduit 120 is pinched with the same pinch force. In addition, since the upper half of the pinna is wider than the ear lobe, the distance from the sound generator 110 installed on the back side of the pinna to the point passing over the ear ring and reaching the entrance of the ear canal becomes longer. Since the sound conduit 120 becomes longer by that amount, the sound generated from the sound generator 110 needs to be attenuated before being emitted to the ear canal, or the output of the sound generator 110 needs to be increased. In addition, the size of the upper half of the auricle

is larger than the size of the ear lobe, so that it is necessary to adjust the length of the sound guide unit 120 when trying to clamp the upper half of the auricle. Therefore, it is troublesome.

[0054] C. Next, the sound generator 110 will be described in detail. The principle by which the sound generation unit 110 generates sound is arbitrary. Here, a description will be given of a structure of the sound generating unit 110 using a sound-generating element such as a speaker that generates a sound pressure change.

[0055] FIG. 10 shows a state in which the sound generator 110 is viewed from the front. FIG. 11 is a sectional view of the sound generator 110 taken along the line AA. The sound generator 110 shown in FIGS. 10 and 11 is a so-called dynamic type speaker. As shown in FIG. 11, a diaphragm 1101 having a voice coil 1105 is arranged inside a sound generator 110 so as to face a magnetic circuit formed by a magnet 1104. Further, the inside of the sound generating unit 110 is partitioned by the diaphragm 1101 into a diaphragm front space (front cavity) 1102 and a diaphragm rear space 1103 (back cavity). When the magnetic field changes in response to a voice signal input to the voice coil 1105 via the cord 602, the diaphragm 1101 moves back and forth by the magnetic force of the magnet 1104, and the diaphragm front space 1102 and the diaphragm rear surface A change in air pressure occurs between the spaces 1103, which becomes sound.

[0056] When the sound generated in the diaphragm front space 1102 is taken into one end 121 of the sound guide 120, it propagates through the tube and is radiated from the other end 122 of the sound guide 120 toward the back of the ear canal. After that, it reaches the eardrum.

[0057] On the other hand, the sound generated in the diaphragm rear space 1103 is radiated to the outside from an exhaust hole 601 formed on the rear side of the housing of the sound generator 110 so as not to hinder the vibration of the diaphragm 1101.

[0058] Considering sound leakage to the outside of the exhaust hole 601, if the sound generating element in the sound generating unit 110 is a dynamic speaker having a diameter of 16 mm, the inner diameter of the exhaust hole 601 is preferably 1.0 mm or less. .

[0059] Note that, in addition to the dynamic type described above, the sound generating element of the sound generating unit 110 may be any one of a balanced armature type, a capacitor type, a piezoelectric type, and an electrostatic type, or may be a composite of two or more. Good.

[0060] In addition, the shape of the sound generation unit 110 illustrated so far is a disk shape, but is not limited thereto. As long as it is attached to one end 121 of the sound guide portion 120 and does not hinder the action of the pinch portion 123 of the sound guide portion 120 being pressed against the back surface of the pinna, the shape of the sound-emitting element housed therein is The sound generator 110 can be configured in any shape to fit or fit the back surface of the pinna. FIG. 12 illustrates an external appearance of the sound output device 100 including the sound generator 110 having an elliptical shape. FIG. 13 illustrates an external appearance of the sound output device 100 including the half-moon-shaped sound generation unit 110.

[0061] Also, the shape of the back of the ear of a person varies greatly between individuals. Therefore, the shape of the sound generating unit 110 may be formed in a shape that matches the shape of the back of the ear of the individual. FIG. 14 illustrates an external appearance of the sound output device 100 including the sound generator 110 having a shape whose side edges conform to the shape of the back of the human ear (indicated by reference numeral 1501 in FIG. 15). FIG. 15 shows a state in which the sound output device 100 shown in FIG. 14 is worn on the left ear of the corresponding listener. In the example illustrated in FIG. 15, the side edge of the sound generation unit 110 is suitably engaged with the back-of-ear shape surface 1501, and in such a case, the sound output device 100 can be heard even with a smaller pinch force of the pinch unit 123. It can be firmly worn on the ear of the person.

[0062] D. When the sound generated in the sound guide section diaphragm front space 1102 is taken into one end 121 of the sound guide section 120, it is guided to the vicinity of the entrance of the ear canal and radiates from the other end 122 of the sound guide section 120 toward the back of the ear canal. Thus, voice information is transmitted to the eardrum.

[0063] The length of the sound guide portion 120 can be minimized by turning the sound guide portion 120 (pinch portion 123) back through the shortest place from the entrance of the ear canal. In this case, the sound guide unit 120 propagates the sound generated by the sound generation unit 110 to the vicinity of the entrance of the ear canal at the shortest distance from the back of the ear, so that the sound loss due to the internal acoustic

resistance of the sound guide unit 120 is minimized. It is possible. The length of the sound guide 120 is, for example, about 40 mm (described above).

[0064] FIG. 16 shows a state in which sound 1600 radiated from the other end 122 of the sound guide unit 120 propagates in the external auditory meatus 1601 and reaches the eardrum 1602, and shows the left ear of the head of the listener wearing the sound output device 100. Shown in the nearby coronal plane.

[0065] The sound guide unit 120 can define five portions A to E in the length direction as shown in FIG. 17 based on functions and structures. Each part of A to E can be manufactured as an individual part, and can be connected in the order shown to form the sound guide part 120, or two or more adjacent parts can be formed as an integral part. .

[0066] The part E is a part connected to the sound generation unit 110 (not shown in FIG. 17), and the tip corresponds to one end (sound input hole) 121 for taking in the sound generated from the sound generation unit 110.

[0067] The D part is connected to the E part and the C part at both ends so as to bend in a V shape. The sound guide section 120 folds the end of the earlobe at the D section. The portion D corresponds to the pinch portion 123 that realizes the opening and closing structure of the sound guide portion 120, and generates a pinch force for returning the opened sound guide portion 120 to the closed position. The details of the structure of the pinch portion 123 will be described later.

[0068] The portion C corresponds to the deformation portion 124. The deformable portion 124 has an elasticity or flexibility that bends when an external force is applied between the portion B and the portion D and is restored when the external force is released, or has a fragility that is broken when an external force is applied. . Due to the flexibility or fragility of the deformable portion 124, even if an external force is applied, the tip of the portion A can be prevented from excessively entering the ear canal. Conversely, if the C portion is not flexible or brittle but has rigidity, when the C portion is pushed by an external force, the A portion is pushed together and its tip goes into the depth of the ear canal, and the end of the ear canal It is dangerous because it may damage the inner wall and eardrum.

[0069] Part A corresponds to the other end (sound output hole) 122 whose tip outputs sound propagating in the sound guide 120. The portion A is supported by the holding portion 130 (not shown in FIG. 17), and when the holding portion 130 engages with the vicinity of the entrance of the ear canal (for example, a bead notch) while abutting against the bottom surface of the concha of the concha. , E, i.e., the other end 122 of the sound conducting section 120 is disposed so as to face the inside of the ear canal. Further, the part B connects the deformable part 124 as the part C and the other end 122 of the sound guide part 120 as the part A. The deformed portion 124 as the portion C is substantially parallel to the plane formed by the earlobe, whereas the other end 122 of the sound guide portion 120 as the portion A faces the back of the ear canal, so that the portion B connecting them is substantially at a right angle. It has a bend shape.

[0070] The sound guide unit 120 is formed of a hollow-structured tube capable of transmitting the sound generated by the sound generation unit 110, that is, the air vibration. 1 and 2 exemplify the sound guide section 120 formed of a square tube. 4 to 6 exemplify the sound guide section 120 formed of a cylindrical tube. The member used for the sound guide section 120 may have any shape as long as it has a hollow structure capable of transmitting air vibration, and is not limited to the above-described square tube type or cylindrical type. FIG. 18 illustrates another cylindrical shape applicable to the sound guide unit 120. As shown in the figure, each of the elliptic cylinder type 1801, square round cylinder type 1802, semicircular cylinder type 1803, and trapezoidal cylinder type 1804 can also be used as the sound guide unit 120.

[0071] In addition, in the examples shown in FIGS. 9, 15, and 16, the sound guide portion 120 is folded back from the back of the auricle to the front of the auricle at the lower edge of the earlobe, and is extended to the vicinity of the entrance of the external auditory canal. The end 122 is supported by a retainer 130 that engages the interbead notch. However, the location where the sound guide 120 passes through the pinna is not limited to the lower edge of the ear lobe.

[0072] FIGS. 19 to 21 illustrate a state in which the sound guide unit 120 is mounted on the left ear of the listener by passing through a portion other than the lower end edge of the ear lobe. In the example shown in FIG. 19, the sound guide section 120 has a pinch 123 folded back from the back of the pinna to the front of the pinna at the diagonally lower edge of the earlobe, and extends from the back of the pinna to the vicinity of the

ear canal entrance. In the example shown in FIG. 20, the pinch portion 123 of the sound guide portion 120 is folded substantially in the horizontal direction from the back of the pinna to the front of the pinna, and extends to the vicinity of the entrance of the ear canal. In the example shown in FIG. 21, the sound guide portion 120 is inserted into a through hole 2101 formed in the earlobe of the listener near the pinch portion 123 that is folded from the back of the pinna to the front of the pinna, and the vicinity of the entrance of the ear canal. Has been extended.

[0073] E. FIG. The holding part holding part 130 engages with the vicinity of the entrance of the external auditory meatus (for example, a bead notch) while abutting on the bottom surface of the concha space, and the sound output hole at the other end 122 of the sound conducting part 120 is located at the back of the ear canal. The vicinity of the other end 122 of the sound guide 120 is held so as to face the side. That is, the holding portion 130 has a role of positioning so that the other end 122 of the sound guide portion 120 faces the ear hole (the back side of the ear canal), and prevents the other end 122 of the sound guide portion 120 from coming off near the entrance of the ear canal. There is a role of retention.

[0074] When the other end 122 of the sound guide unit 120 is correctly positioned so as to face the ear canal, the sound 1600 radiated from the other end 122 of the sound guide unit 120 becomes the ear canal 1601 as shown by reference numeral 1600 in FIG. The light propagates through the inside and reaches the eardrum 1602. On the other hand, if the other end 122 of the sound guide section 120 is disposed so as to be inclined with respect to the ear canal (in the direction of the ear canal), the sensitivity of the sound output is attenuated.

[0075] The holding portion 130 illustrated so far is a ring-shaped structure, and is connected to the vicinity of the other end 122 of the sound conducting portion 120 only by the rod-shaped support member 132. Are hollow structures that all become openings 131. FIGS. 22 and 23 show a state in which the ring-shaped holding unit 130 fixes the other end 122 of the sound conducting unit 120 near the entrance of the ear canal. 22 shows the appearance of the left ear of the listener wearing the sound output device 100, and FIG. 23 shows the coronal surface near the left ear of the listener's head at that time. As shown in FIG. 22, preferably, the holding portion 130 is hung on the intertrabecular notch 2201 while being in contact with the bottom surface of the concha of the concha of the ear, thereby realizing a stable attachment to the listener's ear. In addition, as shown in FIG. 23, when the holding unit 130 is engaged with the bead notch 2301, the other end 122 of the sound guide unit 120 is arranged so as to face the ear hole.

[0076] The holding portion 130 is a ring-shaped structure, and is connected to the vicinity of the other end 122 of the sound guide portion 120 only by the rod-shaped support member 132. Therefore, all other portions of the ring-shaped structure are openings 131. Becomes The inner diameter near the other end 122 of the sound guide section 120 is formed much smaller than the outer diameter of the ear hole. In addition, even in a state of being held near the entrance of the external auditory canal by the holding unit 130, the listener's ear hole is opened without being closed. Therefore, even when the acoustic output device 100 is mounted, the ambient sound enters the external auditory canal from the gap of the ear canal and is heard by the eardrum without being disturbed, so that the natural sound of the ambient sound can be realized. In addition, the opening of the ear canal can give an impression to others around the listener that the listener can talk to the listener, and does not hinder communication between people.

[0077] The ring-shaped holding section 130 supports the vicinity of the other end 122 of the sound guide section 120 with a rod-shaped support member 132 (described above). FIG. 24 shows another configuration example in which the ring-shaped holding section 130 supports the other end 122 of the sound guide section 120. FIG. 24A shows an example in which the holding unit 130 supports the other end 122 of the sound guide unit 120 by a rod-shaped support member 132 at one place. FIG. 24B shows an example in which the holding unit 130 supports the other end 122 of the sound guide unit 120 at two locations by rod-shaped support members 132A and 132B. FIG. 24C illustrates an example in which the holding unit 130 supports the other end 122 of the other end 122 of the sound guide unit 120 at three locations by bar-shaped support members 132A, 132B, and 132C. FIG. 24D illustrates an example in which the holding unit 130 supports the other end 122 of the sound guide unit 120 at one place using a spiral support member 132.

[0078] In any of the configuration examples shown in FIG. 24, the holding portion 130 has a hollow structure and has an ear hole. Therefore, even when the listener engages the holding portion 130 with the intertrabecular notch, the ambient sound enters the external auditory canal through the gap between the ear holes without being disturbed and is heard by the eardrum, so that the natural sound of the ambient sound can be obtained. Can be realized.

[0079] In short, the holding unit 130 may have any shape as long as it has a hollow structure that can capture ambient sound. However, it is assumed that the role of positioning the other end 122 of the sound guide portion 120 and the role of holding the other end 122 of the sound guide portion 120 near the entrance of the ear canal are described above.

[0080] FIG. 25 shows an example of the configuration of a non-ring-shaped holding unit 130 having a hollow structure capable of capturing ambient sound. FIG. 25A is a configuration example of the rectangular holding unit 130, FIG. 25B is a configuration example of the elliptical holding unit 130, and FIG. 25C is a configuration example of the egg-shaped holding unit 130. It is. The holding portions 130 shown in FIGS. 25A to 25C can be grouped into one classification as the holding portion 130 having a ring structure including a ring shape. In addition, other than the annular structure, FIG. 25D shows an example of the configuration of an anchor-shaped holding unit 130, FIG. 25E shows an example of the configuration of a hemispherical holding unit 130, and FIG. 25F shows a perforated hemisphere. The configuration example of the holding unit 130 in the form of a mold is shown. Although not shown, the holding unit 130 may have a spherical shape instead of a hemispherical shape.

[0081] Further, by forming the holding portion 130 from a material that is flexible and more preferably has a restoring force (appropriate elasticity), it is possible to improve the holding ability of the holding portion 130 with respect to the bead notch.

[0082] FIG. 26 shows a configuration example of an egg-shaped holding unit 130 made of a flexible material. FIG. 7A shows a state where the holding unit 130 before deformation is viewed from the front, and FIG. 7B shows a state where the holding unit 130 before deformation is viewed obliquely. FIG. 3C shows the deformed holding unit 130 as viewed from the front. When the sound output device 100 is used, for example, as indicated by reference numeral 2601, an external force acts such that the other end 122 pulls the sound conducting portion 120 connected to the holding portion 130. When the holding portion 130 has an annular structure formed of a flexible material, when such a tensile force 2601 acts, the holding portion 130 is deformed so as to expand in the left-right direction on the paper as indicated by reference numerals 2602 and 2603. Is adapted to the shape of the bottom surface of the concha of the concha and becomes in a state of contact on the surface, so that the retention of the intertrabecular notch becomes better. In FIG. 27, the holding portion 130 shown in FIG. 26 (in the deformed state shown in FIG. 26C) is engaged so as to conform to the shape 2701 of the interbead notch, and is attached to the left ear of the listener. This shows a state of being attached.

[0083] In addition, the holding portion 130 is configured to have a shape that conforms to the shape of the bottom surface of the concha of the concha in the space between the beads of the individual's ear, so that the holding portion 130 can be easily held in the space between the beads. be able to.

[0084] FIG. 28 illustrates a front view of the holding unit 130 configured to have a shape conforming to the shape of the bottom surface of the concha of the concha in the intertrabecular space of the individual's ear. FIG. 29 illustrates a state in which the holding unit 130 illustrated in FIG. 28 is attached to the left ear of the listener. As can be seen from FIG. 29, since the holding portion 130 attached to the inter-notch notch of the left ear conforms to the shape surface 2901 in the inter-notch notch space of the listener's ear, the holding property to the inter-notch notch is more improved. Become good.

[0085] FIG. 30 illustrates an example of the internal configuration of the holding unit 130 having a moderate elasticity and capable of conforming to the shape of the interbead notch space (the bottom shape of the concha of the concha). The illustrated holding unit 130 is formed by coating the surface of an annular structure 3001 made of a shape-changeable / memory wire or a thin and elastic piano wire with a resin such as silicon. The holding section 130 is connected to the vicinity of the other end 122 of the sound guide section 120 by a rod-shaped support member 132 (described above). The holding portion 130 shown in FIG. 30 is flexible and is suitable for the holding portion 130 (see FIGS. 26 and 27) for improving the holding property to the interbead notch and the space shape of the inter-bead notch of the individual's ear. 28 (see FIGS. 28 and 29).

[0086] The configuration example of the holding unit 130 illustrated in FIGS. 26 and 27 and the configuration example of the holding unit 130 illustrated in FIGS. 28 and 29 are in contact with the bottom surface of the concha of the concha (a large contact area). In common. When the contact area is large, the holding portion 130 is pressed against the bottom surface of the concha of the concha by the pinch force of the pinch portion 123, and the pinch force is dispersed. Can be. On the other hand, FIG. 9 shows a state in which the sound output device 100 having the basic configuration is attached to the left ear. (Back side). In this case, since the holding unit 130 contacts the bottom surface of the concha cavity at a point (or a small contact area), and the sound

generation unit 110 contacts the back side of the pinna at a point (or a small contact area). The pinch force concentrates on the narrow contact area. Therefore, if the listener uses the sound output device 100 for a long time in the wearing state as shown in FIG. 75, the listener will gradually feel pain and discomfort at the contact portion.

[0087] FIG. 14 shows an example in which the shape of the sound generating unit 110 is formed in a shape that matches the shape of the back of the ear of the listener. In such a case, the contact area becomes large, so that the sound output device 100 can be firmly attached to the listener's ear even with a smaller pinch force. Pleasure can be improved. Further, the configuration example of the holding unit 130 shown in FIGS. 26 and 27 or the configuration example of the holding unit 130 shown in FIGS. 110 may be used in combination. FIG. 76 shows a state in which the sound output device 100 in which the holding unit 130 conforming to the bottom shape of the concha of the concha and the sound generating unit 110 conforming to the back surface of the ear are combined with the left ear of the listener. I have. FIG. 77 illustrates a state in which the holding unit 130 and the sound generating unit 110 are viewed from the front of the wearer (a direction orthogonal to FIG. 76) in the mounted state illustrated in FIG. 76. The holding portion 130 is not a simple ring shape, and a lower end portion is curved so as to follow the shape of the bottom surface of the concha of the concha. In addition, the sound generating section 110 has a bottom surface shape such that a portion that abuts on the back of the ear conforms to the shape of the back of the ear, and also has a curved cross-sectional shape such as an arc shape (R shape) instead of a flat shape. Has formed. Therefore, since both the holding unit 130 and the sound generation unit 110 are in contact with the corresponding parts on the surface (wide contact area), the sound output device 100 can be firmly attached to the listener's ear even with a smaller pinch force. The discomfort can be greatly improved even when used for a long time because the pinch force is dispersed.

[0088] Further, it is preferable that the holding portion 130 plays a role of guarding the eardrum by preventing the other end 122 of the sound conducting portion 120 from entering the inside of the ear canal more than necessary. For example, the holding unit 130 fixes the vicinity of the other end 122 of the sound guide unit 120 via the support member 132, and if the size is larger than the ear hole, the other end 122 of the sound guide unit 120 is connected to the ear canal. Since it does not penetrate the inside more than necessary, the eardrum can be guarded. FIG. 31 and FIG. 32 show a state in which the holding unit 130 having a role of guarding the eardrum is attached to the listener's ear. However, FIG. 31 shows a state where the ring-shaped holding portion 130 is engaged with the intertrabecular notch 3101 of the left ear of the listener. FIG. 32 shows that the ring-shaped holding portion 130 is disengaged from the intertrabecular notch 3201 and is not in an engaged state. However, since the outer diameter of the ring is larger than the inner diameter of the ear canal entrance 3202, it is physically deep into the ear canal. It shows a state where it cannot enter. Alternatively, the holding section 130 may have a shape that does not allow the holding section 130 to physically enter deep into the ear canal, instead of having a large size.

[0089] In short, the holding portion 130 may have any shape as long as it has a role of guarding the eardrum without physically penetrating deep into the ear canal, and has a hollow structure capable of capturing ambient sounds. However, it is assumed that the role of positioning the other end 122 of the sound guide portion 120 and the role of holding the other end 122 of the sound guide portion 120 near the entrance of the ear canal are described above.

[0090] FIG. 33 illustrates a configuration example of a holding unit 130 other than a ring-shaped holding unit 130 that can play a role of guarding the eardrum. FIG. 33 (A) is a configuration example of a rectangular holding unit 130, FIG. 33 (B) is a configuration example of an elliptical holding unit 130, and FIG. 33 (C) is a configuration example of an egg-shaped holding unit 130. It is. The holding portions 130 shown in FIGS. 33A to 33C can be grouped into one classification as the holding portion 130 having a ring structure including a ring shape. 33 (D) is an example of the configuration of the anchor-shaped holding section 130, FIG. 33 (E) is an example of the configuration of the hemispherical holding section 130, and FIG. The configuration examples of the holding portion 130 having a hemispherical shape are shown. Although not shown, the holding unit 130 may have a spherical shape instead of a hemispherical shape. Also, instead of the structure in which the holding unit 130 supports the vicinity of the other end 122 of the sound conducting unit 120 with one or more supporting members 132 as shown in FIGS.) And a multi-legged holding portion 130 formed radially as shown in FIG.

[0091] F. In the example shown in FIG. 9 and the like, the sound output device 100 uses the opening / closing structure of the pinch portion 123 provided in the middle portion of the sound guide portion 120 to make the sound output device 100 bend. It is attached to pinch the pinna of the listener.

[0092] Since human ears have different shapes from one another, it is expected that the wearing stability will vary from individual to individual. In this embodiment, as shown in FIGS. 7 to 9, the holding portion 130 supporting the vicinity of the other end 122 of the sound conducting portion 120 engages with the bead notch, and the pinch force generated by the pinch portion 123 Since the housing of the sound generation unit 110 connected to the one end 121 of the sound guide unit 120 is pressed against the back surface of the pinna, it is possible to realize the stable mounting regardless of the individual difference of the ear shape as described above. .

[0093] For example, it is possible to produce the pinch force of the pinch portion 123 bent in a dogleg shape by integrally manufacturing the sound guide portion 120 using a material having spring properties.

[0094] Alternatively, the D portion of the sound guide portion 120 is formed of a separate component having a spring property that can be opened and closed, and is connected to the C portion and the E portion as a pinch portion 123, thereby forming a U-shape. The sound guide section 120 that bends and generates a pinch force can be configured.

[0095] FIGS. 34 and 35 show a configuration example of the pinch portion 123 which is configured as a separate component and has a spring property and can be opened and closed. 34 shows the closed state of the pinch portion 123, and FIG. 35 shows the opened state of the pinch portion 123. The illustrated pinch portion 123 includes a shape memory pulling spring 3401 that stores a V-shape at the closed position, a spiral pinch duct 3402 that bends / extends together with the shape memory pulling spring 3401, and the outside of these bent portions. It is composed of a highly stretchable coating 3403 to cover. When the pinch portion 123 is opened, a pinch force for returning to the closed position is generated as indicated by reference numeral 3501 in FIG. Further, with the deformation of the pinch portion 123, the highly elastic coating 3403 expands and contracts inside and outside the bent portion, and keeps the inside of the sound guide portion 120 in a closed space.

[0096] FIGS. 36 and 37 show another configuration example of the pinch portion 123 which is configured as a separate component and has a spring property and can be opened and closed. 36 shows a closed state of the pinch portion 123, and FIG. 37 shows an opened state of the pinch portion 123. The illustrated pinch portion 123 includes a high elastic string 3601 that expands and contracts in the length direction, a fan-shaped split pinch duct 3602 that bends and expands as the high elastic string 3601 expands and contracts, and covers the outside of these bent portions. It is composed of a highly elastic film 3603. When the pinch portion 123 is opened, a pinch force for returning to the closed position is generated as shown by reference numeral 3701 in FIG.

[0097] FIG. 38 illustrates the detailed internal structure of the pinch portion 123 shown in FIGS. 36 and 37. The high elastic string 3601 is inserted through the bent pinch portion 123. The tension 3801 and 3802 acting on the high elasticity string 3601 generates a pinch force 3803 for returning the pinch portion 123 to the closed position. Further, the fan-shaped divided pinch duct 3602 is configured by arranging a plurality of ducts having a fan-shaped cross section toward the inside of the pinch portion 123 that bends the center of each, and the circumferential side toward the outside. Have been. The fan-shaped split pinch duct 3602 opens and closes as the pinch portion 123 bends and expands as the high elasticity string 3601 expands and contracts.

[0098] Up to this point, an example has been described in which the pinch portion 123 corresponding to the bent D portion of the sound guide portion 120 generates a pinch force to pinch the earlobe. Instead of the pinch force generated in the D portion (or in addition to the pinch force generated in the D portion), a method of pinching the earlobe using the pinch force generated by the twist around the axis in the E portion may be considered.

[0099] FIG. 39 shows a pinch force 3901 for returning to the open position, which is generated in the C portion via the D portion due to the torsion of the E portion in the sound guide portion 120 in the closed state. Further, FIG. 40 shows a pinch force (torque) 4001 for returning to the closed position, which is generated in the portion C via the portion D due to the torsion of the portion E in the sound guide portion 120 in the opened state. . FIG. 41 shows a state in which the pinch forces 4101 and 4102 are generated by the torsion of the E portion of the sound guide unit 120 in the acoustic output device 100 mounted on the left ear of the listener.

[0100] FIG. 42 shows, in an enlarged manner, a structure for generating a pinch force in the portion E of the sound guide portion 120 in an enlarged manner. Both ends of the illustrated E portion are a connecting portion 4201 with the sound generating portion 110 and a connecting portion 4202 with the D portion, respectively, which are connected by a pinch force generating spring 4203. The outside of the pinch force generating spring

4203 is covered with a highly elastic film 4204. When the sound guide section 120 is in the open state as shown in FIG. 40, a pinch force (torque) 4205 for returning to the closed position is generated in the pinch force generation spring 4203 of the section E. Further, with the torsion of the portion E, the highly elastic film 4204 expands and contracts with the torsion of the portion E, and keeps the inside of the sound guide portion 120 in a closed space.

[0101] Further, the means for attaching the sound output device 100 to the ear is not limited to the pinch structure of the sound guide unit 120. For example, instead of the pinch portion 123 of the sound guide portion 120 pinching the ear lobe, or in addition to the action of the pinch portion 123 pinching the ear lobe, using a mechanism for attaching the sound generator 110 to the ear lobe. Is also good.

[0102] FIGS. 43 and 44 show examples of the configuration of the pinch mechanism for holding and fixing the earlobe using the housing of the sound generating unit 110.

[0103] In the example shown in FIG. 43, the housing of the sound generating unit 110 is provided with a magnet unit 4301 that can be opened and closed so as to hold the earlobe. Then, as shown in FIG. 43, when the sound generation unit 110 and the magnet unit 4301 are arranged so as to face each other via the earlobe, the sound generation unit 110 is attracted by the magnetism of the magnet unit 4301 to pinch the earlobe. As a result, the sound generator 110 is fixed to the back side of the ear lobe.

[0104] In the example shown in FIG. 44, a screw-type slide portion 4401 that is screwed at a place where it comes into contact with the back surface of the earlobe and a screw-type slide portion 4401 are provided on the housing of the sound generation unit 110. Hook portion 4402 is provided. By turning the screw type slide 4401, the gap between the screw type slide portion 4401 and the hook portion 4402 can be adjusted. Then, as shown in FIG. 44, the screw type ride portion 4401 and the hook portion 4402 are arranged so as to face each other through the earlobe, and the screw type slide 4401 is turned to rotate the screw type slide portion 4401 and the hook portion 4402. When the gap is narrowed, the ear lobe can be sandwiched, and as a result, the sound generation unit 110 is fixed to the back side of the ear lobe. Further, by rotating the screw type slide portion 4401 to adjust the gap between the screw type slide portion 4401 and the hook portion 4402, attachment / detachment is possible.

[0105] G. FIG. As described with reference to FIGS. 1 and 2, the sound guide section 120 has the deformable section 124 between the other end 122 disposed near the entrance of the ear canal and the pinch section 123 that bends. are doing. The deformable portion 124 is deformed when an external force is applied, and prevents the other end 122 of the sound guide portion 120 from entering the ear canal more than necessary.

[0106] FIGS. 45 to 47 show examples of the cross-sectional configuration by cutting out only the deformed portion 124 of the sound guide portion 120. Each of the examples has a structure in which the C portion of the sound guide portion 120 is divided into two portions in the length direction into a B portion side and a D portion side, and these are connected by the deformed portion 124.

[0107] In any of the examples shown in FIGS. 45 to 47, when the sound guide portion 120 is pressed toward the listener's ear and an excessive external force such as a bending force acts on the C portion thereof, the sound guide portion 120 is broken and deformed. As a result of the sound guide section 120 being bent at the C section, the other end 122 of the sound guide section 120 connected via the D section that is bent at a substantially right angle does not enter the ear canal.

[0108] In the example shown in FIG. 45, the C part of the sound guide part 120 divided into two parts is connected by a thin-walled weak part 4501 to form the deformed part 124. When a predetermined or more external force (bending force) is applied to the portion C, the portion C is broken at the thin brittle portion 4501. As a result, the external force is not transmitted to the other end 122 of the sound guide section 120, and therefore, does not penetrate into the ear canal. When the thin-walled fragile portion 4501 is broken, it is difficult to join the divided C portions again, and the sound conductor 120 needs to be replaced.

[0109] In the example shown in FIG. 46, the C portion of the sound guide portion 120 divided into two is connected by the joint weak portion 4601 to form the deformed portion 124. Like the thin-walled fragile portion 4501, the joint-type fragile portion 4601 is formed of a fragile material. Therefore, when an external force (bending force) of a predetermined value or more is applied to the portion C, the portion C is broken at the joint type weak portion 4601. As a result, the external force is not transmitted to the other end 122 of the sound guide section 120, and therefore, does not penetrate into the ear canal. However, the joint-type weakened portion 4601

is different from the thin-walled weakened portion 4501 and, after being cut, can reconnect the divided C portion, and can reuse the sound guide portion 120.

[0110] In the example shown in FIG. 47, the C portion of the sound guide portion 120 divided into two parts is connected by the soft structure bending portion 4701 to form the deformed portion 124. The soft-structure bending portion 4701 is different from the thin-walled weak portion 4501 and the joint-type weak portion 4601 in that it has flexibility, does not break even when bent, and returns to its original straight shape when bent. An attempt is made to generate restoring force. Therefore, when a predetermined or more external force (bending force) is applied to the portion C, the portion C is once bent at the soft structure bending portion 4701. As a result, the external force is not transmitted to the other end 122 of the sound guide section 120, and therefore, does not penetrate into the ear canal. Further, when released from an external force, the C portion of the sound guide portion 120 automatically returns to the original shape due to the restoring force of the soft structure bending portion 4701, so that the sound guide portion 120 can be reused.

[0111] H. The other end 122 of the earwax intrusion prevention sound guide 120 is provided as an acoustic output hole near the entrance so as to face the back of the ear canal. In the ear canal, dust in the air and debris of the skin mix with secretions from the earwax ship and accumulate earwax. If the other end 122 of the sound guide section 120 touches the earwax and closes the sound output hole. This may cause the sound quality to deteriorate. In addition, earwax is filthy and may cause damage to skin such as the inner wall of the ear canal.

[0112] Therefore, an earwax intrusion prevention unit may be provided at the other end 122 of the sound guide unit 120. The earwax intrusion prevention unit may be formed integrally with the other end 122 of the sound guide unit 120, or may be detachable from the other end 122. The removable earwax intrusion prevention part can be removed and cleaned, and it may be replaced when the dirt becomes severe.

[0113] FIG. 48 shows a state in which a removable earwax intrusion prevention unit 4801 is attached to the other end 122 of the sound guide unit 120. FIG. 49 shows a configuration example of earwax intrusion prevention 4801. The illustrated earwax intrusion prevention unit 4801 is a hollow structure, and allows the air vibration of the sound that has propagated in the tube of the sound guide unit 120 to pass through as it is. An earwax intrusion prevention filter 4901 that allows air vibration to pass through but does not allow earwax to pass is provided inside the earwax intrusion prevention unit 4801.

[0114] I. The sound output device 100 according to the present embodiment has a configuration in which the air vibration of the sound generated by the sound generation unit 110 is propagated to the vicinity of the entrance of the ear canal by the sound guide unit 120 having a hollow structure. Therefore, by controlling the inner diameter at a part of the sound guide 120, which is a passage of the air vibration, the volume of the sound output from the other end 122 of the sound guide 120 to the ear canal (or heard by the eardrum) is adjusted. Function can be realized.

[0115] For example, as shown in FIG. 50, a volume control unit 5000 is provided in the C section of the sound guide unit 120 where the listener wearing the sound output device 100 is easy to pick up with a finger, and in response to a fingertip operation on the volume control unit 5000. The sound volume is adjusted by changing the inner diameter of the sound guide unit 120 near the volume control unit 5000.

[0116] FIGS. 51 to 53 show a cross-sectional configuration example of a volume control unit 5000 that realizes a mute function and a series of mute operations. The volume control unit 5000 includes a mute unit 5001 that appears and disappears in the tube of the sound guide unit 120. The mute unit 5001 performs a toggle operation in response to a pressing operation on the surface of the volume control unit 5000 by a fingertip or the like, and alternately switches the appearance and retreat of the sound guide unit 120 into the tube. Specifically, when a fingertip operation is performed in the mute-off state, the mute unit 5001 appears in the tube of the sound guide unit 120 and switches to the mute-on state, but keeps the mute-on state even when the finger is released. Further, when the fingertip is operated again in the mute-on state, the mute unit 5001 is retracted from the tube of the sound guide unit 120, the mute-on is released, and the mute-off state is returned.

[0117] FIG. 51 shows the volume control unit 5000 in the mute / off state. In the mute-off state, the mute unit 5001 protrudes outside the sound guide unit 120. Therefore, since the inside of the sound guide unit 120 is completely open, as shown by reference numeral 5101, the air vibration of the sound taken in from the sound generation unit 110 is not interrupted, and It can proceed toward the end 122.

[0118] On the other hand, FIG. 52 shows the volume control unit 5000 in a mute-on state. In the mute-on state, the mute unit 5001 is recessed inside the sound guide unit 120, and blocks the inside of the sound guide unit 120 serving as a propagation path of air vibration. Therefore, as shown by reference field No. 5201, the air vibration of the sound taken in from the sound generation unit 110 is blocked by the mute unit 5001 that is recessed inward, and hardly reaches the other end 122 of the sound conduction unit 120. Even when the fingertip is released from the mute unit 5001 in the mute-on state, the illustrated mute-off state is maintained. When the mute unit 5001 is operated again with a fingertip in the mute-on state, the mute-on state is released, and the mute unit 5001 returns to the mute-off state shown in FIG.

[0119] FIG. 53 shows a modification of the volume control unit 5000 shown in FIGS. 51 and 52. In the volume control unit 5000 shown in FIG. 53, a mute volume adjustment unit 5002 is disposed in a wall of the sound guide unit 120 on a wall facing the mute unit 5001. In the illustrated example, the mute is realized by the mute unit 5001 that is recessed inwardly abutting on the mute volume control unit 5002 to block the propagation path of the air vibration. Here, the mute volume adjustment section 5002 is movable in the length direction along the inner wall surface of the sound guide section 120. Then, the degree of close contact with the inwardly recessed mute section 5001, that is, the degree of preventing the propagation path of air vibration changes according to the position of the mute volume adjustment section 5002, so that the mute volume can be adjusted.

[0120] FIGS. 54 to 56 show other cross-sectional configuration examples of the volume control unit 5000 that realizes the mute function and a series of mute operations. The volume control unit 5000 includes a mute unit 5001 that appears and disappears in the tube of the sound guide unit 120. However, unlike the examples illustrated in FIGS. 51 to 53, it is assumed that the volume control unit 5000 does not perform a toggle operation. That is, the mute unit 5001 appears in the tube of the sound guide unit 120 only during a period in which it is pressed with a fingertip or the like, and is in a mute-on state. To return to the mute / off state.

[0121] FIG. 54 shows the volume control unit 5000 in the mute / off state. In the mute-off state, the mute unit 5001 has a flat shape and is retracted from the inside of the tube of the sound guide unit 120. Therefore, since the inside of the sound guide unit 120 is completely open, as shown by reference numeral 5401, the air vibration of the sound taken in from the sound generation unit 110 is not interrupted, and It can proceed toward the end 122.

[0122] On the other hand, FIG. 55 shows the volume control unit 5000 in the mute-on state. In the mute-on state, the mute unit 5001 is elastically deformed when pressed with a fingertip or the like, protrudes inside the sound guide unit 120, and blocks the inside of the sound guide unit 120 serving as a propagation path of air vibration. Therefore, as shown by reference field No. 5501, the air vibration of the sound taken in from the sound generation unit 110 is blocked by the mute unit 5001 that is recessed inward, and hardly reaches the other end 122 of the sound conduction unit 120. When the fingertip is released from the pressing by releasing the fingertip from the mute unit 5001 in the mute-on state, the elastic deformation of the mute unit 5001 is released, and the mute unit 5001 returns to the mute-off state shown in FIG.

[0123] FIG. 56 shows a modification of the volume control unit 5000 shown in FIGS. 54 and 55. In the volume control unit 5000 shown in FIG. 56, a mute volume adjustment unit 5002 is provided in the tube of the sound guide unit 120 on the wall surface facing the mute unit 5001. In the illustrated example, the mute is realized by the mute unit 5001 that is recessed inwardly abutting on the mute volume control unit 5002 to block the propagation path of the air vibration. Here, the mute volume adjustment section 5002 is movable in the length direction of the sound guide section 120 along the wall surface. Then, the degree of close contact with the inwardly recessed mute section 5001, that is, the degree of preventing the propagation path of air vibration changes according to the position of the mute volume adjustment section 5002, so that the mute volume can be adjusted.

[0124] FIGS. 57 to 59 show an example of a cross-sectional configuration of the volume control unit 5000 that realizes continuous volume adjustment (not mute) by continuously changing the inner diameter of the sound guide unit 120, and a series of volume adjustment operations. ing. The sound volume control unit 5000 includes a soft tube 5701 inserted into the C portion of the sound guide unit 120, and a ring-shaped sound volume adjustment unit 5702 through which the soft tube 5701 is inserted. The outer periphery of the soft tube 5701 has a tapered structure in which the tip is directed to the volume control section 5702, and the outer diameter increases as the distance from the volume control section 5702 increases. On the other hand, the inner diameter of the volume adjusting section 5702 is larger than the front end of the soft tube 5701 having the tapered structure, but smaller than the rear end. The inner diameter of volume control section 5702 is constant in the length direction, or has a tapered shape whose gradient is gentler than the outer circumference of soft tube 5701.

[0125] The sound volume adjustment unit 5702 can move in the longitudinal direction of the soft tube 5701. The soft tube 5701 is narrowed down as it is accommodated in the ring-shaped volume control section 5702, and as a result, is compressed in the radial direction and becomes thinner. That is, in the examples shown in FIGS. 57 to 59, the soft tube 5701 is narrowed down by changing the position in the longitudinal direction of the ring-shaped volume control unit 5702, and the inner diameter is continuously changed.

[0126] In the state shown in FIG. 57, the soft tube 5701 is completely separated from the volume control unit 5702. Therefore, the soft tube 5701 remains at the initial inner diameter and, as indicated by reference numeral 5711, moves toward the other end 122 of the sound guide unit 120 without interrupting the air vibration of the sound taken in from the sound generation unit 110. Can propagate.

[0127] In the state shown in FIG. 58, about half of the soft tube 5701 is housed in the volume control unit 5702. As a result, the soft tube 5701 is compressed in the radial direction, and is thinner than the initial inner diameter. Therefore, as indicated by reference numeral 5801, the air vibration of the sound taken in from the sound generation unit 110 is attenuated in accordance with the degree of compression of the soft tube 5701, and is radiated from the other end 122 to the listener. The volume of the sound reaching the eardrum decreases. It should be well understood that the volume decreases continuously according to the operation of inserting the soft tube 5701 into the volume adjustment section 5702.

[0128] In the state shown in FIG. 59, the soft tube 5701 is completely housed in the volume control section 5702 and is crushed, so that the propagation path of the air vibration is completely closed. Therefore, as shown by reference field No. 5901, the air vibration of the sound taken in from the sound generation unit 110 is blocked at the place where the soft tube 5701 is crushed, and hardly reaches the other end 122 of the sound guide unit 120. Therefore, the volume is 0.

[0129] FIGS. 60 to 62 show another example of a cross-sectional configuration of the volume control unit 5000 that realizes continuous volume adjustment by continuously changing the inner diameter of the sound guide unit 120, and a series of volume adjustment operations. Volume control section 5000 includes elastic deformation section 6001 that constitutes a part of the side surface of sound guide section 120 at section C, and a cam that is rotatable around rotation axis 6003 and that is arranged to contact elastic deformation section 6001. 6002. Although the cam 6002 may be a disk, the distance to the circumference is not constant because the rotation shaft 6003 is eccentric, and the degree of protrusion of the elastic deformation portion 6001 into the tube of the sound guide portion 120 changes according to the rotation angle. .

[0130] In the state shown in FIG. 60, the cam 6002 is in contact with the elastically deformable portion 6001 at the rotation position where the distance from the rotation shaft 6003 is the shortest. Therefore, the elastically deforming portion 6001 remains in the initial shape and, as indicated by reference numeral 6011, does not interrupt the air vibration of the sound taken in from the sound generating portion 110 and is connected to the other end 122 of the sound conducting portion 120. Can propagate toward it.

[0131] In the state shown in FIG. 61, the cam 6002 is in contact with the elastically deformable portion 6001 at a rotation position where the distance from the rotation shaft 6003 is longer than in the state shown in FIG. Therefore, the elastically deformable portion 6001 is elastically deformed and slightly protrudes inside the sound guide portion 120 to slightly close the inside of the sound guide portion 120 which is a propagation path of the air vibration. In such a case, as indicated by reference numeral 6101, the air vibration of the sound taken in from the sound generation unit 110 is attenuated according to the degree to which the protruding elastic deformation unit 6001 blocks the propagation path. As a result, the volume of the sound radiated from the other end 122 and reaching the eardrum of the listener decreases. It should be well understood that the volume of the elastically deformable portion 6001 obstructs the propagation path, in other words, the sound volume continuously decreases in accordance with the rotation of the cam 6002.

[0132] In the state shown in FIG. 62, the cam 6002 is in contact with the elastic deformation part 6001 at the rotation position where the distance from the rotation shaft 6003 is the longest. . And completely covers the inside of the sound guide section 120 which is a propagation path of air vibration. Therefore, as indicated by reference numeral 6201, the air vibration of the sound taken in from the sound generation unit 110 hardly reaches the other end 122 of the sound guide unit 120, and the volume is 0.

[0133] J. Processing of Audio Signal As described with reference to FIG. 11, a dynamic speaker can be applied to the sound generator 110. That is, the inside of the sound generating unit 110 is partitioned by the diaphragm

1101 into a diaphragm front space (front cavity) 1102 and a diaphragm rear space 1103 (back cavity). When the magnetic field changes in response to a voice signal input to the voice coil 1105 via the cord 602, the diaphragm 198 moves back and forth by the magnetic force of the magnet 1104, and the diaphragm front space 1102 and the diaphragm rear surface A change in air pressure occurs between the spaces 1103, which becomes sound.

[0134] Examples of the sound generating element for generating sound include a dynamic type, a balanced armature type, a condenser type, and the like. However, the applicant considers that the sound generation unit 110 is preferably a dynamic type in order to sufficiently drive the sound guide unit 120 having a bent pipe structure folded back from the back side to the front side of the pinna. .

[0135] FIG. 63 illustrates acoustic characteristics (frequency level characteristics) at the other end 1220 of the sound guide unit 120 when the sound generating unit 110 is configured by a dynamic speaker. The horizontal axis in the figure is the frequency level [Hz], and the vertical axis is the output sound pressure [dBV]. From this figure, it can be confirmed that there is a response in a low frequency range of 100 Hz or less, which is important for listening to music, and that there is a response also in an audible frequency range around 20 kHz.

[0136] There is a problem that the sound propagating through the sound guide unit 120, that is, the pipe, has a weak low frequency. Thus, the resonance of the one-sided opening of the sound guide unit 110 or the attenuation in the low frequency range may be corrected by signal processing.

[0137] For example, when the signal processing (equalizer) having the frequency characteristics shown in FIG. 64 is applied to the audio signal input to the sound generation unit 110, the acoustic characteristics (frequency level characteristics) of the sound output device 100 are changed as shown in FIG. Can be improved as shown in FIG. However, in FIG. 65, the frequency level characteristic improved by the signal processing is shown by a solid line, and the frequency level characteristic before improvement (shown in FIG. 63) is shown by a dotted line for comparison. Compared to before the improvement, it can be seen that while the low range is improved by the signal processing, the wide range is suppressed and the output sound pressure is flattened over a wide band. Such signal processing can be performed inside the sound output device 100. However, the sound signal after the above-described signal processing has been externally performed may be input to the sound output device 100.

[0138] FIGS. 66 to 68 exemplify the one-side open resonance effect of the sound conductor 110. FIG. 66 shows a state in which the sound of a frequency component corresponding to a quarter wavelength of the entire length of the one-side open sound conductor 120 resonates and a standing wave appears. FIG. 67 shows a state in which the sound of a frequency component corresponding to the entire length of the sound guide section 120 corresponding to $1/4$ wavelength resonates and a standing wave appears. Further, FIG. 68 shows a state in which the sound of the frequency component corresponding to the entire length of the sound guide section 120 corresponding to $2 + 4$ wavelength resonance resonates and a standing wave appears. FIG. 69 exemplifies the acoustic characteristics (frequency level characteristics) at the other end 1220 of the sound conductor 120 affected by the one-side open resonance effect. In this case, there is a peak characteristic of the sound pressure frequency due to resonance. That is, the peak of the sound pressure frequency due to the resonance appears near the frequencies corresponding to the lengths of the sound guide section 120 of 波長 wavelength, $1 + 4$ wavelength, $2 + 4$ wavelength, and so on.

[0139] As shown in FIG. 69, if the peak of the sound pressure level appears only in a specific frequency component, the sound quality deteriorates. Preferably, the peaks have a uniform sound pressure level over a wide frequency range, which requires flattening the peaks.

[0140] 70 and 71 show examples of the configuration of the sound guide unit 120 that suppresses the peak characteristic of the sound pressure frequency due to resonance. The sound guide section 120 shown in each figure has an acoustic element (acoustic resistance) that suppresses the resonance action at a portion corresponding to the antinode where the amplitude of the standing wave generated by the one-side open resonance action of the sound guide section 110 is maximized. Are arranged respectively. More specifically, the sound guide section 120 shown in FIG. 70 includes an acoustic element 125 on a wall corresponding to the antinode of a standing wave of sound having a frequency component corresponding to a total length of $1 + 4$ wavelength. Are arranged. In the sound guide unit 120 shown in FIG. 71, an acoustic element 125 is provided on a wall surface corresponding to the antinode of a standing wave of sound having a frequency component corresponding to a total length of $2 + 4$ wavelength. Have been. A general expression that an acoustic element 125 is provided on a wall corresponding to the antinode of a standing wave of sound composed of frequency components corresponding to $N +$ quarter wavelengths (where N is an integer of 1 or more) Can be.

[0141] FIG. 72 shows an enlarged example of the acoustic element 125. The illustrated acoustic element 125 is configured by fine sound holes formed in the wall surface of the sound guide 120. As shown in FIG. 72, the sound hole 7201 attenuates the standing wave propagating in the sound conduit 120 by emitting the standing wave to the outside of the sound guide 120, and adjusts the frequency level characteristic of the resonance component. The acoustic element 125 can achieve different effects depending on the diameter, the length, and the like of the sound hole 7201.

[0142] FIG. 73 shows another example of the acoustic element 125 in an enlarged manner. The illustrated acoustic element 125 includes an air chamber 7301 that is recessed in the wall surface of the sound guide 120. As shown in FIG. 73, the standing wave traveling in the sound conduit 120 is attenuated by going into the air chamber 7301, and adjusts the frequency level characteristic of the resonance component. The acoustic element 125 can achieve different effects depending on the volume, shape, and the like of the air chamber 7301.

[0143] However, when the acoustic element 125 includes only the sound hole or the air chamber, there is a concern that the standing wave component leaks from the sound hole to the outside or goes around the air chamber and is excessively attenuated. Therefore, it is more preferable that the acoustic element 125 adjusts the attenuation of the standing wave component by filling the acoustic holes with acoustic resistance. The acoustic resistance is a member in which the resistance when sound waves pass is higher than that of air, and the resistance increases as the filling density of the acoustic resistance increases. The acoustic resistance is made of, for example, a nonwoven fabric or a foamed foam such as urethane.

[0144] FIG. 74 exemplifies acoustic characteristics (frequency level characteristics) in the case of using the sound conductor 120 that suppresses the peak characteristics of the sound pressure frequency due to resonance. In the figure, the acoustic characteristic (frequency level characteristic) after suppressing the peak characteristic of the sound pressure frequency due to resonance is indicated by a solid line, and the acoustic characteristic before suppression is indicated by a dotted line for comparison. It can be seen that the output sound pressure is flattened over a wide band by suppressing the peak characteristic of the sound pressure frequency due to resonance.

[0145] K. Conclusion Lastly, features of the sound output device 100 according to the present embodiment will be summarized.

[0146] (1) The listener can naturally hear the ambient sound even while wearing the sound output device 100. Therefore, it is possible to normally use the human functions that depend on the auditory characteristics, such as grasping the space, perceiving danger, talking, and grasping subtle nuances during the conversation.

[0147] (2) Since the acoustic output device 100 does not block the ear hole when worn, it has an appearance that can be spoken to by others. In addition, since the listener wearing the sound output device 100 always hears the surrounding sound, as a nature of a person, when a person approaches, from the acoustic information such as footsteps, "turn the body in the direction of sound". And passive attitudes such as "look at the direction of the sound". Such behavior gives the impression that "you may talk" to others, and does not hinder communication between people.

[0148] (3) The sound output device 100 is not affected by self-generated noise sound. The other end 122 of the sound guide portion 120, which is the sound output hole, is separated from the inner wall of the ear canal when the ear hole is attached, so that the listener's own voice, beating sound, mastication sound, sound when swallowing. It is not affected by blood flow sounds, breath sounds, vibration sounds that travel through the body during walking, and rubbing sounds such as cords. Also, no friction noise is generated between the earpiece and the inner wall of the ear canal. In addition, since the ear canal is opened, there is no need to worry about the moisture in the ear canal.

[0149] (4) The sound output device 100 has good wearability to the ear, and can absorb positioning variations caused by individual differences in the size and shape of the ear. The holding portion 130 is configured to engage with the bead notch, and to support the sound output hole at the other end 122 of the sound guide portion 120 so as to face the back side of the ear canal. Therefore, there is no need for length adjustment as in the case of an ear-mounted sound output device in which the sound conductor is folded back by an ear ring. In addition, since the holding portion 130 engages with the inter-bead notch, a good wearing state can be maintained. Furthermore, by pinching and fixing the ear lobe with the pinch portion 123 which is the folded portion of the sound guide portion 120, a good wearing state can be maintained. In addition, the structure in which the sound

guide portion 120 is folded back from the back of the pinna and extended to the vicinity of the entrance of the external auditory meatus, so that even if the listener uses glasses, glasses-type wearable devices, Do not interfere with other devices.

[0150] (5) The sound guide unit 120 propagates the sound generated by the sound generation unit 110 to the vicinity of the entrance of the ear canal at the shortest distance from behind the ear. Therefore, as compared with the ear-attached sound output device, the sound loss can be minimized as much as the length of the sound conducting portion is shortened, and the sound generator 110 is set to have a low output, thereby achieving good sound quality. Can be obtained. In addition, the dimensional tolerance of the sound generation unit 110 is high, and a design corresponding to a required sound band and sound pressure is possible.

[0151] The technology disclosed in this specification has been described above in detail with reference to the specific embodiments. However, it is obvious that those skilled in the art can modify or substitute the embodiment without departing from the gist of the technology disclosed in this specification.

[0152] The acoustic output device to which the technology disclosed in the present specification is applied is used by being attached to a listener's ear like a so-called earphone, but realizes the same ambient sound listening characteristics as the non-wearing state even in the wearing state. In addition, acoustic information can be output at the same time, and even in the wearing state, it appears that surrounding people do not seem to block the ear hole of the listener. Taking advantage of such features, various sport fields (in the course of playing, for example) in which the sound output device to which the technology disclosed in this specification is applied are outdoors and indoors including walking, jogging, cycling, mountain climbing, skiing, and snowboarding. Or remote coaching, etc.), communication or presentation fields that require simultaneous listening of ambient sound and presentation of audio information (for example, supplementary information on play viewing, presentation of museum audio information, bird watching, etc.), driving or navigation, Security guards, newscasters and so on.

[0153] In this specification, the technology disclosed in this specification has been described by way of example. Therefore, the contents described in this specification are not to be construed as limiting. In order to determine the gist of the technology disclosed in this specification, the claims should be considered.

[0154] The technology disclosed in the present specification may have the following configurations. (1) a sound generator disposed on the back of the listener's ear, and one end connected to the sound generator and the other end disposed near the ear canal entrance of the listener; A sound output device comprising: a sound conductor having a hollow structure, which takes in generated sound from the one end and propagates the sound to the other end. (1-1) The acoustic output device according to (1), wherein the sound guide unit has a folded structure that folds back from the front to the back of the ear near the edge of the earlobe of the listener. (1-2) The sound output device according to (1), wherein the other end of the sound guide unit has an outer diameter smaller than an inner diameter of an ear canal of the listener. (2) The acoustic output device according to (1), further including a holding unit that holds the other end of the sound guide unit near an entrance of an ear canal of the listener. (3) The sound output device according to (2), wherein the holding unit engages with a bead notch of the listener. (3-1) The sound output device according to (3), wherein the holding unit supports the sound guide unit such that the other end of the sound guide unit faces the back of an ear canal. (3-2) The acoustic output device according to (3), wherein the holding unit includes an opening that opens an external ear canal entrance to the outside world. (3-3) The sound output device according to (3), wherein the holding unit is in contact with a bottom surface of the concha of the concha. (3-3-1) The acoustic output device according to (3-3), wherein the holding unit includes a contact unit that makes contact with the bottom surface of the concha of ear cavities (or a large contact area). (3-3-2) The acoustic output device according to (3-3), wherein the holding unit includes a contact unit curved to have a bottom surface shape of the concha of the concha. (4) The sound output device according to (1), further including a pinch portion that holds the ear lobe of the listener and attaches the sound output device to the ear. (5) The sound guide portion includes a pinch portion having an open / close structure disposed at a portion turned back from the back side to the front side of the pinna of the listener, and the pinch force for returning the pinch portion to the closed position. The sound output device according to the above (1), wherein the ear lobe is pinched by using the sound source. (6) The sound output device according to (1), further including a pinch unit that holds the listener's ear lobe together with the sound generation unit and attaches the sound generation unit to the ear. (6-1) The sound output device according to the above (6), wherein the sound generation unit includes a contact unit having a shape conforming to a listener's back shape surface. (6-2) The sound output according to any one of (6) and (6-1), wherein the sound generation unit includes a contact portion having a curved shape at a portion that abuts on the back of the listener. apparatus. (7) The sound output device according to (1), further including a guard unit that prevents the other end of the sound guide unit from being

inserted deeply into the ear canal of the listener. (8) The holding portion is engaged with the vicinity of the ear canal entrance (inter-notch notch) of the listener, and fixes the sound conducting portion near the other end so as not to be inserted deeply into the ear canal. The sound output device according to (2). (9) The sound according to (1), further including a deforming portion that is deformed in response to an external force to prevent the other end of the sound guide portion from being inserted deeply into the ear canal of the listener. Output device. (10) The sound output device according to (5), wherein the sound guide unit includes a deformable unit that is deformed in response to an external force between the other end and the pinch unit. (11) The sound output according to (10), wherein the deformable portion is broken when an external force equal to or more than a predetermined value is applied, and prevents the other end of the sound guide portion from being inserted deeply into the ear canal of the listener. apparatus. (12) The deformable portion is broken when an external force greater than a predetermined value is applied, and prevents the other end of the sound guide portion from being inserted deeply into an external auditory canal of the listener, and can be reconnected. The sound output device according to the above (10). (13) The deformed portion bends when an external force is applied to prevent the other end of the sound guide portion from being inserted deeply into the ear canal of the listener, and restores the original shape when released from the external force. The sound output device according to (10). (14) The acoustic output device according to (1), further including an earwax intrusion prevention unit at the other end of the sound guide unit. (14-1) The sound output device according to (14), wherein the earwax intrusion prevention unit is detachable from the other end. (15) The sound output device according to (1), further including a sound volume control unit that adjusts the sound volume of sound output from the other end to the ear canal according to a change in the inner diameter of the sound guide unit. (16) The volume control section switches between a mute-on state and a mute-off state by a toggle operation of a mute section that appears and disappears in the sound guide section in response to a surface being pressed. 3. The sound output device according to claim 1. (17) In response to the pressing of the surface, the mute unit appears in the sound guide unit in a mute-on state in response to the pressing of the surface, and when the surface is released from the pressing, the mute unit controls the sound. The sound output device according to the above (15), wherein the sound output device is retracted from the inside of the guide portion and enters a mute / off state. (18) The volume control section includes a soft tube having a tapered structure inserted into the sound guide section, and a ring-shaped volume control section through which the soft tube is inserted, and according to a position inserted into the volume control section. The sound output device according to (15), wherein the sound volume is continuously set by continuously changing the inner diameter of the soft tube. (19) The volume control unit includes an elastically deforming portion that constitutes a part of a side surface of the sound guiding portion, and a cam rotatably disposed so as to contact the elastically deformable portion. The sound output device according to the above (15), wherein the elastic deformation portion protrudes into the sound guide portion according to a change in an angle, and continuously sets a sound volume. (20) The sound output device according to (1), wherein the sound generation unit includes a dynamic sound generation element. (21) The sound output device according to any one of (1) and (20), further including a signal processing unit that performs a gain adjustment on the audio signal input to the sound generation unit according to a frequency level. (22) The sound output device according to (21), wherein the signal processing unit performs signal processing for correcting low-frequency attenuation of a sound output from the other end of the sound guide unit. (23) The sound output device according to (1), wherein the sound guide unit includes an acoustic element in at least one portion of the hollow structure. (23-1) The sound guide section is provided with the acoustic element in a portion corresponding to an antinode where the amplitude of a standing wave of sound generated by a resonance action in the hollow structure that is open on one side is maximized. The sound output device according to 23). (23-2) The acoustic output device according to (23), wherein the acoustic element includes a sound hole or an air chamber formed in a wall surface of the hollow structure. (23-2-1) The acoustic output device according to (23-2), wherein the acoustic element further includes an acoustic resistor.

[0155] Reference Signs List 100: sound output device, 110: sound generation unit 120: sound conduction unit, 121: one end (sound input hole) 122: other end (sound output hole), 123: pinch unit 124: deformation unit, 130: holding unit, 132 ... Supporting member 1101 ... Diaphragm 1104 ... Magnet 1105 ... Voice coil 3401 ... Shape memory pulling spring 3402 ... Helical structure pinch duct 3403 ... High elasticity film 3601 ... High elasticity string, 3602 ... Sector type pinch Duct 3603 High elasticity coating 4201 Connection part 4202 Connection part 4203 Pinch force generating spring 4204 High elasticity coating 4301 Magnet part 4401 Screw type slide part 4402 Hook part 4501 Thin thin brittle part 4601: Joint type weak portion 4701: Soft structure bending portion 4801: Earwax intrusion prevention portion 4901: Earwax intrusion prevention filter 000 ... sound volume control unit 5001 ... mute unit, 5002 ... mute volume adjusting unit 5701 ... soft tube, 5702 ... volume adjusting unit 6001 ... resilient deformation part, 6002 ... cam, 6003 ... rotary shaft

JP6652164B2 SOUND OUTPUT DEVICE

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The wording below is an initial machine translation of the original publication. To generate a version using the latest translation technology, go to the original language text and use Patent Translate.

A sound generating unit for generating a sound, a holding unit having an annular hollow structure arranged so as to open the ear canal entrance and hang on the intertragus notch of the ear, and a sound generated by the sound generating unit at a sound output end. A sound guide portion for outputting toward the ear canal; and a support member formed on a part of the holding portion and supporting an acoustic output end of the sound guide portion, wherein the sound of the sound guide portion is provided by the support member. The output hole is fixed so as not to enter the ear canal at the entrance of the ear canal, and the sound output portion of the sound guide portion is positioned so that sound can be radiated to the back of the ear canal in the ear hole. A sound output device, which does not have a structure for hanging from above and a structure for inserting the holding portion into an ear canal.

The sound output device according to claim 1, wherein the holding portion has an annular structure.

The sound output device according to claim 2, wherein the annular structure is a ring type.

3. The sound output device according to claim 2, wherein the annular structure is egg-shaped.

The sound output device according to claim 2, wherein the annular structure is elliptical.

The sound output device according to any one of claims 1 to 5, wherein the holding unit has the annular structure formed of a flexible material.

The sound output device according to claim 1, wherein the sound generator has an elliptical shape.

The sound output device according to any one of claims 1 to 6, wherein the sound generation unit has a shape that conforms to the shape of the back of the ear.

The sound output device according to any one of claims 1 to 8, further comprising an earwax intrusion prevention filter in a sound output hole of the sound guide unit.

The sound output device according to claim 1, wherein the sound generation unit inputs a sound signal as a wireless signal.

The sound output device according to claim 1, wherein the sound generation unit is connected to a cord that inputs a sound signal.

The sound output device according to claim 1, wherein the sound generator has a speaker.

13. The sound output device according to claim 12, wherein the speaker is a dynamic speaker.

14. The sound output device according to claim 13, wherein the dynamic speaker generates sound in accordance with a magnetic field change due to a sound signal.

The sound output device according to claim 14, wherein the sound generation unit has an exhaust hole that emits sound generated in a space behind the diaphragm of the speaker to the outside.

The sound output device according to claim 12, wherein the speaker is a balanced armature type speaker.

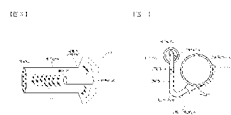
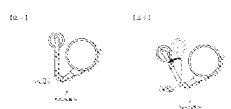
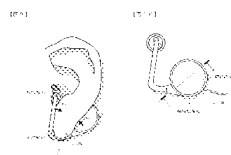
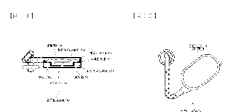
13. The sound output device according to claim 12, wherein the speaker is a condenser speaker.

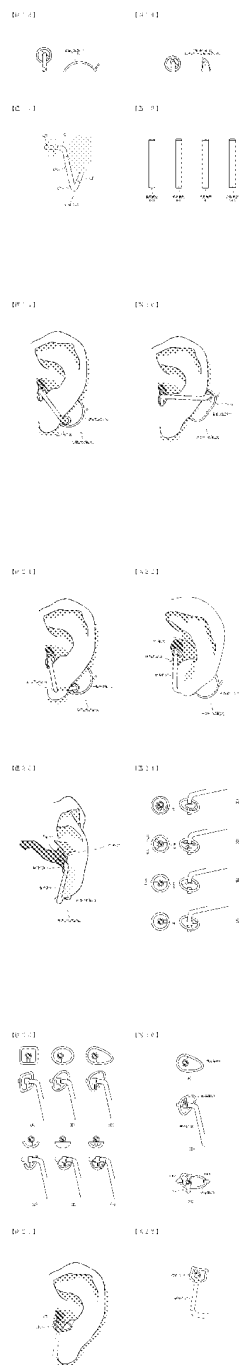
13. The sound output device according to claim 12, wherein the speaker is a piezoelectric speaker.

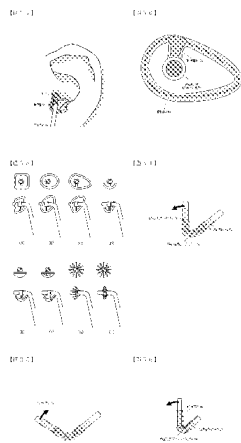
The sound output device according to claim 12, wherein the speaker is an electrostatic speaker.

The acoustic output according to claim 12, wherein the speaker is any one of a dynamic type, a balanced armature type, a capacitor type, a piezoelectric type, and an electrostatic type, or a composite type of two or more types. apparatus.

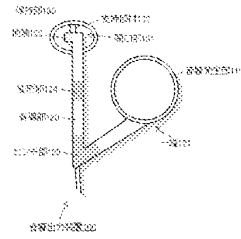
Drawings - JP6652164B2 SOUND OUTPUT DEVICE



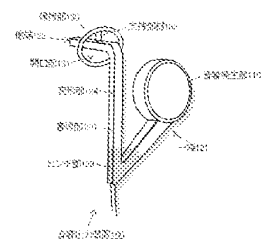




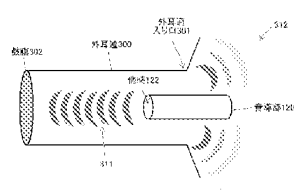
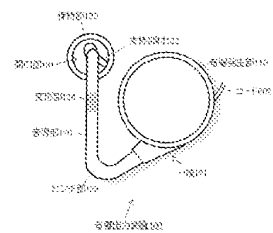
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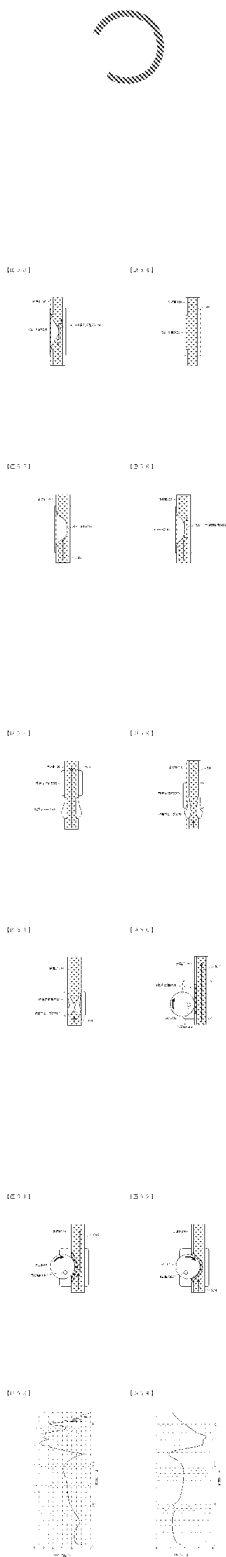


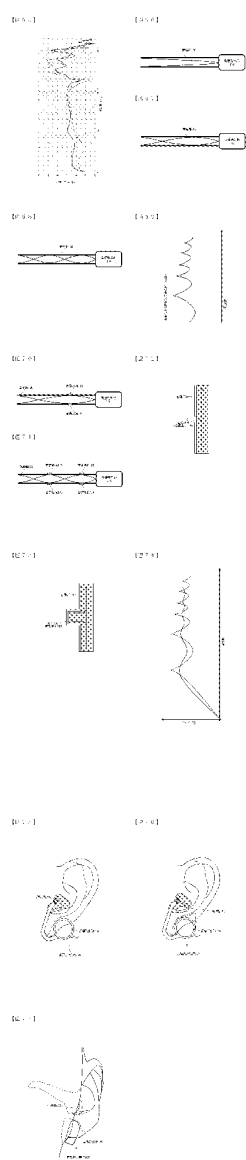
【例 3】



【 24 4 】









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AUTHORIZED BY Matthew Leaper

Documents

TOTAL DOCUMENTS: 44

DOCUMENT	PAGES	DESCRIPTION	SIZE (KB)
generatedADS63455252.pdf	6	Application Data Sheet	146 KB
DF-P01-US08_TLNA.pdf	2	Transmittal of New Application	87 KB
DF-P01-US08_SPECIFICATION.pdf	73	Specification	422 KB
DF-P01-US08_DRAWINGS.pdf	14	Drawings-only black and white line drawings	3326 KB
DF_P01_US08_CLAIMS.pdf	4	Claims	75 KB
DF_P01_US08_ABSTRACT.pdf	1	Abstract	50 KB

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COMMUNICATION DEVICES, METHODS, AND SYSTEMS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a § 1.53(b) continuation of pending prior U.S. Patent Application No. 18/388,489, filed November 9, 2023, which is a continuation of U.S. Patent Application No. 18/143,142, filed May 4, 2023, which is a continuation of U.S. Patent Application 18/092,398, filed January 2, 2023, now U.S. Patent No. 11,684,313, which is a continuation of U.S. Patent Application No. 17/213,117, filed March 25, 2021, now U.S. Patent No. 11,589,816, which is a continuation of U.S. Patent Application No. 16/757,482, filed April 20, 2020, now U.S. Patent No. 10,959,674, which is a § 371 National Stage Entry of International Patent Application No. PCT/US18/56814, filed October 22, 2018, claiming the benefit of priority of U.S. Provisional Patent Application No. 62/676,949, filed May 26, 2018, and U.S. Provisional Patent Application No. 62/575,951, filed October 23, 2017, the entireties of which are incorporated by reference into the enclosed application.

TECHNICAL FIELD

[0002] Aspects of the present disclosure generally relate to communication devices, methods, and systems.

BACKGROUND

[0003] Computer screens have emerged as the most common means for person-to-computer communication. In 2015, for example, it was estimated that the average adult spends roughly 10 hours a day looking at a screen to consume information and/or communicate with others. The human eye was not designed for all this screen time, and numerous health problems have been associated therewith. For example, eyestrain from hours of screen time may cause instances of eye irritation, dryness, fatigue, and/or blurred vision that last for extended periods of time. These

problems are increasingly common, and the near constant production of new screen-oriented devices (e.g., the next iPhone®) suggests further increases.

[0004] Alternate means for person-to-computer communications may reduce the negative effects of excessive screen time. For example, the human body includes many non-optical nerves that are capable of communicating data to the brain, such as the nerves associated with the skin. Further improvements are required to better leverage these and other communication capabilities of living tissue. Aspects of this disclosure may solve the above reference problems, solve other known problems, and/or overcome other deficiencies in the prior art.

SUMMARY

[0005] Numerous aspects are disclosed in this application. One exemplary aspect is a communication device comprising: a body comprising a distal surface compatible with skin; a tissue interface on the distal surface, the tissue interface comprising a plurality of energy generators, each energy generator being operable to output a plurality of energies in a signal direction toward the skin; an attachment element configured to maintain the tissue interface against the skin; and a processing unit configured to communicate with nerves associated with the skin by receiving input data from a data source and causing the plurality of energy generators to output an energy signal in the signal direction with one or more energies of the plurality of energies.

[0006] The body may be flexible. The body may comprise a plurality of communication bays, and each energy generator may be located in and configured to output the energy signal out of one of the communication bays. The body may comprise an insulating material configured to promote flows of the one or more energies out of each communication bay in the signal direction, and limit flows of the one or more energies between the plurality of communication bays. The attachment element may comprise a plurality of holes aligned with the plurality of communication bays, and

each energy generator may be configured to output the plurality of energies through one of the holes. An interior surface of each communication bay or hole may be configured to direct the one or more energies in the signal direction. The interior surface of each communication bay or hole may be configured to focus at least one energy of the one or more energies in the signal direction.

[0007] The attachment element may comprise a biocompatible adhesive disposed on the distal surface of the body. The attachment element may comprise an elastic portion configured to maintain the tissue interface against the skin. The elastic portion may expand to receive a circular portion of the skin and contract to maintain the tissue interface against the circular portion of the skin. The body may be removably attached to the attachment element. The input data may comprise a measurement, and the processing unit may be configured to modify the energy signal based on the measurement. The processing unit may be configured to determine a change of the measurement and modify the energy signal based on the change of the measurement.

[0008] The plurality of energy generators may be spaced apart on the distal surface of the body in a pattern; each energy generator may be operable to output the one or more energies in the signal direction toward a different point on the pattern; and the energy signal may comprise a plurality of symbols based on the pattern. Each symbol may comprise a plurality of dots, and each dot may correspond with one of the different points on the pattern. The plurality of symbols may comprise at least one alphanumeric symbol. The processing unit may be operable with the plurality of energy generators to scroll the plurality of symbols across the skin at a scroll rate in a communication direction transverse with the signal direction.

[0009] The input data may comprise vital signs of a subject, and the plurality of symbols may comprise a symbol associated with each vital sign. The plurality of symbols may comprise a symbol associated with an identity or location of the subject. The processing unit may be

configured to: determine a change of the vital signs; and modify the one or both of the plurality of symbols and the scroll rate based on the change of the vital signs. The processing unit may be configured to: output one or more of the plurality of symbols with a first combination of the one or more energies when the change is within a predetermined range; and output the one or more of the plurality of symbols with a second combination of the one or more energies when the change is outside the predetermined range.

[0010] The data source may comprise one or more data sources, and the processing unit may be configured to: receive the input data from the one or more data sources; generate a control signal based on the input data; and cause the plurality of energy generators to output the energy signal according to the control signal. The processing unit may be configured to: determine a change in the input data; and modify the control signal based on the change of the input data. The control signal may comprise a scroll rate for the energy signal the processing unit may be configured to: determine the scroll rate based on the input data; and cause the plurality of generators to scroll the energy signal across the skin at the scroll rate.

[0011] Each energy generator may comprise a plurality of generator elements and a controller operable with the plurality of generator elements to output the plurality of energies; the control signal may comprise output commands for each controller of each energy generator; and each controller may be configured to receive the control signal, select one of the output commands, and cause one or more of the plurality of generator elements to output the one or more energies based on the selected one of the output commands.

[0012] Each energy generator may comprise a plurality of generator elements, and each generator element may be operable to output one of the plurality of energies in the signal direction. The plurality of generator elements may comprise one or more of: an impact generator element; a

heat generator element; a shock generator element; and a pressure generator element. Each generator element may be configured to output the one of the plurality of energies toward a similar point or area on the skin. The plurality of generator elements may be arranged coaxially with a communication axis parallel to the signal direction.

[0013] The data source may comprise a local sensor that is attached to the body and configured to output a portion of the input data. The data source may comprise at least one remote sensor that is remote from the body and configured to output a portion the input data. The processing unit may be configured to receive the input data from a server in communication with the at least one remote sensor. The at least one remote sensor may comprise a health monitoring device. The device may comprise a power generator attached to the body. The power generator may comprise a photovoltaic cell mounted to a proximal surface of the body. The one or more energies may comprise: a first energy configured to communicate the energy signal; and a second energy configured to modify a penetration depth of the first energy. The first energy may be communicable with a first portion of the nerves, and the second energy may be communicable with a second portion of the nerves.

[0014] The body may comprise an impact absorbing material; and the attachment element may comprise a garment configured to maintain a position of the impact absorbing material relative to a user body. The processing unit may be configured to determine a direction of movement for the user body and output the energy signal based on the direction of movement. The processing unit may be configured to determine a change in the direction of movement and modify the energy signal based on the change in the direction of movement. The attachment element may comprise a shoe, and the distal surface of the body may comprise an interior surface of the shoe. The input

data may comprise GPS signals, the processing unit may be configured to determine a direction of movement for a user body based on the GPS signals.

[0015] The attachment element may comprise a grip, and the body may comprise an exterior surface of the grip. The grip may be integral with a weapon comprising a sight, the input data may comprise data associated with an orientation of the sight, and the energy signal may be configured to communicate a status of the weapon based on the orientation of the sight. The input data may comprise data associated with an alignment of the sight with a target, and the processing unit may be configured to output the energy signal with a first combination of the one or more energies when the target is not aligned with the sight and a second combination of the one or more energies when the target is aligned with the sight.

[0016] The device may be implantable. The attachment element may comprise a bone plate engageable with a bone to orient the tissue interface toward an underside of the skin. The attachment element may comprise a tissue in-growth structure interactable with living tissue to maintain an orientation of the tissue interface toward an underside of the skin.

[0017] The plurality of energy generators may be arranged in bands; the attachment element may be configured to maintain each band against the skin; the input data may comprise input data for each band; and the processing unit may be configured to communicate with nerves associated with the skin by causing the plurality of energy generators in each band to output a different energy signal based on the input data for each band. The body may extend along a longitudinal axis; and the bands may be spaced apart along the longitudinal axis. The body may be configured to wrap around a limb so that the longitudinal axis of body is aligned with a longitudinal axis of the limb, and the bands wrap around the limb about the longitudinal axis. The processing unit may be operable with the plurality of energy generators to scroll each different energy signal in each band

in a communication direction transverse with the signal direction. The input data for each band may comprise different vital signs, and each different energy signal may be based on one of the different vital signs.

[0018] The signal direction may comprise a first signal direction and the device may comprise an optical interface on a proximal surface of the body; the optical interface may comprise at least one display element operable to output at least one color toward eyes in a second signal direction opposite of the first signal direction; and the processing unit may be operable with the tissue interface and the optical interface to communicate simultaneously with nerves associated the skin and the eyes by outputting the energy signal with the one or more energies of the plurality of energies in the first signal direction and outputting an optical signal with the at least one color in the second signal direction.

[0019] The body may extend along a longitudinal axis, and the first and second signal directions may be transverse with the longitudinal axis. The energy signal and the optical signal may be scrolled together along or about the longitudinal axis. The processing unit may be configured to: receive the input data from the data source; generate a control signal based on the input data; cause the plurality of energy generators to output the energy signal according to the control signal; and cause the at least one display element to simultaneously output the optical signal according to the control signal. The energy signal may correspond with the optical signal.

[0020] The input data may comprise vital signs of a subject, the energy signal may comprise a plurality of symbols associated with the vital signs, and the optical signal may comprise the plurality of symbols. The processing unit may be configured to: determine a change of the vital signs; and modify the plurality of symbols based on the change of the vital signs. The device may

comprise a motion sensor attached to the body, and the processing unit may be configured to selectively output the optical signal in response to the motion sensor.

[0021] Another exemplary aspect may comprise a system. For example, the system may comprise: a plurality of any communication devices described herein; and at least one processor that is in communication with the plurality of communication devices and configured to: generate a corrective motion signal based on position data for the plurality of communication devices; and cause each communication device to output its energy signal based on the corrective motion signal.

[0022] The system may comprise at least one position sensor configured to determine the position data and output the position data to the at least one processor. The position data may comprise an actual location of each communication device; and the at least one processor may be configured to generate the corrective motion signal based on the actual location of each communication device and a target location of each communication device. The position data may comprise an actual spatial configuration of the plurality of communication devices; and the at least one processor may be configured to generate the corrective motion signal based on the actual spatial configuration and a target spatial arrangement for the plurality of communication devices. The at least one processor may be configured to: determine a movement direction for each communication device based on the actual and target spatial arrangements; and cause each communication device to scroll its energy signal across the skin in the movement direction.

[0023] Each communication device may be mounted to a different part of a user body; and the target spatial arrangement may comprise a physical position of the user body defined by relative positions of each different part of the user body. The physical position of the user body may comprise a pose or a stance. The at least one processor may be configured to guide the user body

through a series of different positions by determining the movement direction at intervals and modifying the energy signal for each interval.

[0024] Another exemplary aspect may comprise another communication device. In keeping with above, the device may comprise: a body comprising a distal surface compatible with skin; a tissue interface on the distal surface, the tissue interface comprising a plurality of energy generators, each energy generator being operable to output a plurality of energies in a signal direction toward the skin; and a processing unit configured to communicate with nerves associated with the skin by receiving input data, and causing the plurality of energy generators to output one or more energies of the plurality of energies in the signal direction.

[0025] The body may be flexible. The device may further comprise an attachment element configured to maintain the tissue interface in a position on or adjacent the skin. The distal surface of the body may comprise a biocompatible adhesive that is adherable to the skin. The body may comprise a plurality of communication bays, and each energy generator may be located in one of the communication bays. The attachment element may comprise a plurality of holes aligned with the plurality of communication bays, and each energy generator may be configured to output the plurality of energies through one of the holes. An interior surface of each communication bay or hole may be configured to direct the one or more energies in the signal direction. The interior surface may be configured to focus the at least one energy of one or more energies. The attachment element may comprise an elastic band. The body may be removably attached to the attachment element.

[0026] Another exemplary aspect may comprise another communication device. The communication device may comprise: a body comprising a distal surface compatible with skin; a tissue interface on the distal surface, the tissue interface comprising a plurality of energy

generators, each energy generator being operable to output a plurality of energies in a signal direction toward the skin; an attachment element configured to maintain the tissue interface against the skin; and a processing unit configured to communicate an energy signal to nerves associated with the skin by receiving input data, and causing the plurality of energy generators to output one or more energies of the plurality of energies in the signal direction.

[0027] The plurality of energy generators may be spaced apart in a grid pattern, and each energy actuator may be operable to output the plurality of energies towards a different point on the grid pattern. The energy signal may comprise a plurality of symbols, each symbol may comprise a plurality of dots, and each dot may correspond with one of the different points on the grid pattern. The plurality of dots in each symbol may be arranged in a dot pattern within the grid pattern. The processing unit may be operable with the plurality of energy generators to scroll the plurality of symbols across the skin in a communication direction transverse with the signal direction. For example, the processing unit may be operable with the plurality of energy generators to output and scroll each symbol using a different combination of the one or more energies of the plurality of energies.

[0028] The input data may comprise a measurement, and the processing unit may be configured to communicate the energy signal by selecting the one or more energies of the plurality of energies based on the measurement. For example, the processing unit may be configured to communicate the energy signal by determining a change of the measurement and modifying the one or more energies of the plurality of energies based on the change of the measurement.

[0029] Another exemplary aspect may comprise another communication device. For example, the communication device may comprise: a body comprising a distal surface compatible with skin; a tissue interface on the distal surface, the tissue interface comprising a plurality of energy

generators, each energy generator being operable to output a plurality of energies in a signal direction toward the skin; an attachment element configured to maintain the tissue interface on or adjacent the skin; and a processing unit configured to communicate an energy signal to nerves associated with the skin by: (i) receiving input data; (ii) selecting one or more energies of the plurality of energies based on the input data; and (iii) causing the plurality of energy generators to output the one or more energies in the signal direction.

[0030] The processing unit may be further configured to communicate the energy signal by: (iii) determining a change in the input data; and (iv) modifying the one or more energies based on the change. The processing unit may be further configured to communicate the energy signal by: (v) selecting a scroll rate based on the input data; and (vi) causing the plurality of generators to scroll the one or more energies across the skin at the scroll rate. The energy signal may comprise a plurality of symbols scrolled across the skin in a communication direction transverse with the signal direction. At least one symbol of the plurality of symbols may be an alphanumeric symbol.

[0031] Another exemplary aspect may comprise a communication method. The method may comprise: receiving, with a processing unit, input data for a communication device comprising a tissue interface maintainable on or adjacent skin, the tissue interface comprising a plurality of energy generators, each energy generator being operable to output a plurality of energies in a signal direction toward the skin; and operating, with the processing unit, the plurality of energy generators to communicate with nerves associated with the skin by outputting one or more energies of the plurality of energies in the signal direction based on the input data.

[0032] The receiving step may comprise receiving the input data from one or more data sources. For example, the one or more data sources may comprise at least one of patient monitoring device, a remote server, and a sensor. The receiving step may comprise receiving the input data

from the one or more data sources at regular intervals, and the operating step may comprise outputting the one or more energies based on the input data received during each regular interval. The input data may comprise a control signal, and the operating step may comprise outputting the one or more energies based on the control signal.

[0033] The method may further comprise generating, with the processing unit, a control signal based on the input data, wherein the operating step comprises outputting the one or more energies based on the control signal. Generating the control signal to may comprise associating the input data with a plurality of symbols, and the operating step may comprise communicating the plurality of symbols to the skin with the one or more energies. For example, the input data may comprise vital signs of a patient, and each symbol may be associated with one or more of the vital signs. The one or more energies may comprise a first combination of the plurality of energies followed by a second combination of the plurality of energies. The one or more energies also may comprise a first energy communicable with a first portion of the nerves, and a second energy communication with a second portion of the nerves.

[0034] Another exemplary aspect may comprise another communication method. The method may comprise: receiving, with a processing unit, input data for a communication device comprising a tissue interface maintainable on or adjacent skin, the tissue interface comprising a plurality of energy generators, each energy generator being operable to output a plurality of energies in a signal direction toward the skin; and operating, with the processing unit, the plurality of energy generators to communicate an energy signal to nerves associated with the skin by outputting one or more energies of the plurality of energies in the signal direction based on the input data.

[0035] The operating step may comprise outputting different combinations of the one or more energies, and each different combination may communicate a different portion of the energy signal. The energy signal may comprise one or more symbols, and the operating step may comprise outputting the one or more energies to communicate the one or more symbols. The operating step may comprise scrolling the one or more symbols across the skin in a communication direction transverse with the signal direction. The one or more symbols may comprise an alphanumeric symbol.

[0036] The operating step may comprise: outputting a first combination of the one or more energies to communicate a first symbol of the one or more symbols, and outputting a second combination of the one or more energies to communicate a second symbol of the one or more symbols. The operating step may comprise: outputting a first combination of the one or more energies to communicate the energy signal, and outputting a second combination of the one or more energies to communicate a characteristic of the energy signal. The input data may comprise a measurement, and the operating step may comprise outputting the one or more energies based on the measurement. For example, the operating step may comprise modifying the one or more energies based on a change of the measurement.

[0037] Another exemplary aspect may comprise another communication method. For example, the method may comprise: receiving, with a processing unit, input data for a communication device comprising a tissue interface maintainable on or adjacent skin, the tissue interface comprising a plurality of energy generators, each energy generator being operable to output a plurality of energies in a signal direction toward the skin; generating, with the processing unit, a control signal based on the input data; and operating, with the processing unit, the plurality

of energy generators to communicate with to nerves associated with the skin by outputting one or more energies of the plurality of energies in the signal direction based on the control signal.

[0038] Another exemplary aspect may comprise another communication device. The device may comprise: a body comprising a distal surface compatible with skin; a tissue interface on the distal surface, the tissue interface comprising a plurality of energy generators arranged in bands, each energy generator being operable to output a plurality of energies in a signal direction toward the skin; and a processing unit configured to communicate with nerves associated with the skin by receiving input data, and causing the plurality of energy generators in each band to output one or more energies of the plurality of energies in the signal direction.

[0039] The body may be flexible. The device may further comprise an attachment element configured to maintain the tissue interface in a position on or adjacent the skin. For example, the attachment element may comprise a distal surface adherable to the skin. The attachment element may be proximal of the tissue interface and configured to maintain the bands against the skin. The attachment element may be configured to maintain the bands against the skin by applying a tensile force to the body.

[0040] Another exemplary aspect may comprise another communication device. The device may comprise: a body extending along a longitudinal axis, and comprising a distal surface compatible with skin; a tissue interface on the distal surface, the tissue interface comprising a plurality of energy generators arranged in bands spaced apart along the longitudinal axis, each energy generator being operable to output a plurality of energies in a signal direction toward the skin; an attachment element configured to maintain the bands of the tissue interface against the skin; and a processing unit configured to communicate energy signals to nerves associated with

the skin by receiving input data, and causing the plurality of energy generators to output an energy signal in each band with one or more energies of the plurality of energies.

[0041] The body may be configured to wrap around a limb so that the longitudinal axis of body is aligned with a longitudinal axis of the limb, and the bands wrap around the limb about the longitudinal axis. The processing unit may be configured to move the energy signal in each band so as to scroll the energy signal around the limb. The one or more energies may comprise: a first energy configured to communicate one or more symbols; and a second energy configured to modify the one or more symbols.

[0042] Another exemplary aspect may comprise another communication method. The method may comprise: receiving, with a processing unit, input data for a communication device comprising a tissue interface maintainable on or adjacent skin, the tissue interface comprising a plurality of energy generators arranged in bands, each energy generator being operable to output a plurality of energies in a signal direction toward the skin; and causing, with the processing unit, the plurality of energy generators in each band to communicate with nerves associated with the skin by outputting one or more energies of the plurality of energies in response to the input data.

[0043] The receiving step may comprise receiving the input data from one or more data sources. For example, the receiving step may comprise: receiving input data comprise a plurality of measurements; and causing the plurality of energy generators in each band to output the one or more energies based on one measurement of the plurality of measurements. The method may further comprise outputting a first combination of the one or more energies when the one measurement is inside of an acceptable range; and outputting a second combination of the one or more energies when the one measurement is outside of the acceptable range.

[0044] The receiving step may comprise receiving input data comprising a plurality of vital signs; and the causing step may comprise causing the plurality of energy generators in each band to output the one or more energies based on one vital sign of the plurality of vital signs. The input data may comprise a control signal for each band, and the operating step may comprise outputting the one or more energies based on the control signal for each band. The method may further comprise generating, with the processing unit, a control signal for each band based on the input data, wherein the operating step may comprise outputting the one or more energies based on the control signal for each band.

[0045] Another exemplary aspect may comprise another communication method. The method may comprise: receiving, with a processing unit, input data for a communication device comprising a tissue interface maintainable on or adjacent skin, the tissue interface comprising a plurality of energy generators arranged in bands, each energy generator being operable to output a plurality of energies in a signal direction toward the skin; and causing, with the processing unit, the plurality of energy generators to communicate energy signals to nerves associated with the skin by outputting an energy signal in each band with one or more energies of the plurality of energies. The energy signal may comprise one or more symbols based on the input data, and the operating step may comprise outputting the one or more symbols to the skin with one or more energies. The operating step may comprise scrolling the one or more symbols across the skin in a communication direction transverse with the signal direction.

[0046] Another exemplary aspect may comprise a communication system. The system may comprise: (A) a plurality of communication devices, each communication device comprising: a body comprising a distal surface compatible with skin; and a tissue interface on the distal surface, the tissue interface comprising a plurality of energy generators, each energy generator being

operable to output a plurality of energies in a signal direction toward the skin; and (B) a processing unit in communication with at least one of the plurality of communication devices and configured to: generate, with one or more processors, a corrective motion signal based on position data for the plurality of communication devices; and operate, with the one or more processors, the plurality of energy generators of each communication device to output one or more energies of the plurality of energies in the signal direction based on the corrective motion signal.

[0047] The system may further comprise at least one position sensor configured to determine the position data and output the position data to the processing unit. The position data may comprise an actual location of each device of the plurality of communication devices; and the processing unit may be configured to generate, with the one or more processors, the corrective motion signal based on the actual locations and a target location for each device of the plurality of communication devices.

[0048] The position data may comprise an actual spatial arrangement of the plurality of communication devices; and the processing unit may be configured to generate, with the one or more processors, the corrective motion signal based on the actual spatial arrangement and a target spatial arrangement for the plurality of communication devices. The processing unit may be configured to: determine, with the one or more processors, a movement direction for each communication device based on the actual and target spatial arrangements; and operate, with the one or more processors, the plurality of energy generators of each communication device to output the one or more energies toward the skin in the signal direction and move the one or more energies across the skin the movement direction.

[0049] Another exemplary aspect may comprise another communication method. The method may comprise: generating, with one or more processors, a corrective motion signal for a plurality

of communication devices based on position data, each communication device comprising a tissue interface with a plurality of energy generators, each energy generator being operable to output a plurality of energies in a signal direction toward the skin; and operating, with the one or more processors, the plurality of energy generators of each communication device to output one or more energies of the plurality of energies in the signal direction based on the corrective motion signal. The method may comprise receiving the position data from the plurality of communication devices or a remote position sensor.

[0050] Another exemplary aspect may comprise another communication method. The method may comprise: receiving, with one or more processors, position data for a plurality of communication devices mountable on or adjacent skin, each device comprising a tissue interface with a plurality of energy generators, each energy generator being operable to output a plurality of energies in a signal direction toward the skin; receiving or generating, with the one or more processors, a corrective motion signal for the plurality of communication devices based on position data for each communication device; and operating, with the one or more processors, the plurality of energy generators of each communication device to output one or more energies of the plurality of energies in the signal direction based on the corrective motion signal.

[0051] At least one of the communication devices may comprise a position sensor, and the method may comprise receiving, with the one or more processors, the position data from the position sensor. The method may comprise: determining, with the one or more processors, an actual spatial arrangement of the plurality of communication devices based on the position data; and identifying, with the one or more processors, a target spatial arrangement for the plurality of communication devices, wherein the generating step comprises generating, with the one or more processors, the corrective motion signal based on the actual spatial arrangement and the target

spatial arrangement. The method may comprise: determining, with the one or more processors, a movement direction for each communication device based on actual and target spatial arrangements; and operating, with the one or more processors, the plurality of energy generators of each communication device to output one or more energies toward the skin in a shape associated with the movement direction for each communication device.

[0052] The method may comprise operating, with the one or more processors, the plurality of energy generators of each communication device to move the shape across the skin in the movement direction. Each communication device may be mounted to a different portion of a body; and the target spatial arrangement may comprise a physical position of the body defined by the relative positions of each different portion of the body. The physical position of the body may comprise at least one of a stretching position, a lifting position, a pose, or a stance.

[0053] The target spatial arrangement may comprise a series of target spatial arrangements, and the method may comprise: selecting arrangements from the series of target spatial arrangements; and repeating the determining, generating, and operating steps for each selected arrangement. The selecting step may be performed at predetermined intervals so as to coordinate relative movements between each selected arrangement. The series of target spatial arrangements may comprise one or more stretches, yoga poses, or defensive postures.

[0054] Another exemplary aspect may comprise another communication device. The device may comprise: a body comprising a proximal surface compatible with eyes, and a distal surface compatible with skin; a tissue interface on the distal surface, the tissue interface comprising a plurality of energy generators, each energy generator comprising a tissue interface operable to output a plurality of energies in a first signal direction toward the skin; an optical interface on the proximal surface, the optical interface comprising at least one display element operable to output

at least one color in a second signal direction toward the eyes; and a processing unit operable with the tissue interface and the optical interface to communicate simultaneously with nerves associated with skin and eyes by outputting one or more energies of the plurality of energies in the first signal direction and at least one color in the second signal direction.

[0055] The body may extend along a longitudinal axis, and the first signal direction may be transverse with the longitudinal axis. The second signal direction may be transverse with the longitudinal axis. The first and second signal directions may extend oppositely along a signal axis transverse with the longitudinal axis. The body may be conformable with a curved shape. The body comprises a flexible body configured to wrap around a limb so that the longitudinal axis has a circular shape.

[0056] The processing unit may receive input data from one or more sources, the one or more energies may be output as an energy signal based on the input data, and the one or more colors may be simultaneously output as an optical signal based on the input data. The energy signal may correspond with the optical signal. The outputs may be flashed or scrolled together. For example, the optical signal and the energy signal may be scrolled together along the longitudinal axis. The input data may comprise a vital sign of the patient, the energy signal may communicate the vital sign to the skin, and the optical signal may simultaneously communicate the vital sign to the eyes. The processing unit may be configured to determine a change of the vital sign over time and simultaneously modify one or both of the optical signal and the energy signal based on the change. The input data may comprise alphanumeric symbols, the optical signal may communicate the alphanumeric symbols to the eyes, and the energy signal may simultaneously communicate the symbols to skin.

[0057] Another exemplary aspect may comprise another communication device. The device may comprise: a body extending along a longitudinal axis, the body comprising a proximal surface compatible with eyes and a distal surface compatible with skin; a tissue interface on the distal surface of the body, the tissue interface comprising a plurality of energy generators, each energy generator being operable to output a plurality of energies in a first signal direction toward the skin; an optical interface on the proximal surface, the optical interface comprising at least one display element operable to output at least one color in a second signal direction toward the eyes; a sensor on the body; and a processing unit configured to communicate simultaneously with nerves associated with the eyes and the skin by: receiving input data from the sensor or a remote data source, causing the plurality of energy generators to output one or more energies of the plurality of energies in the first signal direction as an energy signal, and causing the display element to output the at least one color in the second signal direction as an optical signal.

[0058] The first and second communication signals may be scrolled together along the longitudinal axis. The energy signal may be output continuously. The optical signal may be output in response to a movement detected by the sensor. The movement may comprise aligning the optical interface with the eyes.

[0059] Another exemplary aspect may comprise another communication device. The device may comprise: a body comprising a proximal surface compatible with eyes and a distal surface compatible with skin; a tissue interface on the distal surface of the body, the tissue interface comprising a plurality of energy generators, each energy generator being operable to output a plurality of energies in a first signal direction toward the skin; at least one sensor; an optical interface on the proximal surface, the optical interface comprising at least one display element operable to output at least one color in a second signal direction toward the eyes; a processing unit

configured to communicate simultaneously with nerves associated with the eyes and the skin by: receiving vital sign data from the at least one sensor, causing the plurality of energy generators to output one or more energies of the plurality of energies in the first signal direction as an energy signal, and causing the at least one display element to output the at least one color in the second signal direction as an optical signal.

[0060] The energy signal and the optical signal may be scrolled across the body in a communication direction transverse with the longitudinal axis. The at least one display element may comprise a touchscreen, and the energy signal may be moveable together with optical signal along or around the longitudinal axis by operation of the touchscreen. The first direction may be transverse with the second direction.

BRIEF DESCRIPTION OF THE DRAWINGS

[0061] The accompanying drawings are incorporated in and constitute a part of this specification. These drawings illustrate exemplary aspects of the present disclosure that, together with the written descriptions provided herein, serve to explain the principles of this disclosure.

[0062] FIG. 1A depicts an exemplary energy signal output onto a living tissue;

[0063] FIG. 1B depicts an exemplary communication device configured to output the energy signal of FIG. 1A;

[0064] FIG. 2A depicts a top-down view of the FIG. 1B device;

[0065] FIG. 2B depicts a bottom-up view of the FIG. 1B device;

[0066] FIG. 2C depicts a cross-section view of the FIG. 1B device taking along section line A-A of FIG. 2A;

[0067] FIG. 3A depicts a cross-section of an exemplary energy generator;

[0068] FIG. 3B depicts a bottom-up view of the FIG. 3A generator;

[0069] FIG. 4A depicts an impact energy output with the FIG. 3A generator;

[0070] FIG. 4B depicts a heat energy output with the FIG. 3A generator;

[0071] FIG. 4C depicts an electrical energy output with the FIG. 3A generator;

[0072] FIG. 4D depicts a pressure energy output with the FIG. 3A generator;

[0073] FIG. 5 depicts an exemplary processing unit;

[0074] FIG. 6A depicts another exemplary communication device;

[0075] FIG. 6B depicts another exemplary communication device;

[0076] FIG. 6C depicts another exemplary communication device;

[0077] FIG. 6D depicts another exemplary communication device;

[0078] FIG. 7A depicts another exemplary communication device;

[0079] FIG. 7B depicts another exemplary communication device;

[0080] FIG. 7C depicts another exemplary communication device;

[0081] FIG. 7D depicts another exemplary communication device;

[0082] FIG. 8A depicts another exemplary communication device;

[0083] FIG. 8B depicts a cross-section view of the FIG. 8A device;

[0084] FIG. 9 depicts an exemplary method;

[0085] FIG. 10 depicts another exemplary method;

[0086] FIG. 11 depicts an exemplary communication system;

[0087] FIG. 12 depicts another exemplary method;

[0088] FIG. 13A depicts another exemplary communication device;

[0089] FIG. 13B depicts another view of the device of FIG. 13A;

[0090] FIG. 14A depicts another view of the device of FIG. 13A; and

[0091] FIG. 14B depicts another view of the device of FIG. 13A.

DETAILED DESCRIPTION

[0092] Aspects of the present disclosure are now described with reference to exemplary communication devices, methods, and systems. Particular aspects reference a healthcare setting, wherein the described devices, methods, and systems may allow a single caregiver to monitor vital signals for a plurality of patients without using a screen, or at least with a reduced amount of screen time. Any references to a particular setting, such as healthcare; a particular user, such as a caregiver; a particular data, such as vital signals; or particular amount of screen time, are provided for convenience and not intended to limit the present disclosure unless claimed. Accordingly, the aspects disclosed herein may be utilized for any analogous communication device, method, or system – healthcare-related or otherwise.

[0093] The terms “proximal” and “distal,” and their respective initials “P” and “D,” may be used to describe relative components and features. Proximal may refer to a position closer to a hand of user, whereas distal may refer to a position further away from said hand. With respect to a hand adjacent a living tissue, for example, proximal may refer to a position away from the tissue, whereas distal may refer to a position toward said tissue. As a further example, with respect to energy directed toward the living tissue, proximal may refer to energy directed away from the tissue and distal may refer to energy directed toward the tissue. Appending the initials P or D to a number may signify its proximal or distal location or direction. Unless claimed, these directional terms are provided for convenience and not intended to limit this disclosure.

[0094] Aspects of this disclosure may be described with reference to one or more axes. For example, an element may extend along an axis, be moved along said axis in first or second direction, and/or be rotated about said axis in a first or second direction. One axis may intersect another axis, resulting in a transverse and/or perpendicular relationship therebetween. For

example, two or three perpendicular axes may intersect at an origin point to define a Cartesian coordinate system. The directional terms proximal and distal may be used with reference to any axis. One axis may be a longitudinal axis extending along a length of an element, such as a central longitudinal axis extending along the length and through a centroid of the element.

[0095] Terms such as "may," "can," and like variation, are intended to describe optional aspects of the present disclosure, any of which may be covered by the claims set forth below. Terms such as "comprises," "comprising," or like variation, are intended to describe a non-exclusive inclusion, such that a device, method, or system comprising a list of elements does not include only those elements, but may include other elements not expressly listed or inherent thereto. The term "and/or" indicates a potential combination, such that a first and/or second element may likewise be described as a first element, a second element, or a combination of the first and second elements. These potential combinations are provided as examples. Numerous other combinations are inherent to this disclosure. Unless stated otherwise, the term "exemplary" is used in the sense of "example" rather than "ideal."

[0096] Aspects of this disclosure are directed to devices, methods, and systems for communicating with the brain through nerves associated with a living tissue. Some aspects are described with reference to an energy signal including one or more energies output to communicate symbols to the living tissue. The symbols may be used to communicate data, and the one or more energies may be used to communicate aspects of the data. The living tissue may be a portion of skin, as shown in FIGs. 1A-8D. In a healthcare setting, the energy signal may be output towards the skin of a caregiver to communicate symbols associated with a status of a patient. For example, an intensity of the one or more energies may escalate responsive to a measure of the status, providing a non-visual alert to the caregiver if the measure changes.

[0097] Exemplary energies and energy signals are now described with reference to FIG. 1A, which depicts an exemplary energy signal 90 including a plurality of symbols 92 output onto a communication area 4 of a skin 2 with one or more energies 32. For illustrative purposes, the symbols 92 of FIG. 1 are shown from a proximal-to-distal direction, as they would be output to skin 2 by an energy transceiver. Each energy 32 may be configured to communicate aspects of the data to the brain through nerves associated with skin 2, such as nerves located distal of communication area 4. For example, the one or more energies 32 shown in FIG. 1A may be recognizable by touch receptors, such as the Meissner's corpuscle; temperature receptors, such the Ruffini corpuscle and Krause corpuscle; electrical receptors, such as the muscles and pain receptors located in the dermis layer; pressure receptors such as the Pacinian corpuscle; and/or other cutaneous or subcutaneous nerves that innervate the skin or other living tissue.

[0098] Each symbol 92 may be associated with different data. For example, in the healthcare setting, each symbol 92 may be associated with a vital sign of the patient, such as body temperature, pulse rate, respiration rate, and/or blood pressure. As shown in FIG. 1A, the plurality of symbols 92 may include a first symbol 92A, a second symbol 92B, and a third symbol 92C. In keeping with the previous example, first symbol 92A may be associated with temperature and pulse rate, second symbol 92B may be associated with respiration rate, and third symbol 92C may be associated with blood pressure. Any number of symbols 92 may be provided and/or associated with a measurable or non-measurable characteristic of the patient.

[0099] Symbols 92A, 92B, and 92C are shown as pip patterns of dots in FIG. 1A, wherein each dot is a shaded area. Each dot may represent an output of the one or more energies 32. Aspects of energies 32 and/or each symbol 92A, 92B, and 92C may increase the complexity of energy signal 90, and thus the amount of data transmitted therewith. As shown in FIG. 1A, symbols 92A,

92B, and 92C may be scrolled across communication area 4 by outputting energies 32 toward the skin in the pip patterns; and moving the patterns across the skin in a communication direction CD. In FIG. 1A, first symbol 92A is a pip five dot pattern; second symbol 92B is a pip six dot pattern; and a third symbol 92C is a pip three dot pattern that has been truncated by an end of communication area 4 due to the scrolling. Symbols 92 may be flashed and scrolled. For example, the five dots of first symbol 92A in FIG. 1A may be output to communicate a temperature range of the patient (e.g., a normal range), and flashed on-and-off to communicate the pulse rate of the patient.

[0100]An exemplary energy transceiver 10 is depicted in FIG. 1B as being configured output energy signal 90 to communication area 4 of skin 2. As shown, energy transceiver 10 may be attached to a portion of skin 2, including any portion located on a limb, such as the underside of a human wrist shown in FIG. 1B for example. Communication area 4 may be sized approximate to a perimeter of transceiver 10. In this configuration, transceiver 10 may be configured to communicate energy signal 90 to skin 2 by outputting the one or more energies 32 toward communication area 4 in a signal direction oriented toward skin 2. As shown in FIG. 1A, the energies 32 may be output individually and/or in combination to communicate aspects of any of symbols 92A, 92B, and 92C to skin 2.

[0101]Additional aspects of exemplary energy transceiver 10 are now described with reference to FIGs. 2A-C. As shown, transceiver 10 may comprise: a body 20; a tissue interface 30; a processing unit 60; and an attachment element 70. With these elements, and the variations described herein, energy transceiver 10 may be configured to communicate energy signal 90 to nerves associated with skin 2 by outputting the one or more energies 32 towards skin 2 with tissue interface 30.

[0102] As shown in FIGs. 2A-C, body 20 may contain the elements of energy transceiver 10. For example, body 20 of FIGs. 2A-C has a length extending along a longitudinal axis X-X, a width extending along a lateral axis Y-Y, and a thickness extending along a proximal-distal axis Z-Z. The length, width, and/or thickness of body 20 may be compatible with skin 2. For example, body 20 may be composed of a flexible biocompatible base material, such as a polymeric material, so that the length and width of body 20 are conformable against a curvature of skin 2.

[0103] Body 20 may include any shape and be conformable with any curvature. For example, body 20 may be conformable with a cylindrical shape of a human forearm (e.g., FIG. 1B), a semi-spherical shape a human forehead (e.g., FIG. 6B), or an irregular curved shape of a human foot (e.g., FIG. 7A). A plurality of bodies 20 may be joined together to accommodate some curvatures. For example, side surfaces of body 20 of FIGs. 2A-C may be removable engageable with side surfaces of additional bodies 20 to create a joined layer conformable with the curvature.

[0104] The base material of body 20 may have insulating and/or energy-directing properties. For example, the base material may include compositions and/or coatings that promote energy flows along proximal-distal axis Z-Z, and limit energy flows along axes X-X and/or Y-Y. Body 20 may be manufactured from the base material using any known process. For example, body 20 may be molded or 3D printed from a base material that is biocompatible, dielectric, impact resistance, sound absorbing, and/or thermally resistant, such as polyether ether ketone (PEEK) and like polymeric materials. Additional materials and/or coatings may be included with the base material and/or applied to body 20 to further promote biocompatibility.

[0105] As shown in FIGs. 2A-C, body 20 may define a proximal surface 22 (FIG. 2A) opposite of a distal surface 24 (FIG. 2B) along proximal-distal axis Z-Z (FIG. 2C). In FIGs. 2A and 2C, for example, proximal surface 22 includes a processor compartment 23 configured to receive

processing unit 60. As shown, and described further below, processing unit 60 may be removable engageable (e.g., snap-fit into) with processor compartment 23. Body 20 may include and/or be compatible with additional mechanisms for securing and/or releasing the snap-fit, such as a retaining screw and/or a lever.

[0106] Body 20 of FIGs. 2A-C includes a plurality of communication bays 25. As shown, each communication bay 25 may be spaced apart from the next on distal surface 24 in a grid pattern. The spacing may be uniform or non-uniform. In FIGs. 2B and 2C, the bays 25 are spaced apart uniformly for communication with the skin 2 of FIG. 1B, which has a fairly planar surface area. Non-uniform spacing may be used to accommodate a curvature of skin 2. As shown in FIG. 2C, each communication bay 25 may extend proximally into body 20 through distal surface 24 along a communication axis z-z that is parallel with the proximal-distal axis Z-Z of transceiver 10. In FIG. 2C, a conduit 26 extends proximally from each bay 25, through an interior portion of body 20, and into processor compartment 23, placing the plurality of bays 25 in communication with compartment 23.

[0107] Aspects of tissue interface 30 are now described with reference to FIGs. 2B and 2C. As shown, tissue interface 30 may include a plurality of energy generators 31, and each generator 31 may be located in one of communication bays 25. Each generator 31 may be operable with processing unit 60 to output energies 32 individually and/or in combination. In FIGs. 2B and 2C, for example, the one or more energies 32 are being output from the shaded generators 31 to communicate energy signal 90 of FIG. 1A. As shown in FIG. 2C, one or more conductors 27 may extend through each conduit 26 to connect processing unit 60 to each energy generator 31, allowing control signals to be transmitted between processing unit 60 and the plurality of energy generators 31 along one or more pathways.

[0108] As shown in FIG. 2C, the one or more conductors 27 may include any number of electrical wires and/or optical fibers configured to transmit the control signals. For example, the conductors 27 may comprise a plurality of electrical conductors interconnecting the plurality of generators 31 with processing unit 60, and allowing electricity-based control signals, energies, and communications to be transmitted between unit 60 and generators 31. In addition or alternatively, the conductors 27 may comprise a plurality of optical fibers interconnecting the plurality of generators with processing unit 60, and allowing light-based control signals, energies, and communications to be transmitted between unit 60 and generators 31. For example, each conductor 27 may comprise a twisted pair including at least one electrical conductor and at least one optical fiber. A flexible energy-insulating medium, such as an epoxy, may be used to seal conductors 27 in conduits 26.

[0109] A cross-section of an exemplary energy generator 31 is depicted in FIG. 3A. As shown, each generator 31 may include: a housing 33; a controller 34; and a plurality of generator elements, such as: an impact generator element 36; a heat generator element 42; a shock generator element 48; and a pressure generator element 52. Examples of each generator element are now described.

[0110] Similar to body 20, housing 33 may include an insulating material that surrounds portions of each generator 31 and/or defines mounting surfaces for generator elements 36, 42, 48, and/or 52. For example, housing 33 may be made of the same base material as body 20 or a compatible material; and/or formed together with body 20 by a molding, printing, or like process. As described below, portions of each generator element 36, 42, 48, and/or 52 may extend distally from housing 33 to contact skin 2. Housing 33 of FIG. 3A includes an attachment feature 33A configured to secure each generator 31 in one of the communication bays 25. For example, attachment feature 33A may include a set of threads on housing 33 that are engageable with an

interior surface of bays 25. Other types of chemical or mechanical attachment may be used, including biocompatible adhesives, snap-fit connections, and the like.

[0111] Exemplary generator elements 36, 42, 48, and 52 may be arranged to output their respective energies 32 in approximately the same direction. As shown in FIGs. 3A and 3B, each generator element 36, 42, 48, and 52 may be arranged coaxially with communication axis z-z so that each energy 32 may be output toward skin 2 in signal direction SD. Because of this coaxial configuration, each energy 32 may be output toward approximately the same point or area on skin 2, making the energies 32 interchangeable. For example, any of the dots included in energy signal 90 of FIG. 1A may be interchangeably communicated to approximately the same point on skin 2 with any of the energies 32.

[0112] As shown in FIG. 3A, controller 34 may be configured receive a control signal 82 from processing unit 60, and activate generator elements 36, 42, 48, and 52 according to signal 82. The one or more conductors 27 may transmit the control signal 82 to generator elements 36, 42, 48, and 52 from processing unit 60 and/or direct electricity to generator elements 36, 42, 48, and 52 from a power source 66 of processing unit 60 (e.g., FIG. 5). Energy transceiver 10 may be an all-electrical device, wherein control signal 82 is an electrical signal and first and the conductors 27 are electrical wires. For varied response times, and energy requirements, transceiver 10 also may be an electro-optical device, wherein control signal 82 includes an optical signal, and at least one of the conductors 27 includes an optical fiber. For example, controller 34 may receive control signal 82 from processing unit 60 with a first one of conductors 27 (e.g., a first electrical and/or optical conductor), and direct electricity to one or more of the generator elements 36, 42, 48, and 52 with a second one of conductors 27 (e.g., a second electrical conductor) according to signal 82.

[0113] Additional aspects of generator elements 36, 42, 48, and 52 are now described with reference to FIGs. 4A-D. As shown in FIG. 4A, for example, impact generator element 36 may be configured to communicate an impact energy 32A to the brain through nerves associated with skin 2. For example, impact generator element 36 may be a mechanical actuator that converts electricity from power source 66 into a mechanical movement recognizable by touch receptors of skin 2, such as Meissner's corpuscle. As shown, generator element 36 may include a drive mechanism 37, a piston 38, a tissue contact 39, and a guide tube 40. Drive mechanism 37 may include a motor assembly that is attached to controller 34 and conductively engaged therewith. In this configuration, controller 34 may direct electricity to drive mechanism 37, causing the motor assembly to move piston 38 distally along communication axis z-z, outputting impact energy 32A in signal direction SD. Different force transfer components also may be used to apply energy 32A, including levers and like actuators.

[0114] As shown, drive mechanism 37 may be configured to move piston 38 between a retracted position, wherein tissue contact 39 is contained housing 33 (e.g., FIG. 3A); and an extended position, wherein at least a portion of contact 39 is distal of housing 33 (e.g., FIG. 4A). Accordingly, impact energy 32A may be output in signal direction SD as a physical movement of skin 2 caused by moving tissue contact 39 distally. Aspects of impact energy 32A may be modified. For example, outer tube 40 may be attached to housing 33 and include interior surfaces configured to modify the timing of energy 32A by guiding the proximal-distal movements of tissue contact 39 (e.g., by rotating or stabilizing contact 39). A resilient element may be added between drive mechanism 37 and contact 39 to dampen such movements.

[0115] Heat generator element 42 may be configured to communicate a heat energy 32B to the brain through nerves associated with skin 2. As shown in FIG. 4B, generator element 42 may

include an electrical resistor that converts electricity from power source 66 into an amount of heat recognizable by temperature receptors of skin 2, such the Ruffini corpuscle. For example, heat generator element 42 may include an electrical resistor 43, a heat reflecting groove 44, a conductor 45, and an insulating material 46. Groove 44 may include a metal plate attached to an exterior surface of outer tube 40 of generator element 36. Resistor 43 may include an electrical wire or coil attached to groove 44. Conductor 45 may include an electrical wire extend between controller 34 and resistor 43, and material 46 may including an epoxy surrounding conductor 45.

[0116] As shown in FIG. 3B, electrical resistor 43 and heat-reflecting groove 44 may be circular elements arranged coaxially with communication axis z-z. Conductor 45 may be configured to transmit electricity to electric resistor 43 for conversion into heat energy 32B. Groove 44 may include a concave shape extending proximally into housing 33 to contain resistor 43, and the shape may include a distal surface configured to reflect heat energy 32B toward skin 2. In this configuration, heat signal 32B may be output in signal direction SD as an amount of heat transferred to skin 2 by resistor 43. Aspects of heat signal 32B may be modified. For example, the size, shape, and/or exterior coating of resistor 43 or groove 44 may be configured to modify the intensity of heat energy 32B.

[0117] Shock generator element 48 may be configured to communicate an electrical energy 32C to the brain through nerves associated with skin 2. As shown in FIG. 4C, shock generator element 48 may be an electroshock generator that converts electricity from power source 66 into an electrical shock recognizable by electricity-sensitive receptors, such as the muscles and pain receptors located in the dermis layer of skin 2. For example, energy generator element 48 may include at least two electric contacts 49, a conductor 50, and an insulating material 51. The conductors 50 may be metallic rods or wires extending distally from controller 34. Insulating

material 51 may be an epoxy surrounding each conductor 50. Each contact 49 may include a discharge shape located on the distal-most end of one of conductors 50. In this configuration, controller 34 may direct electricity through conductors 50, and into the discharge shape of contact 49, allowing electricity to flow through skin 2 between the contacts 49 to output electrical energy 32C.

[0118] As shown in FIG. 3B, the electrical contacts 49 may be spaced apart in a radial pattern coaxial with communication axis z-z. Any number of contacts 49 may be used, in any geometrical and/or spatial configuration. Insulating material 51 may be used to define and maintain the spacing. As shown, insulating materials 51 and 46 may be the same material, such as an epoxy. Four contacts 49 are shown in FIG. 3B, for example, as being arranged in two pairs. Aspects of electrical energy 32C may be modified. For example, the arrangement of contacts 49 may be changed; and/or the size of or spacing between each contact 49 changed to modify the intensity of energy 32C.

[0119] Pressure generator element 52 may be configured to communicate a pressure energy 32D to the brain through nerves associated with skin 2. As shown in FIG. 4D, pressure generator element 52 may be an electroacoustic transducer that converts electricity from power source 66 into a sound wave recognizable by pressure receptors of skin 2, such as the Pacinian corpuscle. For example, pressure generator element 52 may include a cone 53, a voice coil 54, and a magnet 55. In this configuration, controller 34 may direct electricity into voice coil 54 for interaction with magnet 55, causing movements of cone 53 that generate the pressure energy 32D in signal direction SD.

[0120] As shown in FIGs. 3B and 4D, cone 53 may have a frustoconical shape that is coaxial with communication axis z-z. An outer edge of cone 53 may be attached an interior surface of housing 33, and an inner edge of cone 53 may be attached to voice coil 54, which may be coupled

to controller 34 and power source 66 by one or more conductors. As shown, coil 54 may have a circular shape, and generator elements 36, 42, and 48 may be located in the interior of said shape. Aspects of pressure energy 32D may be modified. For example, cone 53 and/or voice coil 54 may include a surround, a spider, a secondary frame, or any other structures configured to modify signal responsiveness; the strength of magnet 55 may be varied; and/or controller 34 may include an amplifier configured to modify an intensity of pressure energy 32D.

[0121] Different generator element types also may be used to communicate signals to the skin with different energies 32, and/or different combinations of energies 32. For example, the plurality of generators 31 may be modified to vary individual or combined outputs of energies 32A, 32B, 32C, and 32D; and/or include additional generator elements configured to output additional signals to skin 2, including optical signals, magnetic signals, and/or any physically recognizable signals. Any type of generator element may be used and likewise coaxially arranged according to FIGs. 3A through 4D.

[0122] Additional aspects of an exemplary processing unit 60 are now described with reference to FIG 5. As shown, processing unit 60 may be configured to receive input data 80 from a data source 81 and output control signal 82 and/or electricity to each controller 34 via conductors 27, causing activation of one or more energy generators 31. For example, processing unit 60 of FIG. 5 includes a housing 61, a data transceiver 62, one or more processors 63, a memory 64, a communication bus 65, and a power source 66.

[0123] Data source 81 may include any combination of local and/or remote data sources. For example, source 81 may include a local sensor that is located in one of communication bays 25 and configured to send input data 80 to unit 60 using conductors 27 and/or bus 65. This configuration may allow for closed loop communications in which energy signal 90 is based on

data from the local sensors. For example, the local sensor may generate the input data 80 based on chemical and/or physical outputs related to skin 2.

[0124] Data source 81 also may include a remote data source in constant communication with processing unit 60 via data transceiver 62, such as a remote sensor configured to send input data 80 to processing unit 60 with data transceiver 62 over a wired or wireless connection. This configuration may allow for open loop communications in which energy signal 90 is based on data from the local sensor and/or the remote sensor.

[0125] Any number and type of local sensors may be used to generate input data 80, and the sensor(s) may be located at any position on or relative to energy transceiver 10. In the healthcare setting, for example, one local sensor may include a personal health tracker (e.g., a Fitbit® or an iWatch®) configured to generate input data 80 based on chemical and/or physical outputs of the wearer (e.g., heart rate, temperature), and communicate input data 80 to data transceiver 62 at regular intervals (e.g., once per second or once per minute).

[0126] Housing 61 may contain the elements of processing unit 60, and/or provide a means for removing processing unit 60 from body 2, allowing for easy repairs and upgrades. As shown in FIGs. 1B and 5, for example, exterior surfaces of housing 61 may be snap-fit with interior surfaces of compartment 23 so that the distal surface of processing unit 60 is maintained against the proximal surface of compartment 23. For example, the exterior surfaces of housing 61 of may include protrusions biased outwardly along the X-X and Y-Y axes, and the interior surfaces of compartment 23 may include grooves configured to receive said protrusions.

[0127] Transceiver 62 may include any wired or wireless communication technology configured to receive input data 80 from any data source(s) 81, such as Bluetooth, Wi-Fi___33, and the like. As shown in FIG. 5, input data 80 may be generated with or stored on data source 81

and received with transceiver 62. In a healthcare setting, for example, data source 81 may include at least one patient monitoring device configured to send input data 80 to a remote server at regular intervals (e.g., once per minute). Data 80 may include various measures regarding the patient, such as body temperature, pulse rate, respiration rate, and/or blood pressure. For example, transceiver 62 may be configured to retrieve and/or receive data 80 from the remote server at regular intervals (e.g., once per second or once per minute).

[0128] Each control signal 82 may be received with input data 80. Data transceiver 62 may be configured to relay the signals 82 to the one or more processors 63 and/or memory 64. Alternatively, processing unit 60 may be configured to generate each control signal 82 based on input data 80. For example, memory 64 may include a signal generating program, and the one or more processors 63 may be configured to generate each control signal 82 with the program. In keeping with previous examples, the signal generating program may be configured to: analyze the input data 80 sent from data sources 81 including a patient monitoring device during an interval; generate symbol 92A from the temperature and pulse rate, symbol 92B from the respiration rate, and symbol 92C from the blood pressure; and output a control signal 82 for communicating the symbols 92A, 92B, and 92C to skin 2.

[0129] As shown in FIG. 5, communication bus 65 may be configured to connect the one or more processors 63 and memory 64 to each generator 31, such as to each controller 34. Bus 65 may include electrical and/or optical connectors 67 located on and/or extending distally through housing 61. For example, communication bus 65 may comprise a flexible circuit board including a proximal surface supporting elements of processing unit 60, and a distal surface including an electrical and/or optical network extending from power source 66 to the connectors 67. Any type of network may be used, such as a mesh network. Connectors 67 may be engageable with

corresponding connectors of conductors 27 to provide at least one pathway for outputting control signal 82 from processing unit 60 to one or more generators 31, and/or electricity from power source 66 to one or more generators 31. Control signal 82 may include electrical and/or optical signals. For example, control signal 82 may include a string of output commands for each generator 31, and the entire string may be output to each generator 31 utilizing the electrical and/or optical signals, adding resiliency, in which the optical signals may be utilized for faster transmission.

[0130] As described above, the snap-fit connection between housing 61 and compartment 23 may place connectors 67 in communication with conductors 27, and maintain that communication over time, allowing for continuous output of control signals 82 from processing unit 60 and/or electricity from power source 66. A cover element may be attached to the proximal surface 24 of body 20 to seal processing unit 60 within compartment 23, and/or reinforce or supplant the snap-fit connection between housing 61 and compartment 23. For example, the cover may include a graphic design, a textual element, a writing surface, and/or like decorative feature. As a further example, the cover may provide a mounting surface for other technologies, such as an antenna, signal amplifier, and/or supplemental data transceiver.

[0131] Power source 66 may include any means for supplying electricity to processing unit 60 and/or the plurality of generators 31 (e.g., to each controller 34). As shown in FIG. 5, power source 66 may include a rechargeable battery, such as a lithium ion battery, chargeable by connection to an external power source, such as a wall outlet. Power source 66 may include power generation technologies. For example, a proximal surface of power source 66 may include a power generator, such as photovoltaic cells configured to charge the battery. As shown in FIG. 5, power source 66 also may include an optical energy source, such as a laser generator that is powered by power

source 66 and configured to output optical energy to one or more generators 31 via optical pathways defined by communication bus 65 and conductors 27.

[0132] Aspects of attachment element 70 are now described with reference to FIG. 2C. As shown, attachment element 70 may be configured to maintain a position of tissue interface 30 against or adjacent skin 2. For example, element 70 may include an adhesive, elastic, and/or fastening element configured to apply a maintaining force in signal direction SD. In FIG. 2C, element 70 includes a proximal surface 72 adhered to the distal surface 24 of body 20, and a distal surface 74 adherable with skin 2. Distal surface 74 of element 70 may include a biocompatible adhesive configured to apply the maintaining force.

[0133] Attachment element 70 may be removably and/or semi-permanently attached to skin 2 by the biocompatible adhesive. For example, a first adhesive material may be used to attach the proximal surface 72 to distal surface 24, and a second adhesive material may be used to attach distal surface 74 to skin 2. As a further example, the first adhesive may be stronger so that energy transceiver 10 may be removed from skin 2 without separating surfaces 72 and 24. Either the first or second adhesive material may be biocompatible, and may include anti-bacterial and/or moisture resistant coatings and/or compositions configured for prolonged contact with skin 2. For example, at least the second adhesive material may be configured for contact with skin 2 during the entirety of a 4-hour, 8-hour, 12-hour, 24-hour shift, or longer shift. One or both adhesives also may be configured for semi-permanent contact with skin 2, such as during the entirety of a multi-month or multi-year treatment period. For example, at least the second adhesive material may include medicinal coatings and/or compositions that promote prolonged or semi-permanent contact with skin 2 by time-releasing treatments configured to prevent or minimize contact-based injuries.

[0134] Body 20 and/or attachment element 70 may be configured to boost the efficacy of energy signal 90 by minimizing and/or maintaining the distance between tissue interface 30 and skin 2, allowing signal 90 to be communicated with less energy. For example, any of the one or more energies 32 may be output through body 20 and/or attachment element 70. As shown in FIGs. 2B and 2C, attachment element 70 may include a plurality of openings 76. Each opening 76 may be sized approximate to one of communication bays 25, allowing the energies 32 to be output towards skin 2 in signal direction SD through openings 76. For example, each opening 76 may have an inner diameter approximate to an outer diameter of the communications bay 25 or housing 33 for each generator 31. As shown in FIG. 2C, attachment element 70 may have a thickness that allows tissue contact 39, electrical resistor 43, and/or electrical contacts 49 to contact skin 2 through opening 76 or be adjacent to skin 2 within opening 76.

[0135] Aspects of body 20 and/or attachment element 70 may direct and focus the energies 32, making it easier for the brain to distinguish one output of energies 32 from another. In keeping with previous examples, body 20 and attachment element 70 of FIGs. 2B and 2C may be composed of base materials including an impact absorbing material configured to absorb any excessive vibrations of skin 2 caused by impact energy 32A. One or both base materials may include an insulating material configured to direct heat energy 32B, electrical energy 32C, and pressure energy 32D through openings 76 along axis Z-Z; and prevent transmission of energies 32B, 32C, and 32D along axis X-X and Y-Y. For example, body 20 and element 70 of FIG. 2C may be configured to absorb any portion of energies 32 output incidentally in directions transverse to signal direction SD to promote signal distinction by limiting unwanted communications. As a further example, each opening 76 of attachment element 70 in FIG. 2C may have a reflective

coating and/or a frustoconical interior shape centered about axis z-z to further focus the energies 32 towards skin 2.

[0136] As described herein, energy transceiver 10 may be operable to communicate energy signal 90 to skin 2 by outputting any energy 32, such as impact energy 32A, heat energy 32B, electrical energy 32C, and/or pressure energy 32D, individually or together. For example, any energies 32A-D may be used interchangeably or in combination to communicate any of the dots shown in FIG. 1A as symbols 92A, 92B, and 92C. As now described, aspects of each energy 32 may be modified to increase the complexity of signal 90, and thus the amount of data transmitted therewith. Modifiable aspects may include energy type, energy intensity, output duration, scroll rate, symbol shape, and the like.

[0137] Energy signal 90 may be communicated to skin 2 with energies 32, individually or together. In FIG. 1A, for example, each dot within first symbol 92A may be output with impact energy 32A; each dot within second symbol 92B may be output with heat energy 32B; and each dot within third symbol 92C may be output with electrical energy 32C. The energies 32 may be combined for additional emphasis. For example, the first symbol 92A may be output with impact energy 32A in response to a baseline measure, and output with a combination of impact energy 32A and heat energy 32B if the measure changes. The energies 32 also may be combined to enhance the penetration depth of energy signal 90. For example, first symbol 92A may be formed by first outputting pressure energy 32D to activate a portion of the nerves associated with skin 2, and second outputting heat energy 32B to the activated nerves. Any individual dot may be similarly modified relative to any other dot.

[0138] The intensity of energies 32 may be modified for emphasis. For example, processing unit 60 may be configured to output first symbol 92A with impact energy 32A at a first intensity

level in response to a baseline measure, and a second intensity level to highlight signal 92A if the measure changes. Output duration may be similarly modified. For example, the output duration of energies 32 may be instantaneous for normal measures, like a quick tap (e.g., about 100ms); extended for abnormal measures, like a short hold (e.g., 500ms to 1s); or a combination thereof, as with Morse code. Scroll rate may be similarly modified. For example, symbols 92 may not be scrolled at all (i.e., a scroll rate of zero), and output duration may be used to communicate change over time by flashing symbols 92 off and or in a fixed position. As a further example, in the healthcare setting, the scroll rate may be based on an update schedule (e.g., one revolution per minute), and/or the output duration may be based on patient status (e.g., faster for more critical patients).

[0139] Symbol shape also may be modified. The plurality of symbols 92 are shown as pip pattern shapes in FIG. 1A, but any symbol shape may be used, particularly those amenable to dot-matrix representation. For example, the plurality of symbols 92 may include known Morse code, binary symbols, lines, and/or directional arrows that are scrolled across communication area 4 in communication direction CD. Alphanumeric symbols also may be communicated. For example, input data 80 may include a control signal 82 generated from a Twitter® feed, and the symbols 92 may include alphanumeric symbols for communicating the author, date, and content of each Tweet® contained in the feed. As a further example, input data 80 may include the subject and sender of an email, and the signal generating program included in memory 64 may be configured to: prioritize the email based on the sender; and generate a control signal 82 for outputting a set symbols 92 based on the subject, sender, and priority of the email. For example, first symbols 92 may be output with impact energy 32A to communicate the subject and/or sender of prioritized

emails in a shorthand notation, and at least one of heat energy 32B, electrical energy 32C, pressure energy 32D to communicate the priority level of the shorthand notation.

[0140] The resolution of tissue interface 30 may match or exceed the distinguishing capabilities of the nerves associated with skin 2. For example, in the grid formation shown in FIG. 2B, the resolution of tissue interface 30 may be measured as energy output per square inch, which may exceed the natural energy receptivity limits of the nerves associated with skin 2. As shown, the resolution of interface 30 may be relative to the spacing between each bay 25, the configuration of body 20 and/or attachment element 70, and/or the intensity of energies 32. The energy receptivity limits of skin 2 may vary by location. For example, energy transceiver 10 may be attached to a portion of skin 2 located in a highly innervated or sensitive area, such as the face, allowing even more complex symbol shapes to be communicated.

[0141] With sufficient resolution, tissue interface 30 may likewise be configured to output signal 90 to replicate image patterns and/or other sensory perceptions with energies 32, including any of the symbols described herein and even more complex interactions. As described herein, the multi-energy capabilities of energy transceiver 10 may be configured to layer energies 32 so as to communicate far more complex image patterns and/or sensory perceptions that would otherwise be possible by communicating with a single energy because of the natural receptivity limits of the nerves, and their tendency to become less receptive during prolonged exposures.

[0142] Additional aspects of this disclosure are now described with reference to numerous additional examples of energy transceiver 10, including: an exemplary energy transceiver 110 shown conceptually in FIG. 6A; an exemplary energy transceiver 210 shown conceptually in FIG. 6B; an exemplary energy transceiver 310 shown conceptually in FIG. 6C; an exemplary energy transceiver 410 shown conceptually in FIG. 6D; an exemplary energy transceiver 510 shown

conceptually in FIG. 7A; an exemplary energy transceiver 610 shown conceptually in FIG. 7B; an exemplary energy transceiver 710 shown conceptually in FIG. 7C; an exemplary energy transceiver 810 shown conceptually in FIG. 7D; and an exemplary energy transceiver 910 shown conceptually in FIGs. 9A-B.

[0143] Each variation of transceiver 10, such as transceivers 110, 210, 310, 410, 510, 610, 710, 810, 910, may include elements similar to those of transceiver 10, but within the respective 100, 200, 300, 400, 500, 600, 700, 800, or 900 series of numbers, whether or not those elements are depicted in FIGs. 6A through 9B. Any aspects described with references to transceivers 110, 210, 310, 410, 510, 610, 710, 810, and 910 may be included within any variation of transceiver 10 described herein, each possible combination or iteration being part of this disclosure. For example, any variation of transceiver 10 may comprise any combination of the wearable aspects of transceivers 110, 210, 310, and 410; the contact-based aspects of transceivers 510 and 610; and the implantable aspects of transceivers 710 and 810; and/or any multi-signal aspects of transceiver 910.

[0144] Additional wearable aspects are now described with reference to FIGs. 6A-D. As shown in FIG. 6A, energy transceiver 110 may include: a body 120 and a tissue interface 130, both shown conceptually with a dotted line; and an attachment element 170, shown conceptually as a sweat band. Any type of band may be used, such as a head band, an arm band, or a bandana. Body 120 may wrap around a portion of skin 2, such as circular portion of skin 2, like around a human forearm or forehead. As shown in FIG. 6A, body 120 may be mounted on attachment element 170; and tissue interface 130 may be mounted on a distal surface of body 120. For example, body 120 may be mounted on a distal surface of element 170; and tissue interface 130 may wrap around the circular portion of skin 2 with body 120, providing a curved rectangular communication area 4

and a semi-circular (e.g., less than 360°) or circular (e.g., 360°) communication direction CD for energy signal 90.

[0145] Attachment element 170 (e.g., a sweat band) may be configured to maintain tissue interface 130 against or adjacent a portion of skin 2, such as against the arm or forehead, allowing energy signal 90 to be output in signal direction SD and/or scrolled around the head to communication area 4 in communication direction CD. For example, the band may include an elastic portion that pushes body 120 and tissue interface 130 distally toward skin 2 when placed around the circular portion of skin 2, i.e., when the sweat band of FIG. 6A is worn. As shown, the elastic portion may be proximal of energy transceiver 110, attached to a proximal surface of body 120, and configured to apply a circumferential maintaining force that maintains the position of interface 130 when element 170 is worn.

[0146] As shown in FIG. 6B, energy transceiver 210 may include: a body 220 and a tissue interface 230, both shown conceptually with a dotted line; and an attachment element 270, shown conceptually as a baseball cap. Any cap, hat, helmet, or like headwear may be used. Body 220 may wrap around a circular portion of skin 2 including the forehead and/or scalp. As shown in FIG. 6B, body 220 may be mounted on attachment element 270; and tissue interface 230 may be mounted on a distal surface of body 220. For example, body 220 may be mounted on a distal surface of element 270; and tissue interface 230 may wrap around the circular portion of skin 2 with body 220, providing a semi-circular (e.g., less than 360°) or circular (e.g., 360°) communication area 4 and communication direction CD for energy signal 90. As a further example, body 220 and tissue interface 230 may have a semi-spherical shape covering interior surfaces of cap 270 for output of energy signal 90 to a semi-spherical communication area 4 of skin 2 in any communication direction(s) CD.

[0147] Similar to attachment element 170 of FIG. 6A, attachment element 270 (e.g., a cap) also may include an elastic or non-elastic portion configured to maintain tissue interface 230 against or adjacent a portion of skin 2, such as against the forehead, allowing energy signal 90 to be output in signal direction SD and/or scrolled around the head in communication direction CD. For example, the elastic or non-elastic portion may push body 220 and tissue interface 230 distally toward skin 2 when placed around the circular portion of skin 2, i.e., when the cap of FIG. 6B is worn. As shown, the elastic or non-elastic portion may be proximal of energy transceiver 210, attached to a proximal surface of body 220, and configured to apply a circumferential maintaining force that maintains the position of interface 230 when attachment element 270 is worn. For example, the elastic or non-elastic portion may comprise a tension fastening mechanism, such as any snaps, Velcro®, or other typically found on headwear.

[0148] As shown in FIG. 6C, energy transceiver 310 may include a body 320 and a tissue interface 330, both shown conceptually a dotted line; and an attachment element 370, shown conceptually as a sock. Any tube-like garment may be used, including gloves, shoes, stockings, and the like. Body 320 may wrap around a circular portion of skin 2, such as around a leg. As shown in FIG. 6C, body 320 may be mounted on attachment element 370; and tissue interface 330 may be mounted on a distal surface of body 320. For example, body 320 may be mounted on a distal surface of element 370, and tissue interface 330 may wrap around the circular portion of skin 2 with body 320, providing a semi-circular (e.g., less than 360°) or circular (e.g., 360°) communication area 4 and direction(s) CD.

[0149] Similar to above, attachment element 370 (e.g., a sock) may include an elastic layer configured to maintain tissue interface 330 against or adjacent a portion of skin 2, such as against the leg, allowing energy signal 90 to be output in signal direction SD and/or scrolled around the

head in communication direction CD. For example, the elastic layer may push body 320 and tissue interface 330 distally toward skin 2 when placed around the circular portion of skin 2, i.e., when the sock of FIG. 6C is worn. As before, the elastic layer may be proximal of energy transceiver 310, attached to a proximal surface of body 320, and configured to apply a circumferential maintaining force that maintains the position of interface 330 when attachment element 370 is worn.

[0150] As shown in FIG. 6C, transceiver 310 may be removably attached to attachment element 370, and thus operable with a plurality of elements 370, such as plurality of socks or other tube-like garments that typically become soiled during use. For example, element 370 may include a pouch configured to receive and secure body 320, orient tissue interface 330 toward skin 2, and/or maintain the position tissue interface 330 on or adjacent skin 2. As a further example, the elastic layer and/or the pouch may include an opening, and portions of body 320 may be engageable with (e.g., snap fit into) the opening to further maintain interface 330.

[0151] As shown in FIG. 6D, for example, energy transceiver 410 may include a body 420 and a tissue interface 430, both shown conceptually with a dotted line; and an attachment element 470, shown conceptually as a compression garment. Any type of compressive garment may be used, such as those made by Under Armour®. Body 420 of FIG. 6D may wrap around a portion of skin 2, and be composed of an impacting absorbing material (e.g., foam) configured to dissipate external impact forces directed toward the skin 2. For example, body 420 may be a thigh pad used in hockey or American football, a shin guard used in soccer, or any other type of protective pad with a distal surface that is desirably maintained against skin 2. Similar to above, body 420 may be mounted on attachment element 470; and tissue interface 430 may be mounted on a distal surface of body 420. For example, body 420 may be mounted on a distal surface of element 470;

and tissue interface 430 may wrap around the circular portion of skin 2 with body 420, providing a curved communication area 4 and direction CD for signal 90.

[0152] Attachment element 470 (e.g., the compression garment) may include an elastic weave configured to maintain tissue interface 430 against or adjacent a portion of skin 2, such as against the arm or forehead, allowing energy signal 90 to be output in signal direction SD and/or scrolled around the head to communication area 4 in communication direction CD. For example, the elastic weave may push body 420 and tissue interface 430 distally toward skin 2 when placed around the circular portion of skin 2, i.e., when the compression garment of FIG. 6D is worn. In this example, the elastic weave may be attached to body 420, and configured to apply a circumferential maintaining force that maintains the position of interface 430 when attachment element 470 is worn.

[0153] Similar to above, energy transceiver 410 may be removably attached to attachment element 470, and thus operable with a plurality of elements 470, such as plurality of compressive garments. For example, impact absorbing body 420 may be mounted in a pocket of attachment element 470, and tissue interface 430 may be mounted on a distal surface of impact absorbing body 420, such as in a distal compartment of body 420. Transceiver may be a game-time accessory. For example, as shown in FIG. 6D, signals 90 may comprise a plurality of arrows scrolled along communication direction CD to communicate movements to the user. In this example, the user may be trained to move in a particular direction (e.g., left or right) and intensity (e.g., slow or fast) based on the output of energy signal 90 and the particular combination of energies 32 associated therewith.

[0154] Although not shown in FIGs. 6A-D, attachment elements 170, 270, 370, and 470 may include any adhesive and/or energy focusing elements, including those described above. For

example, any aspects of attachment element 70 of FIG. 2C may be combined with any aspects of attachment elements 170, 270, 370, or 470 of FIG. 6A-D to further maintain a position of tissue interface 430 relative to skin 2 and/ or focus the energies 32 according to aspects of this disclosure. Aspects of any attachment elements may be combined and operable together. For example, attachment element 470 may be include an opening, body 420 may be snapped into the opening, and a second attachment element (e.g., a biocompatible low-tack adhesive) may be configured to further fix the position of interface 430 relative to skin 2 during rigorous physical activity, such as running.

[0155] As described above, aspects of energy transceivers 110, 210, 310, and 410 may be included with any wearable item, giving aspects of this disclosure incredible breadth. For example, aspects of any of attachment elements 170, 270, 370, and 470 may be integrated into any wearable item including any type of band, strap, or like item including any combination elastic and/or non-elastic layers or portions. Exemplary attachment elements may include: bandages, wherein the tissue interface may be located on a distal surface of a skin-attachment portion; belts, wherein the tissue interface may be located on a distal surface of the belt; bras, wherein the tissue interface may be located on a distal surface of a bra strap; earrings, wherein the tissue interface may be located on a distal surface of an earring front or back; pants, wherein the tissue interface may be located on a distal surface of a waste line or seam; rings, wherein the tissue interface may be located on an interior distal surface; shirts, wherein the tissue interface may be located on a distal surface of a neckline; underwear, wherein the tissue interface may be located on a distal surface of the legs or waistline; watches, wherein the tissue interface may be located on a distal surface of the watch strap; and any known or obvious variation of the same.

[0156] Aspects of transceivers 10, 110, 210, 310, and 410 may be likewise included on any non-wearable object with a distal surface that is desirably maintained against skin 2 during use by application of an external force, such as a gravity force, a gripping force, or other externally applied maintaining force. Additional external force-based aspects are now described with reference energy transceiver 510 of FIG. 7A and energy transceiver 610 of FIG. 7B.

[0157] As shown in FIG. 7A, energy transceiver 510 may include: a body 520 and a tissue interface 530, both shown conceptually with a dotted line; and an attachment element 570, shown conceptually as a shoe or a shoe insert. Any type of footwear and/or foot support with equivalent surfaces may be used. Body 520 may include a surface contoured for placement against skin 2, such as an underside of a foot. As shown in FIG. 7A, body 520 may be mounted on attachment element 570; and tissue interface 530 may be mounted on or embedded in a distal portion of body 520, allowing gravity to at least partially maintain interface 530 against or adjacent skin 2, and providing a foot-shaped communication area 4 and communication direction CD for energy signal 90.

[0158] Attachment element 470 may additionally comprise any tensioning elements configured apply a maintaining force that maintains the position of interface 530 when attachment element 570 is worn, such as shoe laces, Velcro, pumping mechanisms, elastic straps or structures, and the like. As a further example, attachment element 570 may be composed of an impact absorbing material, such as a polymeric material configured to distribute forces around body 520 when walking or running; and include bolster shapes contoured to further maintain tissue interface 530 by limiting lateral movements of the foot relative thereto.

[0159] Accordingly, energy signal 90 may be communicated to the communication area 4 of skin 2 by tissue interface 530 in any communication direction CD with any combination of

energies 32. As shown in FIG. 7A, energy signal 90 may include a plurality of directional shapes (e.g., the arrows of FIG. 7A) flashed and/or scrolled in a linear direction to communication directional movements. The directional shapes may be responsive to directional data. For example, transceiver 510 may be configured to receive the directional data from one or more sources (e.g., GPS signals), determine communication direction CD based on the directional data, and scroll energy signal 90 across skin 2 as directional shapes scrolling along communication direction CD to compel movement of the user in a direction.

[0160] In keeping with above, transceiver 510 also may be configured to determine an importance measure based on the directional data, and communicate energy signal 90 with a particular combination of energies 32 and/or at a particular scroll rate based on the importance measure to direct a movement aspect, such as pace or direction. In the healthcare setting, for example, the directional data may include a vital sign of a patient and the GPS location of the patient; and transceiver 510 may determine the scroll rate based on the vital sign, allowing energy signal 90 to guide a healthcare provider toward the patient at walking pace appropriate for the condition of the patient. For example, energy signal 90 may be communicated a faster scroll rate with high intensity energies 32 to alert the provider to run if needed.

[0161] As shown in FIG. 7B, for example, energy transceiver 610 may include a body 620 and a tissue interface 630, both shown conceptually with a dotted line; and an attachment element 670, shown conceptually as a grip panel attached to the grip of a gun. Any type of gun may be used, including the handgun with a pistol grip and any other type of gun with similar surfaces that are gripped during use. In FIG. 7A, tissue interface 630 may be located on a distal surface of element 670 that is typically pushed toward a portion of skin 2 of a hand by a grip force applied by the hand during use, providing a regular or irregular shaped communication area 4. Attachment

element 630 may further maintain interface 630 by limiting movements the hand. For example, element 630 may be 3D printed based on a scan of the hand to include an outwardly curving surface shaped that maintains interface 630 against skin 2 by limiting movements of the hand relative to tissue interface 430 when gripped.

[0162] Accordingly, energy signal 90 may be communicated to the communication area 4 of skin 2 by tissue interface 630 in any communication direction CD with any combination of energies 32. Aspects of energy signal 90 may be responsive to data, as with previous examples. For example, as shown in FIG. 7B, attachment element 670 (e.g., the gun) may include a sight, and energy signal 90 may include at least one decisional shape flashed and/or scrolled to communicate a status associated with gun based on a position of the sight. For example, energy transceiver 610 may include an elevation or motion sensor, and signal 90 may be output to skin 2 as a first shape (e.g., a circle) with a first energy (e.g., any combination of energies 32A-D) whenever the sensor indicates that the sight of the gun has been raised with the safety off, alerting the user to a status of the gun. As a further example, energy transceiver 10 and/or the gun may be configured to determine whether the sight is aligned with a specific target, and output signal 90 as a second shape (e.g., an X shape) with a second energy (e.g., any combination of energies 32A-D), alerting the user to a status of the target.

[0163] Any individual or combined aspects of energy transceivers 10, 110, 210, 310, 410, 510, and 610 may likewise be included on any non-wearable object with a distal surface that is desirably maintained against skin 2 during use by application of an external force, such as a gravity, a gripping force, or other externally applied maintaining force. For example, aspects of tissue interfaces 510 and 610 may likewise be included on a distal surface of any load bearing surface of any type of attachment element. For example, aspects of attachment element 570 or 670 of FIGs.

7A-B alternatively may include a bar, a chair, a handle, a floor, a rope, a wall, or any like object with a skin facing surface that is generally maintained against skin 2 during use; and aspects of issue interfaces 530 or 630 of FIGs. 7A-B alternatively may be mounted therewith so that energy signal 90 may be output to skin 2 whenever the alternative attachment element 570 or 670 is used.

[0164] Additional implantable aspects are now described with reference to energy transceiver 710 of FIG. 7C and energy transceiver 810 of FIG. 7D. As shown in FIG. 7C, for example, energy transceiver 710 may include a body 720 and a tissue interface 730, both shown conceptually with a dotted line; and an attachment element 770, shown conceptually as a portion of a bone plate. Any type of bone plate or other implantable object may be used. Attachment element 770 of FIG. 7C includes a proximal bone-facing surface and a distal skin-facing surface. The bone-facing surface may be maintained against the bone by any combination of adhesives, screws, wires, and/or other bone fixation technologies. The skin-facing surface may maintain the position of tissue interface 730 relative to the bone, allowing for movement of skin 2 relative to interface 730. For example, tissue interface 730 may be mounted in a compartment on the skin-facing surface.

[0165] As above, energy signal 90 may be communicated to the communication area 4 of skin 2 by tissue interface 730 in any communication direction CD with any combination of energies 32. As shown in FIG. 7C, signal 90 may include any combination of shapes moving in any communication direction CD, including any combination of shapes and/or directions, any of which may be flashed and/or scrolled with any energies 32. In contrast to above, energy signal 90 of FIG. 7C may be output toward the underside of skin 2, allowing for more direct communication with nerves associated with skin 2. Aspects of transceiver 710 and energy signal 90 may be modified according to the implanted location of attachment element 770. For example, tissue interface 730 may be embedded in an attachment element 770 sized for placement against a radius or finger bone

wherein the distance between skin 2 and bone is minimal, allowing signal 90 to be communicated with less energy. As a further example, interface 730 may be mounted on an attachment element 770 sized for placement against a radius or ulna, wherein the distance between skin 2 and the bone is larger.

[0166] Similar to above, aspects of body 720 and/or attachment element 770 may direct and focus the energies 32, making it easier to distinguish one output of energies 32 from another and/or prevent the energies 32 from being output to bone. Alternatively, all or portion of the energies 32 may be output toward the bone-facing surface of element 770 to communicate signals and/or apply treatments to the bone. For example, the energies 32 may be output through body 720 and/or attachment element 770 in a proximal and/or distal direction, such as through a plurality of openings extending through element 770. As a further example, the distal surface of body 720 may include a first tissue interface 730 and/or the bone-facing surface of body 730 may include a second tissue interface 730, allowing a corresponding set of first and/or second energy signals 90 to be toward in a first direction toward skin 2 and/or a second direction toward the bone.

[0167] As shown in FIG. 7D, for example, energy transceiver 810 may include a body 820 and a tissue interface 830, both shown conceptually with a dotted line; and an attachment element 870, shown as a biocompatible outer surface layer surrounding body 820. Any type of biocompatible material or containing structure may be used. In this example, attachment element 870 may comprise a tissue in-growth promoting exterior layer that maintains the orientation and/or position of tissue interface 30 over time by interacting with living tissue. For example, element 870 may be composed of a polymeric material, such as a variant of polyether ether ketone (or “PEEK”); and/or include an outer surface textured to promote tissue ingrowth.

[0168] Energy signal 90 may be output from tissue interface 830 as above. As shown in FIG. 7D, tissue interface 830 may be oriented so that the signals 90 are output through attachment element 870 and toward a communication area 4 under skin 2 in a signal direction SD. For example, aspects of body 820 and/or attachment element 870 may direct and focus the energies 32 toward discrete areas 4 on the underside of skin 2, making it easier for the brain to distinguish one output of energies 32 from another and/or preventing the energies 32 from being output other living portions, such as bone or muscle. Alternatively, all or portion of the energies 32 may be output simultaneously from proximal and distal sides of element 870 to communicate with nerves associated with skin 2 and the other living portions. For example, the energies 32 may be output through body 820 and/or attachment element 870 in either direction through a plurality of openings extending therethrough. Also similar to above, transceiver 810 may include a first interface 830 disposed opposite a second interface 830, allowing for output of a corresponding set of first and second energy signals 90.

[0169] Additional aspects are now described with reference to energy transceiver 910 of FIGs. 8A and 8D, demonstrating that any variation of transceiver 10 described herein may be configured to output a plurality of signals 90. For example, energy transceiver 910 may be configured to output a plurality of energy signals 90 in a signal direction SD toward skin 2. As shown in in FIGs. 8A and 8B, transceiver 910 may output a first signal 990₁ in a first divided area or band 924₁, and a second signal 990₂ in a second divided area or band 924₂. Each signal 990₁ and 990₂ may include a plurality of symbols. In FIG. 8A, for example, the symbols include dots made visible through an exemplary cut-out in transceiver 910 as they would be communicated to skin 2, similar to FIG. 1A. Likewise, some of the generators 931 are shaded in FIG. 8A indicate output of energies 32, similar to FIG. 2B.

[0170] Transceiver 910 may comprise: a body 920; a tissue interface 930; a processing unit 960; and an attachment element 970. Similar to above, body 920 may contain elements of transceiver 10 within a flexible biocompatible base material that is conformable against skin 2, and maintainable against skin 2 for prolonged and/or semi-permanent durations. As shown in FIGs. 8A and 8B, body 920 may have a length extending along a longitudinal axis X-X, a width extending along a lateral axis Y-Y, and a thickness extending along a proximal-distal axis Z-Z, similar to body 20 of FIGs. 2A-C. The length, width, and/or thickness of body 920 may be compatible with a curved portion of skin 2, as in FIG. 8A, where body 920 is curved along axis X-X. For example, body 920 may be curved and/or wrapped around any body shape, such as a human forearm, a human shin, and/or portions of a human torso.

[0171] As also shown in FIGs. 8A and 8B, body 920 may define a proximal surface 922, a distal surface 924, a distal compartment 926, and an interior conduit 928. The proximal surface 922 may include a cover 923 mounted thereto. Cover 923 may include a graphic design, a textual element, a writing surface, and/or like decorative feature. As shown in FIG. 8B, a distal surface of cover 923 may include a first attachment element (e.g., a first Velcro strip) engageable with a second attachment element (e.g., a second Velcro strip) on the proximal surface 922, allowing cover 923 to be switched-out as needed. The second attachment element also may attach body 920 to another object such as the inside of a garment.

[0172] Tissue interface 930 may be similar to any variation of tissue interface 30 described herein. As shown in FIG. 8B, tissue interface surface 930 may be mounted in the distal compartment 926 of body 920, and include plurality of energy generators 931 directed toward skin 2. Each generator 931 may be similar to generators 31 described above. For example, each generator 931 may be operable with processing unit 960 to output energies 32 individually and/or

in combination in a signal direction SD; and contained with base material 933 (e.g., epoxy) that directs and/or focusses energies 32 in the signal direction SD. Each generator 931 may likewise include a plurality of generator elements arranged (e.g., coaxially) to output their respective energies 32 in approximately the same direction along an axis z-z, making the outputs interchangeable. As before, the energies 32 may include impact energy 32A (e.g., FIG. 4A), heat energy 32B (e.g., FIG. 4B), shock energy 32C (e.g., FIG. 4C), pressure energy 32D (e.g., FIG. 4D); and/or any like energies.

[0173] In contrast to above, the plurality of generators 931 may be arranged into a plurality of divided areas or bands. As shown in FIG. 8B, the width of body 920 along lateral axis Y-Y may include the first band 924₁ of generators 931, which may extend around the length of body 920 along a first longitudinal axis X₁-X₁ of transceiver 910; and the second band 924₂ of generators 931, which may extend around the length of body 20 along a second longitudinal axis X₂-X₂. The generators 931 located in first band 924₁ may be configured to output first signal 990₁, and the generators 931 located in second band 924₂ may be configured to output second signal 990₂. To enhance distinguishability, an interior portion of compartment 926 and/or base material 933 may physically separate first band 924₁ from second band 924₂, as in FIG. 8B.

[0174] As shown in FIG. 8A, processing unit 960 may be configured to: receive first input data 980A from a first data source 981A; receive second input data 980B from a second data source 981B; and output a control signal 982 and/or to electricity to generators 931, causing various combinations of said generators 931 to output first signal 990₁ and second signal 990₂. For example, processing unit 960 of FIGs. 8A and 8B may include any elements of processor 60 of FIG. 5, such as transceiver 62, one or more processors 63, memory 64, communication bus 65, and power source 66. Each of these elements may perform a similar function within processing

unit 960. Similar to above, one or more wired and/or wireless connections (e.g., such as conductors 27) may extend between processing unit 960 and each generator 931.

[0175] Attachment element 970 may maintain a position of tissue interface 930 against or adjacent skin 2. As shown in FIG. 8B, attachment element 970 may be proximal of tissue interface 930, and configured to maintain the position of interface 930 by applying a distally-directed force to body 920. The distally-directed force may press tissue interface 930 against skin 2, and/or cause portions of interface 930 to conform against a curvature of skin 2. As also shown in FIG. 8B, attachment element 970 may include a strap 972 extending through an interior conduit 928 of body 920. Strap 972 may apply the distally-directed force. For example, strap 972 may be composed of a resilient material (e.g., metal) having a cross-sectional shape (e.g., a semi-circular shape) that maintains body 920 in either an elongated configuration (e.g., FIGs. 2A-C) or a curved configuration (e.g., FIG. 8A), like a slap bracelet.

[0176] Attachment element 970 also may apply the distally-directed force by applying a tensile force to strap 972. As shown in FIG. 8A, a first end 973 of strap 972 may extend from one end of conduit 928, a second end 977 of strap 972 may extend from another end of conduit 928, and the tensile force may be imparted by removably attaching ends 973 and 974. For example, a proximal surface of the first end 973 may include a first attachment element (e.g., a first Velcro strip), a distal surface of second end 974 may include a second attachment element (e.g., a second Velcro strip), and the first and second attachment elements may be overlapped to impart the tensile force. Any type of attachment element may be used to attached ends 973 and 974, including buckles, ratchets, and the like. In some aspects, band 972 may be an elastic band, and ends 973 and 974 may be permanently attached together.

[0177] Processing unit 960 may be removably attached to transceiver 910, allowing for easy repairs and upgrades. As shown in FIG. 8A, processing unit 960 may be attached to a distal surface of the first end 973 of strap 972, and connected to tissue interface 930 by one or more conductors. For example, similar to conductors 27 described above, the conductors may include a network that is located in distal compartment 926 with tissue interface 930, and configured to transmit power and/or control signals between processing unit 960 and generators 931. As shown in FIG. 8A, a distal surface of processing unit 960 may include one or more sensors 968, and attachment element 970 may be configured to maintain a position of the one or more sensors 968 one or adjacent to skin 2, allowing characteristics of the user to be monitored and/or output with processing unit 960.

[0178] Signals 990₁ and 990₂ may be similar to signal 90 of FIG. 1A. For example, first signal 990₁ may include a plurality of first symbols output in first band 924₁, and second signal 990₂ may include a plurality of second symbols output in second band 924₂. As shown in FIGs. 8A and 8B, each of first and second symbols and/or dot may be associated with different data. For example, in the healthcare setting, first signal 990₁ may include first symbols associated with a first patient, and each first symbol may be associated with a vital sign for the first patient; whereas second signal 990₂ may include second symbols associated with a second patient, and each second symbol may be associated with a vital sign for the second patient, allowing the user to simultaneously monitor the first and second patients with transceiver 910.

[0179] As shown in FIG. 8A, first signal 990₁ may be scrolled around first band 924₁ by outputting energies 32 toward skin 2 in signal direction SD, and moving the output across skin 2 in a first communication direction CD₁; and second signal 990₂ may be scrolled around second band 924₂ by outputting energies 32 toward skin 2 in signal direction SD, and moving the output across skin 2 in a second communication direction CD₂. Each signal 990₁ and 990₂, and/or each

first or second symbol included therein, may be configured for increased complexity, allowing more data to be transmitted therewith. In keeping with the previous healthcare example, each signal 990₁ and 990₂ may be scrolled in one of communication directions CD₁ or CD₂ at a scroll rate associated with a vital sign of the respective first and second patients (e.g., pulse rate); each first and second symbol may be associated with another vital sign for said first and second patients (e.g., body temperature, pulse rate, respiration rate, and/or blood pressure); and the first and second symbols may be output with different combinations of energies 32 to communicate different aspects the vital signals (e.g., an increase or decrease in body temperature, pulse rate, respiration rate, and/or blood pressure).

[0180] Although shown as having two divided areas (e.g., first band 924₁ and second band 924₂) configured to output two different energy signals (e.g., first signal 990₁ and second signal 990₂), transceiver 910 may include any number of divided areas having any shape. For example, the width of body 920 may accommodate a plurality of divided areas, at least one tissue interface 930 may be located in each divide area, and attachment element 970 may be configured to maintain each tissue interface 930 against a different portion of skin 2. For example, body 920 of FIG. 8A may accommodate a plurality of bands spaced apart along a length of a limb (e.g., a forearm), and each band (e.g., similar to bands 924₁ and 924₂) may output a different energy signal (e.g., similar to signals 990₁ and 990₂) based on input data from a different data source (e.g., similar to sources 981₁ and 981₂). In a healthcare setting, each data source may include a patient monitoring device, allowing the user to simultaneously monitor a plurality of different patients with transceiver 910.

[0181] Various methods associated with transceiver 10 are now described, including methods of operating transceiver 10. Aspects of each method may be used with any variation of transceiver 10 described herein, such as transceivers 110, 210, 310, 410, 510, 610, 710, 810, and 910 described

above. For ease of description, aspects these methods are now described with various references to these exemplary transceivers, including numerous references to energy transceiver 10. Unless claimed, these references are exemplary and non-limiting.

[0182] As shown in FIG. 9, an exemplary method 1000 may comprise: receiving, with processing unit 60, input data 80 for a communication device 10 including a tissue interface 30 maintainable on or adjacent skin 2, the interface 30 including a plurality of energy generators 31, each generator 31 being operable to output a plurality of energies 32 in a signal direction SD toward skin 2 (a receiving step 1020); and operating, with processing unit 60, the plurality of energy generators 31 to communicate with nerves associated with the skin 2 by outputting one or more energies (e.g., any of energies 32A, 32B, 32C, and 32D) of the plurality of energies 32 in the signal direction SD based on input data 80 (an operating step 1040).

[0183] Receiving step 1020 may comprise receiving input data 80 from one or more data sources 81. For example, the one or more data sources 81 may include at least one of patient monitoring device, a remote server, and a sensor. In this example, receiving step 1020 may comprise receiving input data 80 from the one or more data sources 81 at regular intervals, and operating step 1040 may comprise outputting the one or more energies based on the input data 80 received during each regular interval.

[0184] Input data 80 may include a control signal 80, and operating step 1040 may comprise outputting the one or more energies based on the control signal 82. Alternatively, method 1000 may comprise: generating, with processing unit 60, control signal 82 based on input data 80, wherein operating step 1040 may comprise outputting the one or more energies based on control signal 82. For example, the generating step 1030 may include associating the input data 80 with a plurality of symbols 92, and operating step 1040 may comprise communicating the symbols 92

with the one or more energies. In this example, the input data 80 may include measurements (e.g., vital signs of a patient), and each symbol may be associated with one or more of the measurements (e.g., one or more of the vital signs).

[0185] In any of these examples, the one or more energies may include a first combination of the plurality of energies 32 (e.g., impact energy 32A and pressure energy 32D); and a second combination of the plurality of energies 32 (e.g., heat energy 32B and pressure energy 32D). The first combination may be followed by any second combination(s). For example, the one or more energies may include a first energy (e.g., impact energy 32A) communicable with a first portion of the nerves (e.g., Meissner's corpuscle); and a second energy (e.g., heat energy 32D) communication with a second portion of the nerves (e.g., the Ruffini corpuscle).

[0186] Operating step 1040 may alternatively comprise: operating, with processing unit 60, the plurality of energy generators 31 to communicate energy signal 90 to nerves associated with the skin 2 by outputting one or more energies of the plurality of energies 32 in signal direction SD based on input data 80. For example, step 1040 may comprise outputting different combinations of the one or more energies, and each different combination may communicate a different portion of the energy signal 90. Similar to above, energy signal 90 may include one or more symbols 92, and operating step 1040 may comprise outputting the one or more energies to communicate the one or more symbols 92. Step 1040 may comprise scrolling the one or more symbols 92 across skin 2 in a communication direction CD transverse with the signal direction SD; and/or flashing any of symbols 92 on-and-off. The plurality symbols 92 may include any type of signal, including pip patters, alphanumeric symbols, and the like.

[0187] Various energy types may be used. For example, operating step 1040 may comprise outputting a first combination of the one or more energies to communicate a first symbol of the

one or more symbols (e.g., symbol 92A), and outputting a second combination of the one or more energies to communicate a second symbol of the one or more symbols (e.g., symbol 92B). In some aspects, operating step 1040 may comprise: outputting a first combination of the one or more energies to communicate energy signal 90 and outputting a second combination of the one or more energies to communicate a characteristic of energy signal 90, so as to highlight energy signal 90 or a portion thereof. Input data 80 may include a measurement, and step 1040 may comprise outputting a first combination of the one or more energies based on the measurement. In this example, step 1040 may comprise modifying the first combination based on a change of the measurement, and/or outputting a second combination of the one or more energies based on the change of the measurement.

[0188] The larger size of transceiver 910 relative to transceivers 10 may allow for different methods of operation. As shown in FIG. 10, for example, an exemplary method 1100 may comprise: receiving, with processing unit 960, input data 980 for a communication device 910 including a tissue interface 930 maintainable on or adjacent skin 2, the interface 930 including a plurality of energy generators 931 arranged in bands 924₁ and 924₂, each generator 931 being operable to output a plurality of energies 32 in a signal direction SD toward the skin 2 (a receiving step 1120); and operating, with processing unit 60, the plurality of energy generators 931 in each band 924₁ and 924₂ to communicate with nerves associated with the skin 2 by outputting one or more energies of the plurality of energies 32 in response to the input data 80 (an operating step 1140).

[0189] Receiving step 1020 may comprise receiving input data 980 from one or more data sources 981. As shown in FIG. 10, for example, step 1020 may comprise receiving a first input data 980A from a first data source 981A, and a second input data 980B from a second data source

981B. Input data 980 may include a plurality of measurements. Accordingly, receiving step 1020 may comprise receiving input data include a plurality of measurements; and operating step 1040 may comprise operating the plurality of energy generators 931 in each band 924₁ and/or 924₂ to output the one or more energies based on one measurement of the plurality of measurements.

[0190] In the healthcare setting, first data source 981A may include a patient monitoring device or sensor configured to output measurements associated with a first patient, and second data source 981AB may include a patient monitoring device or sensor configured to output measurements associated with a second patient. The measurements may include vital signs for the respective first and second patients. In this example, receiving step 1120 may comprise receiving input data 980 including a plurality of vital signs; and operating step 1140 may comprise operating the plurality of energy generators 931 in each band 924₁ and 924₂ to output the one or more energies based on one vital sign of the plurality of vital signs. For example, step 1140 may comprise operating the generators 931 in band 924₁ to output energies 32 based on the vital signs for the first patient, and/or operating the generators 931 in band 924₂ to output energies 32 based on the vital signs for the second patient.

[0191] Aspects of energies 32 may be modified based on the measurements. For example, operating step 1040 may comprise: outputting a first combination of energies 32 when the at least one of the measurements is inside of an acceptable range; and outputting a second combination of energies 32 when at least one of the measurements is outside of the acceptable range. In the healthcare setting, one of the vital signs of the patient (e.g., pulse rate) may serve as the baseline measure.

[0192] Similar to above, input data 980 may include a control signal for each band 924₁ and 924₂, and operating step 1140 may comprise outputting the energies 32 based on the control signal

for each band 924₁ or 924₂. Alternatively, method 1100 may further comprise: generating, with the processing unit 960, a control signal for each band 924₁ and 924₂ based on input data 980, wherein the operating step 1140 comprises outputting the energies 32 based on the control signal for each band.

[0193] Also similar to above, operating step 1140 also may comprise operating the plurality of energy generators 931 to simultaneously communicate a plurality of energy signals to nerves associated with the skin 2 by outputting an energy signal in each band with energies 32, and/or scrolling the energy signal in its respective band. As shown in FIG. 10, step 1140 may comprise outputting first energy signal 990₁ in first band 924₁ with a first combination of energies 32, and outputting second energy signal 990₂ in second band 924₂ with a second combination of energies 32. Each signal 990₁ and 990₂ may include a plurality of symbols (e.g., symbols 92), and operating step 1140 may comprise scrolling the symbols across one of bands 924₁ and 924₂. In keeping with above, first signal 990₁ (and any symbols contained therein) may be scrolled along a first communication direction CD₁ transverse with signal direction SD, and second signal 990₂ (and any symbols contained therein) may be scrolled along a second communication direction CD₂ transverse with signal direction SD.

[0194] Although described with reference to two divided areas (e.g., first band 924₁ and second band 924₂) configured to output two energy signals (e.g., first signal 990₁ and second signal 990₂), it is contemplated that method 1100 may be configured for any number of divided areas. Accordingly, variations of method 1100 may allow the user to simultaneously monitor a plurality of sources of input data, from one or more data sources, with aspects of transceiver 910 described herein.

[0195] Additional aspects described above with reference to transceivers 10, 110, 210, 310, 410, 510, 610, 710, 810 and 910, and methods 1000 and 1100, are now described with reference to a communication system 2000. Aspects of an exemplary system 2000 are depicted in FIGs. 11 and 12. As shown in FIG. 11, communication system 2000 may comprise a plurality of energy transceivers configured to receive input data and output one or more of a plurality of energies 32 to different locations of skin 2 according to the input data. Each transceiver may include any element and perform any function described above with reference to transceivers 10, 110, 210, 310, 410, 510, 610, 710, 810 and 910, and methods 1000 and 1100. Different aspects may be combined in system 2000. For example, as shown in FIG. 11, system 2000 may comprise: a first energy transceiver 2012 on a head of a user 1, similar to transceiver 110 of FIG. 6A; a second energy transceiver 2014 on one arm of user 1, similar to transceiver 900 of FIGs. 9A-B; a plurality of energy transceivers 2016 attached to a torso of user 1, similar to transceiver 10 of FIGs. 2A-C; an energy transceiver 2018 on each leg of user 1, similar to transceiver 410 of FIG. 6D; and an energy transceiver 2020 in each shoe of user 1, similar to transceiver 510 of FIG. 7A.

[0196] Each transceiver 2012, 2014, 2016, 2018, and 2020 may be interconnected in system 2000 so that coordinated control signals may be output to each transceiver for output of a corresponding signal 90 with a corresponding one or more of energies 32. The coordinated control signals may be used to coordinate activities or movements of user 1 in response to the input data. As shown in FIG. 11, each of said transceivers may output data associated with a first form or position of user 1, receive input data regarding a second form or position, and output signals 90 in the same or communication directions CD to direct the user 1 to move according to the desired form or position. In one aspect, the first form or position may be a first pose or stance, and the second form or position may be a second pose; in other aspects, the first form or position may be

a first (e.g., GPS) position on a field, and the second form or position may be a second (e.g., GPS) position on the field.

[0197] As shown in FIG. 11, for example, transceiver 2012 may scroll a first signal 90 in a first communication direction CD_1 around the head; transceiver 2014 may scroll a second signal 90 around the arm in a second communication direction CD_2 ; transceivers 2016 may output third signals 90 without scrolling; transceivers 2018 may scroll fourth signals 90 in communication directions CD_{3R} and CD_{3L} around the legs; transceivers 2020 may scroll fourth signals 90 in communication directions CD_{4R} and CD_{4L} across the feet. Accordingly, each of the respective signals and communication directions may be coordinated in system 2000 to direct the user to move in a particular direction and/or move one or more of their limbs into a particular form or position.

[0198] Aspects of methods 1000 and 1100 may be modified for use within system 2000. As shown in FIG. 12, for example, an exemplary method 2100 may comprise: receiving, with one or more processors, position data for a plurality of communication devices (e.g., transceivers 2012, 2014, 2016, 2018, 2020) mountable on or adjacent skin, each device including a tissue interface with a plurality of energy generators 31, each generator 31 being operable to output a plurality of energies 32 in a signal direction SD toward skin 2 (a “receiving step 2120”); receiving or generating, with the one or more processors, a corrective motion signal for the plurality of communication devices based on position data for each communication device (a “receiving or generating step 2140”); and operating, with the one or more processors, the plurality of energy generators 31 of each communication device to output one or more energies of the plurality of energies 32 in signal direction SD based on the corrective motion signal. Although described with

reference to elements of transceiver 10, method 2100 may be performed with any transceiver described herein.

[0199] Additional aspects described above with reference to transceivers 10, 110, 210, 310, 410, 510, 610, 710, 810 and 910, methods 1000 and 1100, system 2000, and method 2100 are now described with reference to aspects of an energy transceiver 3010 shown in FIGs. 13A, 13B, 14A, and 14B. As before, any aspect of energy transceiver 3010 may be combined with any aspect described above.

[0200] As shown in FIG. 13A, energy transceiver 3010 may include: a body 3020 and a tissue interface 2030; and an attachment element 3070, shown conceptually as a band in this example. As above, body 3020 may wrap around a circular portion of skin 2, such as around the human forearm shown in FIG. 13B. For example, as before, body 3020 may be mounted on attachment element 3070; and tissue interface 3030 may be mounted on a distal surface of body 3020, providing a curved rectangular communication area 4 and a semi-circular (e.g., less than 360°) or circular (e.g., 360°) communication direction CD for energy signal 90. In keeping with above, attachment element 3070 (e.g., the band) may be configured to maintain tissue interface 3030 against or the forearm when element 3070 is worn, allowing energy signal 90 to be output communication area 4 in signal direction SD and/or scrolled across area 4 in communication direction CD.

[0201] As described above, aspects of each energy 32 may be modified to increase the complexity of energy signal 90, and thus the amount of data transmitted therewith; and the modifiable aspects may include energy type, energy intensity, output duration, scroll rate, symbol shape, and the like, providing an incredibly broad range of obtainable complexity. Training may be required to leverage the full communicative capabilities of tissue interface 3030 and signal 90.

For example, within a repetition program, the user may be trained to more easily and/or quickly to distinguish between: any number of known shapes output by one of energies 32, such as between a pip two dot pattern output with impact energy 32A and a pip four dot pattern output with energy 32A; or the same shape output with different energies 32, such as a pip five dot pattern with impact energy 32A or heat energy 32B.

[0202] Communicating more complex variations, unknown signals, and/or unknown shapes may require additional training. For example, interface 3030 may output energy signal 90 to include pip patterns in which each dot is output with a different combination of energies 32, allowing the pattern to be associated with a target, and each dot to be associated with a characteristic thereof. In the healthcare setting, for example, the pattern may be associated with a patient, and each dot may be associated with a different vital sign of the patient, providing immediate insight into patient health that may be updated continuously. Further training may be required to quickly distinguish between the characteristics communicated by each dot in these examples, particularly if energy signal 90 includes a plurality of pip patterns, as shown in FIG. 2C; or a dynamic shape, such as the echocardiogram depicted in FIGs. 13A and 13B; the plurality of echocardiograms depicted in FIG. 14A; or the alphanumeric symbol stream depicted in FIG. 14B.

[0203] Aspects of energy transceiver 3010 may be configured to provide additional communicative capabilities to, for example, assist with training. As shown in FIG. 13A, transceiver 3010 may further comprise an optical interface 3030' compatible with eyes of the user. For example, optical interface 3030' may comprise at least one display element operable to output an optical energy signal 90' to the eyes, such as a flexible LED configured to output a plurality of colors. Any display technology may be used. As shown in FIG. 13A, interface 3030' may provide a curved optical communication area that wraps around apparatus 3010 along an axis X-X and/or

substantially corresponds with the communication area 4. For example, tissue interface 330 may be configured to output non-optical energy signal 90 toward skin 2 with one or more energies 32 in a first or distal direction toward skin 2; and optical interface 330' may be configured to output optical signal 90' with one or more colors in a second or proximal direction toward the eyes.

[0204] Energy transceiver 3010 may comprise a processing unit similar to any variation of processing unit 60 described herein. For example, the processing unit may be operable with tissue interface 3030 and optical interface 3030' to simultaneously communicate with nerves associated with skin 2 and the eyes by outputting signal 90 distally and signal 90' proximally at the same time. Additional training capabilities may be realized by the simultaneous outputs. For example, the user may already be trained to react to optical signal 90', whether or not signal 90 is communicated, such as when transceiver 3010 excludes interface 3030. Accordingly, by consistently outputting energy signal 90 with optical signal 90', the user may be trained to react to recognize and react to energy signal 90 with or without optical signal 90'.

[0205] In a healthcare setting, for example, optical signal 90' may communicate a vital sign of a patient to the eyes of a provider, such as the echocardiogram of FIG. 13A; and energy signal 90' may communicate the same vital sign to skin 2 of the provider at the same time. For example, signals 90' and 90 may be scrolled together in communication direction CD along axis X-X to simultaneously communicate aspects of the vital sign over time. As a further example, signal 90' may comprise a plurality of colors, and the output of energies 32 in signal 90 may be modified according to a color matching algorithm to communicate similar aspects to skin 2 at the same time. Reactions to different vital signs may be trained in this manner. As shown in FIG. 13B, for example, a first portion of optical interface 3030' may output a first optical signal 90A', a second portion of interface 3030' may output a second optical signal 90B', corresponding portions of

tissue interface 3030 may output corresponding energy signals 90, much like interface 930 described above. As also shown in FIG. 13B, the signals 90A' and 90B' may be different, in which one may be a vital sign and other may include symbols communicating related patient data as above.

[0206] Accordingly, by simultaneously outputting optical signal 90' together with energy signal 90, transceiver 3010 may train reactions to any stimulus, such as the exemplary vital signs and signals depicted in FIGs. 13 and 13B. As shown in FIGs. 14A and 14B, the complexity of the stimulus may be increased. For example, as shown in FIG. 14A, optical interface 3030' and tissue interface 3030 may output their respective signals in a plurality of rows arranged around axis X-X, wherein each row includes a different set of corresponding signals movable along a communication direction CD that is transverse with axis X-X. In this example, four rows are shown as outputting four different optical signals, including a first optical signal 90A', a second optical signal 90B', a third optical signal 90C', and a fourth optical signal 90D'. A corresponding set of rows and outputs may be realized by tissue interface 90.

[0207] In the healthcare setting, for example, each output of optical signals 90A', 90B', 90C' and 90D' together with its corresponding energy signal 90 may communicate a different vital sign of a different patient to a provider, training them to simultaneously monitor all of the different patients at once. As described above, aspects of each energy signal 90, such as energies 32, may be modified to communicate changes in the associated vital sign. For training purposes, the color of optical signals 90A, 90B, 90C, and 90D may be varied based on these changes so that the provider may be trained to first recognize the changes based one of the optical signals; and second recognize the same changes based on one of the energy signals based on the color matching algorithm. For example, the color matching algorithm may comprise a correspondence between

visual colors and energy intensity, in which warmer colors (e.g., red) are associated with higher intensities and cooler colors (e.g., blue) are associated with lower intensities.

[0208] Another example is provided in FIG. 14B, in which each output of signals 90A', 90B', 90C' and 90D' together with its corresponding signal 90 may communicate aspects of an alphanumeric stream. As shown in FIG. 14B, for example, each alphanumeric stream may comprise a stock ticker so that the user may be trained to simultaneously monitor a plurality of tickers. As before, aspects of the different optical signals 90A', 90B', 90C', and 90'D may be modified simultaneously with aspects of their corresponding energy signals 90 to communicate changes over time.

[0209] In keeping with above, optical interface 3030' and tissue interface 3030 may be configured to individually and/or simultaneously output signals 90' and 90 to include any symbols and shapes, as well as more complex depictions, such as graphics. For example, for more complex depictions, the color matching algorithm may be used to output different combinations of energies 32 based on color.

[0210] Optical interface 3030' may comprise touchscreen capabilities allowing manipulation of signals 90 and/or 90' by interaction therewith. For example, the position of each row depicted in FIGs. 14A and 14B may be movable via a tactile interaction with interface 3030'. As shown in FIG. 13B, for example, attachment element 3070 may maintain the position of tissue interface 3030 on or adjacent skin 2 of a forearm, meaning that at least some portion of optical interface 3030' may not be aligned with the eyes of the user at all times. Accordingly, because of the dynamic capabilities of interfaces 3030 and 3030', the touchscreen capabilities of apparatus 3010 may allow the user to move a particular row into alignment with the eyes by scrolling the rows together around axis X-X, in which the outputs of signals 90A', 90B', 90C', and 90'D and

corresponding energy signal 90 move with each row. Any type of touchscreen-enabled two-way communication means may be used, including buttons, sliders, textual inputs, graphic inputs, and the like.

[0211] Aspects of methods 1000, 1100, and 2100 and/or system 200 may be modified according to aspects of energy transceiver 3010. For example, any method steps described herein may be modified to comprise training and/or communication steps according to the above-described aspects of transceiver 3010. As a further example, the second energy transceiver 2014 shown in FIG. 11 may comprise transceiver 3010, which may be further operable with each of transceivers 2012, 2016, 2018, and 2020 to train the user. To provide another example, aspects of each transceiver within system 2000 also may be configured to placement at a particular sensory zone of skin 2, and transceiver 3010 may be used to both tune the respective energy signals 90 for output to each zone and train the user to react accordingly based on one or more of the signals 90. In this example, the receptive capabilities of the nerves associated with skin 2 in each zone may vary, and transceiver 3010 may be configured to operate the transceivers in system 2000 so that the most complex signals are communicated to the most receptive zones.

[0212] While principles of the present disclosure are disclosed herein with reference to illustrative aspects for particular applications, the disclosure is not limited thereto. Those having ordinary skill in the art and access to the teachings provided herein will recognize additional modifications, applications, aspects, and substitution of equivalents all fall in the scope of the aspects disclosed herein. Accordingly, the present disclosure is not to be considered as limited by the foregoing description.



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(54) **Method and apparatus for sensory stimulation**

Verfahren und Vorrichtung zur sensorischen Stimulation

Procédé et appareil de stimulation sensorielle

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(73) Proprietor: **Senseg Oy**
02600 Espoo (FI)

(72) Inventors:
• **Mäkinen, Ville**
02600 Espoo (FI)
• **Suvanto, Petro**
02600 Espoo (FI)
• **Linjama, Jukka**
02600 Espoo (FI)

(74) Representative: **Kolster Oy Ab**
(Salmisaarenaukio 1)
P.O. Box 204
00181 Helsinki (FI)

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Description

Background of the invention

[0001] The present invention relates to an apparatus and method for sensory stimulation. The invention is particularly applicable for stimulating the sense of touch.

[0002] Manual input devices, such as joysticks and mice, are frequently complemented by means for providing tactile sensations such that the manual input devices provide tactile feedback to their users. There are hundreds of US patents for tactile feedback devices. In most or all of the prior art devices the tactile stimulation is generated by means of moving or vibrating mechanical members. A problem shared by most such devices is that such moving mechanical members tend to be bulky, unreliable and/or difficult to control. Examples of tactile stimulation devices are disclosed in the following documents:

KACZMAREK, K.A., et al., "Polarity Effect in Electrovibration for Tactile Display"; IEEE Transactions on Biomedical Engineering, Volume 53, Issue 10, Oct. 2006 Page(s): 2047-2054, <DOI: 10.1109/TBME.2006.881804>

YAMAMOTO, A., et al., "Electrostatic tactile display with thin film slider and its application to tactile telepresentation systems"; IEEE Transactions on Visualization and Computer Graphics, Volume 12, Issue 2, March-April 2006 Page(s): 168-177 <DOI: 10.1109/TVCG.2006.28>

AGARWAL, A.K., et al., "A hybrid natural/artificial electrostatic actuator for tactile stimulation"; 2nd Annual International IEEE-EMB Special Topic Conference on Microtechnologies in Medicine & Biology, 2-4 May 2002 Page(s): 341-345 <DOI: 10.1109/MMB.2002.1002343>

BEEBE, D.J., et al., "A polyimide-on-silicon electrostatic fingertip tactile display"; Engineering in Medicine and Biology Society, 1995., IEEE 17th Annual Conference Volume 2, 20-23 Sept. 1995 Page(s): 1545-1546 vol.2 <DOI: 10.1109/IEMBS.1995.579819>

Brief description of the invention

[0003] An object of the present invention is to provide a method and apparatus for alleviating at least one of the problems identified above.

[0004] The object of the invention is achieved by features which are disclosed in the attached independent claims. The dependent claims and the present patent specification disclosed additional specific embodiments and non-essential features of the invention.

[0005] The invention is based on the surprising discovery that subcutaneous Pacinian corpuscles can be stimulated by means of a capacitive electrical coupling and an appropriately dimensioned control voltage, either without any mechanical stimulation of the Pacinian cor-

puscles or as an additional stimulation separate from such mechanical stimulation. An appropriately dimensioned high voltage is used as the control voltage. In the present context a high voltage means such a voltage that direct galvanic contact must be prevented for reasons of safety and/or user comfort. This results in a capacitive coupling between the Pacinian corpuscles and the apparatus causing the stimulation, wherein one side of the capacitive coupling is formed by at least one galvanically isolated electrode connected to the stimulating apparatus, while the other side, in close proximity to the electrode, is formed by the body member, preferably a finger, of the stimulation target, such as the user of the apparatus, and more specifically the subcutaneous Pacinian corpuscles.

[0006] Without committing themselves to any particular theory, the inventors find it likely that the invention is based on a controlled formation of an electric field between an active surface of the apparatus and the body member, such as a finger, approaching or touching it. The electric field tends to give rise to an opposite charge on the proximate finger. A local electric field and a capacitive coupling can be formed between the charges. The electric field directs a force on the charge of the finger tissue. By appropriately altering the electric field a force capable of moving the tissue may arise, whereby the sensory receptors sense such movement as vibration.

[0007] A benefit of the invention is independence from mechanical vibration and its associated problems in the prior art.

[0008] An aspect of the invention is an apparatus for generating an electro-sensory stimulus to at least one body member. The apparatus comprises one or more conducting electrodes each of which is provided with an insulator. When the body member is proximate to the conducting electrode, the insulator prevents flow of direct current from the conducting electrode to the body member. A capacitive coupling over the insulator is formed between the conducting electrode and the body member. The apparatus also comprises a high-voltage source for applying an electrical input to the one or more conducting electrodes, wherein the electrical input comprises a low-frequency component in a frequency range between 10 Hz and 1000 Hz. The capacitive coupling and electrical input are dimensioned to produce an electro-sensory sensation which is produced independently of any mechanical vibration of the one or more conducting electrodes or insulators.

[0009] Another aspect of the invention is a method for causing an electrosensory sensation to a body member. The method comprises providing one or more conducting electrodes. Each conducting electrode is provided with an insulator wherein, when the body member is proximate to the conducting electrode, the insulator prevents flow of direct current from the conducting electrode to the body member. A capacitive coupling over the insulator is formed between the conducting electrode and the body member. A high-voltage source is provided for applying

an electrical input to the one or more conducting electrodes. The electrical input comprises a low-frequency component in a frequency range between 10 Hz and 1000 Hz, while the capacitive coupling and electrical input are dimensioned to produce an electrosensory sensation. The electrosensory sensation is produced independently of any mechanical vibration of the one or more conducting electrode(s) or insulator(s).

[0010] It is beneficial to vary the capacitive coupling such that the variation comprises one or more frequency components in a range wherein the Pacinian corpuscles exhibit their maximal sensitivity. This frequency range is roughly 10 to 1000 Hz and in most humans 100 to 500 Hz. The capacitive coupling can be varied by varying the control voltage and/or parameters of the capacitive coupling.

[0011] By way of example, the high-voltage charge applied to the electrode can have a voltage of at least 750, 1000, 1500 or 2000 V and at most 20, 50 or 100 kV (no-load measurements). In the present context, voltage values may refer to voltage in direct current or effective (RMS) voltages in alternating current. The high-voltage current applied may be direct current or alternating current. When alternating current is being used, the frequency of the current may be high, such as at least 1 kHz, 10 kHz, 20 kHz or 30 kHz and at most 100 kHz, 500 kHz or 1 MHz, provided that the signal also exhibits a low-frequency component, for example such that high-frequency signal has an envelope whose frequency stimulates the desired sensory cells. The high-frequency alternating current can be modulated by means of a control signal having a low-frequency component, for example.

[0012] When high-voltage direct current is being used, the electrode may be embodied as a MEMS component (micro electromechanical system), which comprises a set of rotating, preferably individually controllable tiny electrodes. The strength of the capacitive coupling formed by the electrode can be adjusted by adjusting these tiny electrodes. In this case the strongest coupling is achieved when the tiny electrodes are oriented such that they collectively form a plane. In the inventive technique, by measuring the characteristics of the capacitive coupling, for example the capacitance of its variation, it may be possible to measure the distance of the body member from the surface of the apparatus, for example. Additionally, it may be possible to detect separately the touching of the surface by the body member. The inventive technique may be further enhanced by power control functionality of the electric field being formed, for example. Utilization of some embodiments of the invention in the implementation of a proximity sensor may require a weaker electric field than what is required by causing the inventive sensory stimulus. Accordingly it may be beneficial to be able to vary the strength of the electric field depending on the currently needed functionality. Such variation may, for instance, involve strengthening the electric field such that a sense of touch or vibration is caused in the body member when it is brought sufficiently

close to the electrode or insulator.

[0013] By way of example, the low-frequency component of the control signal being used in the inventive technique may be generated by modulating a high-frequency alternating current. The modulation signal may be continuous or pulsed, for example. The duration of individual pulses may be 0.01, 0.5 or 4 ms and the pause between pulses can be at least 1, 10 or 100 ms.

[0014] The low-frequency component of the control signal may have a frequency of at least 10, 50 or 100 Hz and at most 300, 500 or 1000 Hz. In one specific embodiment the control signal has an exemplary frequency of 120 Hz. In the inventive technique the alternating electric field, which causes the stimulus to be provided, may exhibit an intensity peak of at least 100 V/mm, 200 V/mm or 500 V/mm and at most 10 kV/mm, 30 kV/mm or 100 kV/mm. The field strength may be measured, for example, by means of a grounded electrode with a surface area of eg 1 cm² positioned 0.05 to 5 mm, preferably about 1 mm from the surface of the insulated electrode.

[0015] By way of example, the electric field generated by the electrode can be controlled according to a processing logic being executed in a computer or other electronic data processing apparatus. For example, the control logic can be used to control the variation frequency and/or intensity of the electric field generated by an individual electrode. Furthermore, the control logic can be used to pulse the varying electric field, for example. The control logic can also receive control information via a data network from another apparatus, such as another computer or data processing apparatus.

[0016] An inventive apparatus for sensory stimulation comprises at least one insulated electrode, wherein the apparatus is operable to apply a charge to the electrode such that the charge causes a stimulation of the Pacinian corpuscles. For humans this normally requires a voltage of at least 750 V. The apparatus further comprises means for varying the intensity of the charge-generated, capacitively-coupled electric field by utilizing a signal having a component with a frequency of at least 10 Hz and at most 1000 Hz.

[0017] Some embodiments of the inventive apparatus can be implemented, when so desired, without mechanically moving parts, and such embodiments do not pose similar restrictions on the mechanical characteristics of the materials as do actuators based on mechanical movement of the surface. Accordingly, some embodiments of the invention are applicable to a wide variety of surfaces of different shapes. For instance, the surface shape of the electrode and/or insulator attached to it may be planar, rounded, spherical or concave. Likewise, the insulator material can be selected from a variety of materials having characteristics particularly suitable for the chosen application. As regards mechanical characteristics, the surface material can be hard, soft, stiff, bending, transparent or flexible. The surface, as well as the material being used as the conductor, can also be transparent.

[0018] An individual electrode of the apparatus and/or the insulator attached to the electrode can have a surface area of 0.1, 1, 10 or 100 cm² or more. The apparatus can comprise multiple insulated electrodes which can be arranged in an array forming an X-Y coordinate system. Each electrode of such a system can, when so desired, be controlled by a control logic according to some embodiments of the invention, for example. The electrodes can be fixedly mounted or movable.

[0019] The apparatus may comprise means for varying the variation frequency of the electric field, for example by modulating the high-voltage alternating current or by moving the electrodes of the MEMS device according to the control signal.

[0020] The insulator to be arranged between the electrode of the apparatus and the body member can have a thickness of at least 0.01 mm, 0.05 mm, 0.1 mm or 0.5 mm and at most 10 mm, 20 mm or 50 mm. The insulator material can be selected according to the intended use and/or voltage to be used, for example.

[0021] In some embodiments the insulator comprises multiple layers. For instance, the inventors have discovered that the bulk of the insulator layer between the electrode and the body part approaching or touching it may comprise glass but glass is not optimal as the insulator's surface material. In the present context, optimal means an insulator material which best supports the creation of the electro-sensory sensation. A glass insulator works much better if covered with a plastic film.

[0022] The inventive apparatus can be implemented such that its power consumption is low. For example, the power required to cause a sensory stimulus may be 1 mW, 5 mW or 10 mW or more. Power consumption can be measured on the basis of the electric power applied to the electrode when a human touches the apparatus surface or when a capacitively grounded 50 pF capacitor is connected to the apparatus surface.

[0023] The apparatus may comprise means for measuring the capacitance of the capacitive coupling being formed. The apparatus may further comprise means for adjusting the characteristics of the electric field, such as intensity or variation frequency, based on the obtained measurement information.

[0024] The inventive apparatus for sensory stimulation can be integrated as a part of some other apparatus or system. For instance, a prior art touch display can be complemented by apparatuses according to some embodiments of the present invention. This way it is possible to provide a touch display which produces a sensation of touch even if the display is not physically touched. Control components of the feedback system can be combined, or they may be arranged to exchange information with one another. An advantageous embodiment of the presently disclosed method and apparatus is a control device based on touch or proximity, such as a touch display that produces a feedback which can be sensed via the sense of touch.

[0025] In some embodiments of the invention, the local

charge/field can be controlled by means of capacitive grounding. In various embodiments of the invention, it is possible to take into account the fact that the dependence of the electric coupling on the insulated electrode, ie, capacitance, depends on several factors. The capacitance value affects the potential difference between the finger and electrode if the apparatus or subject (such as human) is not grounded, and their ground potential is determined via stray capacitances. Prior art implementations ignore control and processing of the distribution of capacitances and voltages, and some embodiments of the present invention aim at alleviating this separate problem.

[0026] For example, the invention differs from prior art solutions in that no touching or mechanical movement or vibration is required to generate the stimulus. Accordingly, the invention provides advantages over solutions which are based on, say, stroking the finger over the electrodes and on locally varying friction caused by the electric field. Furthermore, the various embodiments of the invention support solutions which are based not only on alternating current but also on direct current. Yet further, the inventive solution can be provided with a functionality to detect proximity and touch, whereby the same component can be used for input and output functions. In addition, various embodiments of the invention may utilize thick insulators, for example, which are mechanically stronger than thin insulators. Moreover, it has been discovered in connection with several embodiments of the invention that it is beneficial to use particular variation frequencies for the electric field, as they will enable smaller energy consumption in the generation of the stimulus.

[0027] In one embodiment the electrical input also comprises a high-frequency component having a frequency which is higher than the frequency of the low-frequency component and lower than 500 kHz. This embodiment may also comprise a modulator or other means for modulating the high-frequency component by the low-frequency component.

[0028] The electrical input to the one or more conducting electrodes has a peak-to-peak voltage of 750 to 100,000 Volts and the insulator should be dimensioned accordingly. In practical implementations with currently available materials the insulator thickness is typically between 0.1 mm and 50 mm.

[0029] In order to convey time-variant information, as opposed to a steady-state sensation, the apparatus may comprise means for modulating the electrical input according to the time-variant information.

[0030] A simple but effective implementation of the invention comprises precisely one conducting electrode for each spatially distinct area of the body member. There may be more than one conducting electrode such that each conducting electrode stimulates a spatially distinct area of one or more body members. The apparatus may comprise an enclosure which contains the high-voltage source which is common to all the several conducting electrodes and wherein the enclosure also contains means for conveying the electrical input to zero or more

of the several conducting electrodes simultaneously. The inventive apparatus and/or the one or more conducting electrodes may be positioned such that the body member most likely to be affected is part of a human hand. For example, five conducting electrodes under control of a common controller, may stimulate, at different times, zero to five fingertips in parallel. The five conducting electrodes thus convey five bits of information in parallel. The apparatus may be implemented as part of an input/output peripheral device connectable to a data processing equipment.

Brief description of the drawings

[0031] In the following the invention will be described in greater detail by means of specific embodiments with reference to the attached drawings, in which

Figure 1 illustrates the operating principle of a capacitive electro-sensory interface ("CEI");
 Figure 2 illustrates an embodiment of the CEI;
 Figure 3 shows an enhanced embodiment with multiple independently-controllable electrodes;
 Figure 4 shows a specific implementation of the embodiment shown in Figure 3;
 Figure 5 is a graph which schematically illustrates the sensitivity of a test subject to sensations produced by the inventive capacitive electrosensory interface at various frequencies;
 Figure 6 is a graph which further clarifies the operating principle of the CEI;
 Figures 7A and 7B show an implementation of the CEI wherein the strength of the capacitive coupling is adjusted by electrode movement;
 Figure 8 shows an implementation of the CEI wherein the charges of different electrodes have opposite signs;
 Figure 9 shows an implementation of the CEI wherein a group of electrodes are organized in the form of a matrix;
 Figure 10 illustrates distribution of an electric field-generating potential in capacitive couplings when the apparatus is grounded;
 Figure 11 illustrates distribution of an electric field-generating potential in capacitive couplings when the apparatus is floating (not grounded);
 Figure 12 illustrates distribution of an electric field-generating potential in capacitive couplings when the apparatus is floating and the user is sufficiently close to the apparatus and capacitively grounded to the ground (reference) potential of the apparatus;
 Figure 13 shows an arrangement wherein capacitive couplings are utilized to detect touching; and
 Figures 14 and 15 illustrate embodiments in which a single electrode and temporal variations in the intensity of the electro-sensory stimulus can be used to create illusions of a textured touch screen surface.

Detailed description of specific embodiments

[0032] Figures 1 through 15 relate to the operation and implementation of a capacitive electro-sensory interface ("CEI") which can be employed in the inventive touch screen interface.

[0033] Figure 1 illustrates the operating principle of the CEI. Reference numeral 100 denotes a high-voltage amplifier. The output of the high-voltage amplifier 100, denoted OUT, is coupled to an electrode 106 which is insulated against galvanic contact by an insulator 108 which comprises at least one insulation layer or member. Reference numeral 120 generally denotes a body member to be stimulated, such as a human finger. Human skin, which is denoted by reference numeral 121, is a relatively good insulator when dry, but the CEI provides a relatively good capacitive coupling between the electrode 106 and the body member 120. The capacitive coupling is virtually independent from skin conditions, such as moisture. The inventors' hypothesis is that the capacitive coupling between the electrode 106 and the body member 120 generates a pulsating Coulomb force. The pulsating Coulomb force stimulates vibration-sensitive receptors, mainly those called Pacinian corpuscles which reside under the outermost layer of skin in the ipodermis 121. The Pacinian corpuscles are denoted by reference numeral 122. They are shown schematically and greatly magnified.

[0034] The high-voltage amplifier 100 is driven by an input signal IN which results in a substantial portion of the energy content of the resulting Coulomb forces to reside in a frequency range to which the Pacinian corpuscles 122 are sensitive. For humans this frequency range is between 10 Hz and 1000 Hz, preferably between 50 Hz and 500 Hz and optimally between 100 Hz and 300 Hz, such as about 240 Hz. The frequency response of the Pacinian corpuscles is further discussed in connection with Figures 5 and 6.

[0035] It should be understood that, while "tactile" is frequently defined as relating to a sensation of touch or pressure, the electrosensory interface according to the present CEI, when properly dimensioned, is capable of creating a sensation of vibration to a body member even when the body member 120 does not actually touch the insulator 108 overlaying the electrode 106. This means that unless the electrode 106 and/or insulator 108 are very rigid, the pulsating Coulomb forces between the electrode 106 and body member 120 (particularly the Pacinian corpuscles 122) may cause some slight mechanical vibration of the electrode 106 and/or insulator 108, but the method and apparatus according to the CEI are capable of producing the electrosensory sensation independently of such mechanical vibration.

[0036] The high-voltage amplifier and the capacitive coupling over the insulator 108 are dimensioned such that the Pacinian corpuscles or other mechanoreceptors are stimulated and an electrosensory sensation (a sensation of apparent vibration) is produced. For this, the

high-voltage amplifier 100 must be capable of generating an output of several hundred volts or even several kilovolts. In practice, the alternating current driven into the body member 120 has a very small magnitude and can be further reduced by using a low-frequency alternating current.

[0037] Figure 2 illustrates an apparatus which implements an illustrative embodiment of the present CEI. In this embodiment the high-voltage amplifier 100 is implemented as a current amplifier 102 followed by a high-voltage transformer 104. In the embodiment shown in Figure 2, the secondary winding of the high-voltage transformer 104 is in a more or less flying configuration with respect to the remainder of the apparatus. The amplifier 100, 102 is driven with a modulated signal whose components are denoted by 112 and 114. The output of the high-voltage amplifier 100 is coupled to an electrode 106 which is insulated against galvanic contact by the insulator 108. Reference numeral 120 generally denotes a member to be stimulated, such as a human finger. Human skin, which is denoted by reference numeral 121, is a relatively good insulator when dry, but the CEI provides a relatively good capacitive coupling between the electrode 106 and the electrically conductive tissue underneath the skin surface 121. Mechanoreceptors, such as the Pacinian corpuscles 122, reside in this conductive tissue. In Figures 1 and 2, the Pacinian corpuscles 122 are shown schematically and greatly magnified.

[0038] A benefit of the capacitive coupling between the electrode 106 and the electrically conductive tissue underneath the skin surface, which is known as the Corneus Layer and which contains the Pacinian corpuscles 122, is that the capacitive coupling eliminates high local current densities to finger tissue, which would result from contact that is conductive at direct current.

[0039] It is beneficial, although not strictly necessary, to provide a grounding connection which helps to bring the subject to be stimulated, such as the user of the apparatus, closer to a well-defined (non-floating) potential with respect to the high-voltage section of the apparatus. In the embodiment shown in Figure 2, the grounding connection, denoted by reference numeral 210, connects a reference point REF of the high-voltage section to a body part 222 which is different from the body part(s) 120 to be stimulated. In the embodiment shown in Figure 2, the reference point REF is at one end of the secondary winding of the transformer 104, while the drive voltage for the electrode(s) 206A, 206B, 206C is obtained from the opposite end of the secondary winding.

[0040] In an illustrative implementation, the apparatus is a hand-held device which comprises a touch display activated by finger(s) 120. The grounding connection 210 terminates at a grounding electrode 212. An illustrative implementation of the grounding electrode 212 is one or more ground plates which are arranged such that they are conveniently touched one hand 222 of the user while the apparatus is manipulated by the other hand. The ground plate(s) may be positioned on the same side of

the apparatus with the touch display and next to the touch display, or it/they may be positioned on adjacent or opposite side(s) from the side which comprises the touch display, depending on ergonomic considerations, for example.

[0041] In real-world apparatuses, the coupling 210 between the reference point REF and the non-stimulated body part 222 may be electrically complex. In addition, hand-held apparatuses typically lack a solid reference potential with respect to the surroundings. Accordingly, the term "grounding connection" does not require a connection to a solid-earth ground. Instead the grounding connection means any connection which helps to decrease the potential difference between the reference potential of the apparatus and a second body member distinct from the body member(s) to be stimulated. This definition does not rule out any capacitive parallel or stray elements, so long as the grounding connection 210 helps bring the user of the apparatus, along with the non-stimulated body part 222, to a potential which is reasonably well defined with respect to the high-voltage section of the apparatus. A capacitive grounding connection will be discussed in connection with Figure 12. In the present context, the reasonably well-defined potential should be understood in view of the voltage OUT which drives the electrode(s) 206A, 206B, 206C. If the electrode drive voltage OUT is, say, 1000 V, a potential difference of, say, 100 V, between the user's body and the reference point REF may not be significant.

[0042] The non-capacitive coupling 210 between the reference point REF of the high-voltage section and the non-stimulated body part 222 greatly enhances the electro-sensory stimulus experienced by the stimulated body part 120. Conversely, an equivalent electro-sensory stimulus can be achieved with a much lower voltage and/or over a thicker insulator when the non-capacitive coupling 210 is being used.

[0043] The amplifier 100, 102 is driven with a high-frequency signal 112 which is modulated by a low-frequency signal 114 in a modulator 110. The frequency of the low-frequency signal 114 is such that the Pacinian corpuscles, which reside in the electrically conductive tissue underneath the skin surface, are responsive to that frequency. The frequency of the high-frequency signal 112 is preferably slightly above the hearing ability of humans, such as 18 to 25 kHz, more preferably between about 19 and 22 kHz. If the frequency of the signal 112 is within the audible range of humans, the apparatus and/or its drive circuit may produce distracting sounds. On the other hand, if the frequency of the signal 112 is far above the audible range of humans, the apparatus drives more current into the member 120. A frequency of about 20 kHz is advantageous in the sense that components designed for audio circuits can generally be used, while the 20 kHz frequency is inaudible to most humans. Experiments carried out by the inventors suggest that such modulation is not essential for the CEI. Use of a high-frequency signal with low-frequency mod-

ulation, such as the one schematically shown in Figure 2, as opposed to a system which relies on the low-frequency signal alone, provides the benefit that the relatively high alternating voltage (a few hundred volts or a few kilovolts) can be generated with a relatively small transformer 104.

[0044] Terms like frequency or kHz should not be understood such that the high- or low-frequency signals 112, 114 are restricted to sinusoidal signals, and many other waveforms can be used, including square waves. The electrical components, such as the modulator 110, amplifier 102 and/or transformer 104 can be dimensioned such that harmonic overtones are suppressed. The inventors have discovered that pulses with durations of 4 ms (approximately one half-cycle of the low-frequency signal) or longer can be readily detected and with a practical insulator thickness the peak-to-peak voltage in the electrode 106 needs to be at least about 750 V. Unloaded peak-to-peak voltage measured in the electrode 106 should be in the range of approximately 750 V - 100 kV. Near the lower limit of this voltage range, the insulator thickness may be 0.05 - 1 mm, for example. As material technology and nanotechnology develop, even thinner durable insulating surfaces may become available. This may also permit a reduction of the voltages used.

[0045] The elements of Figures 1 and 2 described so far produce a steady-state electrosensory sensation as long as the body member, such as the finger 120, is in the vicinity of the electrode 106. In order to convey useful information, the electrosensory sensation must be modulated. In some simple embodiments, such modulation can be implemented by positioning the electrode 106 such that useful information is conveyed by the fact that the finger 120 can sense the presence of the electrode 106. For example, the electrode 106 can be positioned over a switch, or in the vicinity of it, such that the switch can be detected without having to see it.

[0046] In other embodiments, such information-carrying modulation can be provided by electronically controlling one or more operating parameters of the inventive apparatus. The information-carrying modulation should not be confused with the modulation of the high-frequency signal 112 by the low-frequency signal 114, the purpose of which is to reduce the size of the transformer 104. In the schematic drawing shown in Figure 2, such information-carrying modulation is provided by controller 116, which controls one or more of the operating parameters of the inventive apparatus. For instance, the controller 116 may enable, disable or alter the frequency or amplitude of the high- or low-frequency signals 112, 114, the gain of the amplifier 102, or it may controllably enable or disable the power supply (not shown separately) or controllably break the circuit at any point.

[0047] Figure 3 shows an enhanced embodiment of the inventive apparatus with multiple independently-controllable electrodes. In Figure 3, elements with reference numerals less than 200 have been described in connection with Figures 1 and 2, and a repeated description is

omitted. This embodiment comprises multiple independently-controllable electrodes 206A, 206B and 206C, of which three are shown but this number is purely arbitrary. Reference numeral 216 denotes an implementation of a controller which controls a switch matrix 217 which provides the high-voltage signal OUT to the electrodes 206A, 206B and 206C under control of the controller 216. The controller 216 may be responsive to commands from an external device, such as a data processing equipment (not shown separately).

[0048] A benefit of the embodiment shown in Figure 3 is that virtually all the drive circuitry, including the high-voltage amplifier 100, controller 216, and switch matrix 217, can be integrated into a common enclosure which is denoted by reference numeral 200. In this embodiment only the electrodes 206A, 206B and 206C and a single connecting wire for each electrode are outside the enclosure 200. As stated earlier, the electrodes need to be nothing more than simple conducting or semi-conducting plates covered by appropriate insulators. Therefore the enclosure 200 can be positioned in virtually any convenient position because the only elements external to it are very simple electrodes and connecting wires (and, in some implementations a power supply, not shown separately).

[0049] Some prior art systems provide direct stimulation of nerves via galvanic current conduction to the outermost layer of the skin. Because of the galvanic current conduction, such systems require two electrodes to stimulate an area of skin. In contrast to such prior art systems, the embodiment described in connection with Figure 3 involves multiple electrodes 206A, 206B and 206C, but each electrode alone stimulates a distinct area of skin, or more precisely, the mechanoreceptors, including the Pacinian corpuscles underlying the outermost layers of skin. Therefore a configuration of n electrodes conveys n bits of information in parallel.

[0050] Figure 4 shows a specific implementation of the embodiment shown in Figure 3. In this implementation the switch matrix 217 comprises a bank of triacs 207A, 207B and 207C, but other types of semiconductor switches can be used, including semiconductor relays. Conventional electromechanical relays can be used as well. In this embodiment the switches (triacs) 207A, 207B and 207C are positioned logically after the transformer 104, ie, in the high-voltage circuitry. This implementation requires high-voltage switches (several hundred volts or several kilovolts) but it provides the benefit that the remainder of the circuitry, including the elements 100 through 114, can serve all of the electrodes 206A, 206B and 206C. As shown in Figure 4, the controller 216 may be connectable to a data processing equipment, an example of which is shown here as a personal computer PC.

[0051] Figure 5 is a graph which schematically illustrates the sensitivity of a randomly selected test subject to sensations produced by an apparatus substantially similar to the one shown in Figure 2. The x-axis of the graph shows frequency of the low-frequency signal (item

114 in Figure 2) multiplied by two, while the y-axis shows the amplitude required to detect an electrosensory stimulation. The amplitude scale is relative. The small dip at 75 Hz may be a measurement anomaly. The reason for placing the doubled low-frequency signal on the x-axis is that the Coulomb forces between the electrode 106 and the body member 120 have two intensity peaks for each cycle of a sinusoidal low-frequency signal, as will be schematically illustrated in connection with Figure 6.

[0052] The relative sensitivity at various frequencies is remarkably similar to the one published in section 2.3.1 (figure 2.2) of Reference document 1. Reference document 1 relates to vibrotactile (mechanical) stimulation of skin, but the similarity of the frequency response shown in Figure 5 to the one published in Reference 1 suggests that the present CEI operates such that the electrode 106 and the sensitive member 120 (see Figure 1) form a capacitor over the insulator 108, and in that capacitor the oscillating Coulomb forces are converted to mechanical vibrations which are sensed by mechanoreceptors, including the Pacinian corpuscles. The inventors have also studied an alternative hypothesis wherein the Pacinian corpuscles are stimulated by current flowing through them, but this hypothesis does not explain the observations as well as the one which is based on Coulomb forces acting on the Pacinian corpuscles. However, the technical CEI described herein does not depend on the correctness of any particular hypothesis attempting to explain why the CEI operates the way it does.

[0053] Figure 6 is a graph which further clarifies the operating principle of the CEI and the interpretation of frequencies in connection with the present CEI. Reference numeral 61 denotes the low-frequency input signal to the modulator 110 (shown as item 114 in Figure 2). Reference numeral 62 denotes the output of the modulator, ie, the high-frequency input signal as modulated by the low-frequency input signal.

[0054] Reference numerals 63 and 64 denote the resulting Coulomb forces in the capacitive coupling between the electrode 106 and the body member 120 over the insulator 108. Because the two sides of the capacitive coupling have opposite charges, the Coulomb force between the two sides is always attractive and proportional to the square of the voltage. Reference numeral 63 denotes the actual Coulomb force while reference numeral 64 denotes its envelope. The envelope 64 is within the range of frequencies to which the Pacinian corpuscles are sensitive, but because the Coulomb force is always attractive, the envelope 64 has two peaks for each cycle of the modulator output signal 62, whereby a frequency-doubling effect is produced. Because the Coulomb force is proportional to the square of the voltage, any exemplary voltages disclosed herein should be interpreted as effective (RMS) values in case the voltages are not sinusoidal.

[0055] The statement that the two sides of the capacitive coupling have opposite charges whereby the Coulomb force is always attractive holds for a case in which

the apparatus and the body member to be stimulated are at or near the same potential. High static charges can cause deviations from this ideal state of affairs, which is why some form of grounding connection between a reference potential of the high-voltage source and the body element other than the one(s) to be stimulated is recommended, as the grounding connection helps to lower the potential differences between the apparatus and its user.

[0056] The CEI can be implemented as part of an input/output peripheral device which is connectable to a data processing equipment. In such a configuration the data processing equipment can provide prompting and/or feedback via electrically-controllable electrosensory sensation.

[0057] Figures 7A and 7B show implementations of the CEI wherein the strength of the capacitive coupling is adjusted by electrode movement. Generation of the electric field, and its variation as necessary, is effected via a set of electrodes 704 which comprises individual electrodes 703. The individual electrodes 703 are preferably individually controllable, wherein the controlling of an electrode affects its orientation and/or protrusion. Figure 7A shows an implementation wherein a group of electrodes 703 are oriented, via the output signal from the controller 216, such that the electrodes 703 collectively form a plane under the insulator 702. In this situation the high-voltage current (DC or AC) from the high-voltage amplifier 100 to the electrodes 703 generates an opposite-signed charge of sufficient strength to a body member (eg the finger 120) in close proximity to the apparatus. A capacitive coupling between the body member and the apparatus is formed over the insulator 702, which may give rise to a sensory stimulus.

[0058] Figure 7B shows the same apparatus shown in Figure 7A, but in this case the strength of the capacitive coupling generated with the current from the high-voltage amplifier 100 is minimized by orienting the electrodes (now shown by reference numeral 714) such that they do not form a plane under the insulator 702. In some implementations of the present invention, the electric field alternating with a low frequency can be generated by alternating the state of the apparatus between the two states shown in Figures 7A and 7B. The frequency of the state alternation can be in the order of several hundred, eg 200 to 300 full cycles per second.

[0059] Figure 8 shows an implementation of the CEI wherein the individual electrodes 803 in the set of electrodes 804 may have charges of opposite signs. The charges of individual electrodes 803 may be adjusted and controlled via the controller 216. The individual electrodes 803 may be separated by insulator elements 806, so as to prevent sparking or shorting between the electrodes. The capacitive coupling between the CEI and the body member proximate to it may give rise to areas having charges with opposite signs 801. Such opposing charges are mutually attractive to one another. Hence it is possible that Coulomb forces stimulating the Pacinian corpuscles may be generated not only between the CEI

and the body member but between infinitesimal areas within the body member itself.

[0060] Figure 9 shows an implementation of the CEI wherein a group of individually controllable electrodes 910a through 910i are organized in the form of a matrix. Such a matrix can be integrated into a touch screen device, for example. Since the CEI described above does not require direct connection (touching) between the CEI and a body member of its user, the electrodes of the CEI apparatus can be positioned behind the touch screen, wherein "behind" means the side of the touch screen opposite to the side facing the user during normal operation. Alternatively, the electrodes can be very thin and/or transparent, whereby the electrodes can overlay the touch screen on the side normally facing the user. The electric charges, which are conducted from the high-voltage amplifier 100 to the electrodes 910a through 910i via the switch array 217, may all have similar signs or the charges conducted to different electrodes may have different signs, as illustrated in connection with Figure 8. For instance, the controller 216 may control the switches in the switch array individually, or certain groups may form commonly-controllable groups. The surface of an individual electrode and/or its associated insulator can be specified according to the intended range of operations or applications. The minimum practical area is about 0.01 cm², while the practical maximum is roughly equal to the size of a human hand. It is expected that surface areas between 0.1 and 1 cm² will be found most usable in practice.

[0061] The matrix of electrodes 910a through 910i and the switch array 217 provide a spatial variation of the electro-sensory stimulation. In other words, the sensory stimulation provided to the user depends on the location of the user's body member, such as a finger, proximate to the CEI apparatus which is integrated to the inventive touch screen. The spatially varying sensory stimulation provides the user with an indication of the layout of the touch-sensitive areas of the touch screen interface.

[0062] In addition to the spatially varying sensory stimulation, the controller 216 may direct the switch array 217 to produce a temporally varying (time-dependent) electro-sensory stimulation, which can be used for a wide variety of useful effects. For instance, the temporally varying electro-sensory stimulation can be used to indicate a detected activation of a touch-sensitive area ("key press"). This embodiment address a common problem associated with prior art touch screen devices, namely the fact that a detection of a key press produces no tactile feedback. Prior art application-level programs used via touch screen devices may provide visual or aural feedback, but such types of feedback exhibit the various problems described earlier. In addition, production of the visual or aural feedback from the application-level program causes a burden on the programming and execution of those programs. In some implementations of the invention, an interface-level or driver-level program provides a tactile feedback from a detected activation of a touch-

sensitive area by using the temporally and spatially variant electro-sensory stimulation, and such interface-level or driver-level programs can be used by any application-level programs. For example, the application-level programs can be coupled to the inventive touch screen interface via an application programming interface ("API") whose set of available functions includes the feedback generation described above.

[0063] The temporally and spatially variant electro-sensory stimulation can also be used to change the layout of the touch-sensitive areas "on the fly". In hindsight, this operation may be considered roughly analogous to changing the keyboard or keypad layout depending on the application program or user interface screen currently executed. However, when prior art touch screen devices change keyboard or keypad layout on the fly, the new layout must be somehow indicated to the user, and this normally requires that the user sees the touch screen device.

[0064] Some embodiments of the inventive touch screen device eliminate the need to see the touch screen device, assuming that the layout of the touch-sensitive areas is sufficiently simple. For instance, up to about two dozen different "key legends" can be indicated to the user by providing different patterns for the temporally and spatially variant electro-sensory stimulation. As used herein, the expression "key legend" refers to the fact that prior art touch screen devices, which produce no tactile feedback, normally produce visual cues, and these are commonly called "legends". In some embodiments of the present invention, the function of the key legends can be provided via different patterns. For instance, the following patterns can be identified with one fingertip: pulses with low, medium or high repetition rate; sweeps to left, right, up or down, each with a few different repetition rates; rotations clockwise or anticlockwise, each with a few different repetition rates.

[0065] From the above, it is evident that the inventive electro-sensory interface can produce a large number of different touch-sensitive areas, each with a distinct "feel" (technically: a different pattern for the temporal and spatial variation of the electro-sensory stimulus). Hence the screen section of a conventional touch screen is not absolutely needed in connection with the present invention, and the term touch device interface should be interpreted as an interface device which, among other things, is suitable for applications commonly associated with touch screen devices, although the presence of the screen is not mandatory.

[0066] Moreover, the strength of the capacitive coupling between the inventive CEI and a body member of its user (or the capacitive coupling between an individual electrode or a group of electrodes and the user's body member) can be determined by direct or indirect measurements. This measurement information can be utilized in various ways. For instance, the strength of the capacitive coupling can indicate the body member's proximity to the electrode, or it can indicate touching the electrode

by the body member. Such measurement functionality can be provided by a dedicated measurement unit (not shown) or it can be integrated into one of the blocks described earlier, such as the switch matrix 217. The switch matrix 217 (or the optional dedicated measurement unit) can send the measurement information to the controller 216 which can utilize it to vary the electric fields generated by the electrodes, by varying the voltage or frequency. In addition or alternatively the controller 216 may forward the measurement information, or some information processed from it, to a data processing equipment, such as the personal computer PC shown in Figure 4.

[0067] Yet further two or more inventive touch device interfaces can be interconnected via some communication network(s) and data processing equipment. In such an arrangement, the electro-sensory stimulation provided to the users of the touch screen devices may be based on some function of all users' contribution to the proximity to their respective devices. In one illustrative example, such an interconnection of two (or more) touch screen devices can provide their users with tactile feedback whose strength depends on the sum of the areas of hands touch the touch-sensitive areas. This technique simulates a handshake whose strength reflects the sum of hand pressure exerted by both (or all) users. In another illustrative example, a music teacher might "sense" how a remotely located student presses the keys of a simulated piano keyboard.

[0068] Figures 10 through 13 are equivalent circuits (theoretical models) which may be useful in dimensioning the parameters of the capacitive coupling. Figure 10 illustrates distribution of an electric field-generating potential in capacitive couplings when the apparatus is grounded. The underlying theory is omitted here, and it suffices to say that in the arrangement shown in Figure 10, the drive voltage e of an electrode is divided based on the ratio of capacitances C_1 and C_2 , wherein C_1 is the capacitance between the finger and the electrode and C_2 is the stray capacitance of the user. The electric field experienced by the finger is caused by voltage U_1 :

$$U_1 = \frac{C_2}{C_1 + C_2} e$$

[0069] This voltage is lower than the drive voltage e from the voltage source. In a general case the reference potential of the apparatus may be floating, as will be shown in Figure 11. This arrangement further decreases the electric field directed to the body member, such as finger.

[0070] For these reasons some embodiments of the invention aim at keeping the capacitance C_1 low in comparison to that of C_2 . At least capacitance C_1 should not be significantly higher than C_2 . Some embodiments aim at adjusting or controlling C_2 , for instance by coupling the reference potential of the apparatus back to the user, as shown in Figure 12.

[0071] Further analysis of the actual value of capacitance C_1 shows that it can be treated as a capacitance consisting of three series-coupled partial capacitances: C_i of the insulator material, C_a of the air gap between insulator and finger, and C_s formed by the outmost skin layer that is electrically insulating the inner, conducting tissue from the environment. Each partial capacitance is given by:

$$C = \epsilon \frac{S}{d}$$

[0072] Herein, ϵ is the permittivity (dielectric constant) of the insulating material, S is the (effective) surface area and d is the distance between the surfaces of the capacitor. In a series arrangement of capacitances, the smallest one of the individual capacitances dominates the overall value of the total capacitance C_1 . When the body member does not touch the surface of the insulated electrode but only approaches it, the capacitive coupling is weak. Thus the value of C_1 is small and mainly determined by the air gap, C_a . When the body member touches the surface, the effective air gap is small (approximately the height ridges of the fingerprint profile on the skin surface). As capacitance is inversely proportional to the distance of the conducting surfaces forming the capacitor, corresponding C_a obtains a high value, and the value of C_1 is determined by C_i and C_s . Thus the effectiveness of the electro-sensory stimulus generation can be enhanced by appropriate selection of insulator material, particularly in terms of thickness and dielectric properties. For instance, selecting a material with a relatively high dielectric constant for the insulator reduces the electric field in the material but increases the electric field strength in the air gap and skin.

[0073] Furthermore, in applications where the surface is likely to be touched while the electro-sensory stimulation or response is given, the effectiveness of the electro-sensory stimulus generation can be enhanced by optimal selection of the material that will be touched by the body member. This is particularly significant in connection with insulators which are good volume insulators (insulators in the direction of the surface's normal) but less so in the direction along the surface.

[0074] An insulator's insulation capability along the surface may be negatively affected by surface impurities or moisture which have a negative effect on the apparent strength of the sensation felt by the body member to be stimulated. For instance, glass is generally considered a good insulator, but its surface tends to collect a thin sheet of moisture from the air. If the electrode of the CEI is insulated with glass, the electro-sensory effect is felt in close proximity (when there is still an air gap between body member and the glass surface). However, when the glass surface is touched, even lightly, the electro-sensory tends to weaken or disappear altogether. Coating the outer insulating surface with a material having a

low surface conductance remedies such problems. The inventors speculate that if the surface having some surface conductivity is touched, it is the conductive layer on the surface that experiences the coulomb force rather than the body member touching the surface. Instead the touching body member acts as a kind of grounding for the conductive surface layer, for example via the stray capacitance of the body.

[0075] Instead of the measures described in connection with Figures 10 through 12, or in addition to such measures, stray capacitances can be controlled by arrangements in which several electrodes are used to generate potential differences among different areas of the touch screen surface. By way of example, this technique can be implemented by arranging the touch-sensitive surface of a hand-held device (eg the top side of the device) to a first potential, while the opposite side is arranged to a second potential, wherein the two different potentials can be the positive and negative poles of the device. Alternatively, a first surface area can be the electric ground (reference potential), while a second surface area is charged to a high potential.

[0076] Moreover, within the constraints imposed by the insulator layer(s), it is possible to form minuscule areas of different potentials, such as potentials with opposite signs or widely different magnitudes, wherein the areas are small enough that the user's body member, such as finger, is simultaneously subjected to the electric fields from several areas with different potentials.

[0077] Figure 13 shows an embodiment in which the capacitive coupling is utilized to detect touching or approaching by the user's body member, such as finger. A detected touching or approaching by the user's body member can be passed as an input to a data processing device. In the embodiment shown in Figure 13, the voltage source is floating. A floating voltage source can be implemented, via inductive or capacitive coupling and/or with break-before-make switches. A secondary winding of a transformer is an example of a simple yet effective floating voltage source. By measuring the voltage U_4 , it is possible to detect a change in the value(s) of capacitance(s) C_1 and/or C_2 . Assuming that the floating voltage source is a secondary winding of a transformer, the change in capacitance(s) can be detected on the primary side as well, for example as a change in load impedance. Such a change in capacitance(s) serves as an indication of a touching or approaching body member.

[0078] In one implementation, the apparatus is arranged to utilize such indication of the touching or approaching body member such that the apparatus uses a first (lower) voltage to detect the touching or approaching by the body member and a second (higher) voltage to provide feedback to the user. For instance, such feedback can indicate any of the following: the outline of the/each touch-sensitive area, a detection of the touching or approaching body member by the apparatus, the significance of (the act to be initiated by) the touch-sensitive area, or any other information processed by the applica-

tion program and which is potentially useful to the user.

[0079] Figure 14 schematically illustrates an embodiment in which a single electrode and temporal variations in the intensity of the electro-sensory stimulus can be used to create illusions of a textured touch screen surface. Reference numeral 1400 denotes a touch-sensitive screen which, for the purposes of describing the present embodiment, comprises three touch-sensitive areas A_1 , A_2 and A_3 . The approaching or touching by the touch-sensitive areas A_1 , A_2 and A_3 of a user's finger 120 is detected by a controller 1406.

[0080] According to an embodiment of the invention, a conventional touch-sensitive screen 1400 can be complemented by an interface device according to the invention. Reference numeral 1404 denotes an electrode which is an implementation of the electrodes described in connection with previously-described embodiments, such as the electrode 106 described in connection with Figures 1 and 2. A supplemental insulator 1402 may be positioned between the touch-sensitive screen 1400 and the inventive electrode 1404, in case the touch-sensitive screen 1400 itself fails to provide sufficient insulation.

[0081] In addition to conventional touch-screen functionality, namely detection of approaching or touching by the touch-sensitive areas by the user's finger, the controller 1406 uses information of the position of the finger 120 to temporally vary the intensity of the electro-sensory stimulation invoked by the electrode 1404 on the finger 120. Although the intensity of the electro-sensory stimulation is varied over time, time is not an independent variable in the present embodiment. Instead, timing of the temporal variations is a function of the position of the finger 120 relative to the touch-sensitive areas (here: A_1 , A_2 and A_3). Thus it is more accurate to say that the present embodiment is operable to cause variations in the intensity of the electro-sensory stimulation invoked by the electrode 1404 on the finger 120, wherein the variations are based on the position of the finger 120 relative to the touch-sensitive areas.

[0082] The bottom side of Figure 14 illustrates this functionality. The three touch-sensitive area A_1 , A_2 and A_3 are demarcated by respective x coordinate pairs $\{x_1, x_2\}$, $\{x_3, x_4\}$ and $\{x_5, x_7\}$. Processing in the y direction is analogous and a detailed description is omitted. The controller 1406 does not sense the presence of the finger, or senses the finger as inactive, as long as the finger is to the left of any of the touch-sensitive areas A_1 , A_2 and A_3 . In this example the controller 1406 responds by applying a low-intensity signal to the electrode 1404. As soon as the finger 120 crosses the x coordinate value x_1 , the controller 1406 detects the finger over the first touch-sensitive area A_1 and starts to apply a medium-intensity signal to the electrode 1404. Between the areas A_1 and A_2 (between x coordinates x_2 and x_3), the controller again applies a low-intensity signal to the electrode 1404. The second touch-sensitive area A_2 is processed similarly to the first touch-sensitive area A_1 , but the third touch-sensitive area A_3 is processed somewhat differently. As soon

as the controller 1406 detects the finger 120 above or in close proximity to the area A_3 , it begins to apply the medium-intensity signal to the electrode 1404, similarly to areas A_1 and A_2 . But the user decides to press the touch screen 1400 at a point x_6 within the third area A_3 . The controller 1406 detects the finger press (activation of the function assigned to the area A_3) and responds by applying a high-intensity signal to the electrode 1404.

[0083] Thus the embodiment shown in Figure 14 can provide the user with a tactile feedback which creates an illusion of a textures surface, although only a single electrode 1404 was used to create the electro-sensory stimulus. A residual problem is, however, that the user has to memorize the significance of the several touch-sensitive areas or obtain visual or aural information on their significance.

[0084] Figure 15 shows a further enhanced embodiment from the one described in connection with Figure 14. The embodiment shown in Figure 15 uses different temporal variations of the intensity of the electro-sensory stimulus, wherein the different temporal variations provide the user with a tactile feedback indicating the significance of the touch-sensitive areas.

[0085] The operation of the embodiment shown in Figure 14 differs from the one described in connection with Figure 14 in that the controller, here denoted by reference numeral 1506, applies different temporal variations to the intensity of the signal to the electrode 1404. In this example, the first touch-sensitive area A_1 is processed similarly to the preceding embodiment, or in other words, the intensity of the electro-sensory stimulus depends only on the presence of the finger 120 in close proximity to the area A_1 . But in close proximity to areas A_2 and A_3 , the controller 1506 also applies temporal variations to the intensity of the electro-sensory stimulus. For example the significance (coarsely analogous with a displayed legend) of area A_2 is indicated by a pulsed electro-sensory stimulus at a first (low) repetition rate, while the significance of area A_3 is indicated by a pulsed electro-sensory stimulus at a second (higher) repetition rate. In an illustrative example, the three touch-sensitive areas A_1 , A_2 and A_3 can invoke the three functions in a yes/no/cancel-type user interface, wherein the user can sense the positions of the user interface keys (here: the three touch-sensitive areas) and the indication of an accepted input only via tactile feedback. In other words, the user needs no visual or aural information on the positions of the touch-sensitive areas or on the selected function. The embodiment described in connection with Figure 15 is particularly attractive in car navigators or the like, which should not require visual attention from their users.

[0086] In the embodiments shown in Figures 14 and 15, when the user's finger 120 has selected the function assigned to area A_3 and the controller CTRL 1406, 1506 generates the high-intensity electro-sensory stimulus via the electrode 1404, the high-intensity stimulus is sensed via any of the areas A_1 , A_2 and A_3 . In other words, if one finger of the user presses the area A_3 , other finger(s) in

close proximity to the other areas A_2 and/or A_3 will also sense the high-intensity stimulus. In cases where this is not desirable, the embodiments shown in Figures 14 and 15 can be combined with the multi-electrode embodiment disclosed in connection with Figure 9, such that the signal to each of several electrodes (shown in Figure 9 as items 910a through 910i) is controlled individually.

[0087] It is readily apparent to a person skilled in the art that, as the technology advances, the inventive concept can be implemented in various ways. The invention and its embodiments are not limited to the examples described above but may vary within the scope of the claims.

References

[0088]

1. Gunther, Eric: "Skinscape: A Tool for Composition in the Tactile Modality" Master's thesis, Massachusetts Institute of Technology 2001, available on the Internet address: <http://mf.media.mit.edu/pubs/thesis/guntherMS.pdf>

Claims

1. An apparatus for producing an electrosensory sensation to at least one body part (120) to be stimulated, the apparatus comprising:
 - a touch screen surface, and
 - one or more conducting electrodes (106) overlaid on the touch screen surface, each conducting electrode being provided with an insulator (108) wherein, when the at least one body part (120) to be stimulated is proximate to the conducting electrode, the insulator prevents flow of direct current from the conducting electrode to the body part to be stimulated and a capacitive coupling over the insulator (108) is formed between the conducting electrode (106) and the at least one body part (120) to be stimulated, and wherein the one or more conducting electrodes (106) and the respective one or more insulators are transparent;
 - a high-voltage source (100, 102, 104) for applying an electrical input (OUT) to the one or more conducting electrodes, wherein the electrical input has at least a portion of its energy content in a frequency range between 10 Hz and 1000 Hz;
 - wherein the capacitive coupling and electrical input are dimensioned to produce an electrosensory sensation; and
 - whereby the electrosensory sensation is produced independently of any mechanical vibration of the one or more conducting electrodes

(106) or insulators (108);

wherein the apparatus further comprises:

- a controller (1406, 1506) configured to use position information on a position of the at least one body part (120) to temporally vary the electrosensory sensation;
- whereby the electrosensory sensation is based at least partially on the position of the at least one body part relative to the touch screen surface.

2. The apparatus according to claim 1, wherein the touch screen surface has a single conducting electrode.

3. The apparatus according to claim 1 or 2, wherein the controller (1506) is further configured to use:

- area information on a plurality of predefined areas (A1, A2, A3) on the touch screen surface;
- significance information indicating significance of the predefined areas;

whereby the electrosensory sensation is based on a detected position of the at least one body part in one of the predefined areas, and on the significance of that predefined area.

4. The apparatus according to claim 3, wherein the controller (1506) is further configured to use:

- information on a function assigned to each of the predefined areas;
- information on a detected activation of a function by the at least one body part;

whereby the electrosensory sensation depends on whether or not the at least one body part has activated a function assigned to the predefined area in which the at least one body part currently is.

5. The apparatus according to any one of the preceding claims, further comprising a grounding connection (210) between:

- a reference voltage (REF) of the high-voltage source (100, 102, 104) other than the electrical input (OUT) to the one or more conducting electrodes; and
- at least one grounding electrode (212) separate from the one or more conducting electrodes (106), wherein the grounding electrode (212) is positioned so as to be touched by a second body part (222) distinct from each of the at least one body part to be stimulated (120; 220A, 220B, 220C).

6. The apparatus according to any one of the preceding claims, wherein the apparatus comprises one conducting electrode for each spatially distinct body part to be stimulated (120; 220A, 220B, 220C).

7. The apparatus according to any one of the preceding claims, wherein the apparatus comprises one conducting electrode (206A, 206B, 206C) for each of several spatially distinct body parts to be stimulated (220A, 220B, 220C).

8. The apparatus according to any one of the preceding claims, wherein the electrical input comprises a low-frequency component (114) in a frequency range between 10 Hz and 1000 Hz and a high-frequency component (112) having a frequency which is higher than the frequency of the low-frequency component (114) and lower than 500 kHz.

9. The apparatus according to claim 8, comprising means (110) for modulating the high-frequency component (112) by the low-frequency component (114).

10. The apparatus according to any one of the preceding claims, wherein the electrical input to the one or more conducting electrodes (106) has a peak-to-peak voltage of 750 to 100,000 Volts.

11. The apparatus according to any one of the preceding claims, wherein the insulator has a thickness between 0.1 mm and 50 mm.

12. The apparatus according to any one of the preceding claims, wherein at least one insulator comprises a first layer and a second layer such that the first layer is closer to the conducting electrode than the second layer, and wherein the second layer has a lower surface conductivity than the first layer.

13. A method for causing an electrosensory sensation to at least one body part (120) to be stimulated, the method comprising:

- providing a touch screen surface with one or more conducting electrodes (106), each conducting electrode being provided with an insulator (108) wherein, when the at least one body part (120) to be stimulated is proximate to the conducting electrode, the insulator prevents flow of direct current from the conducting electrode to the body part to be stimulated and a capacitive coupling over the insulator (108) is formed between the conducting electrode (106) and the body part (120) to be stimulated, and wherein the one or more conducting electrodes (106) and the respective one or more insulators are transparent;
- providing a high-voltage source (100, 102, 104)

for applying an electrical input (OUT) to the one or more conducting electrodes, wherein the electrical input has at least a portion of its energy content in a frequency range between 10 Hz and 1000 Hz;

- wherein the capacitive coupling and electrical input are dimensioned to produce an electrosensory sensation; and
- whereby the electrosensory sensation is produced independently of any mechanical vibration of the one or more conducting electrodes (106) or insulators (108);

wherein the method further comprises:

- using position information on a position of the at least one body part (120) to temporally vary the electrosensory sensation;
- whereby the electrosensory sensation is based at least partially on the position of the at least one body part relative to the touch screen surface.

Patentansprüche

1. Vorrichtung zum Hervorrufen einer elektrosensorischen Empfindung für mindestens einen zu stimulierenden Körperteil (120), wobei die Vorrichtung umfasst:

- eine Berührungsbildschirm-Oberfläche, und
- eine oder mehrere leitende Elektroden (106), die auf der Berührungsbildschirm-Oberfläche überlagert sind, wobei jede leitende Elektrode mit einem Isolator (108) versehen ist, wobei, wenn sich der mindestens eine zu stimulierende Körperteil (120) in der Nähe der leitenden Elektrode befindet, der Isolator den Fluss von Gleichstrom von der leitenden Elektrode zu dem zu stimulierenden Körperteil verhindert, und eine kapazitive Kopplung über den Isolator (108) zwischen der leitenden Elektrode (106) und dem mindestens einen zu stimulierenden Körperteil (120) gebildet wird, und wobei die eine oder die mehreren leitenden Elektroden (106) und der jeweils eine oder die mehreren Isolatoren transparent sind;
- eine Hochspannungsquelle (100, 102, 104) zum Anlegen eines elektrischen Eingangs (OUT) an die eine oder die mehreren leitenden Elektroden, wobei der elektrische Eingang mindestens einen Teil seines Energieinhalts in einem Frequenzbereich zwischen 10 Hz und 1000 Hz aufweist;
- wobei die kapazitive Kopplung und der elektrische Eingang so bemessen sind, dass sie eine elektrosensorische Empfindung hervorrufen;

und

- wodurch die elektrosensorische Empfindung unabhängig von einer mechanischen Vibration der einen oder der mehreren leitenden Elektroden (106) oder Isolatoren (108) hervorgerufen wird;

wobei die Vorrichtung ferner umfasst:

- eine Steuerung (1406, 1506), die konfiguriert ist, um Positionsinformation zu einer Position des mindestens einen Körperteils (120) zu verwenden, um die elektrosensorische Empfindung zeitlich zu variieren;
- wodurch die elektrosensorische Empfindung mindestens teilweise auf der Position des mindestens einen Körperteils im Verhältnis zur Berührungsbildschirm-Oberfläche basiert.

2. Vorrichtung nach Anspruch 1, wobei die Berührungsbildschirm-Oberfläche eine einzelne leitende Elektrode aufweist.

3. Vorrichtung nach Anspruch 1 oder 2, wobei die Steuerung (1506) ferner konfiguriert ist zum Verwenden von:

- Bereichsinformation von mehreren im Voraus definierten Bereichen (A1, A2, A3) auf der Berührungsbildschirm-Oberfläche;
- Signifikanzinformation, die die Signifikanz der im Voraus definierten Bereiche angibt;

wodurch die elektrosensorische Empfindung auf einer erfassten Position des mindestens einen Körperteils in einem der im Voraus definierten Bereiche und auf der Signifikanz dieses im Voraus definierten Bereichs basiert.

4. Vorrichtung nach Anspruch 3, wobei die Steuerung (1506) ferner konfiguriert ist zum Verwenden von:

- Information über eine Funktion, die jedem der im Voraus definierten Bereiche zugewiesen ist;
- Information über eine erfasste Aktivierung einer Funktion durch den mindestens einen Körperteil;

wodurch die elektrosensorische Empfindung davon abhängt, ob der mindestens eine Körperteil eine dem im Voraus definierten Bereich zugeordnete Funktion aktiviert hat oder nicht, in der sich der mindestens eine Körperteil gegenwärtig befindet.

5. Vorrichtung nach einem der vorhergehenden Ansprüche, ferner umfassend eine Erdungsverbindung (210) zwischen:

- einer anderen Referenzspannung (REF) der Hochspannungsquelle (100, 102, 104) als dem elektrischen Eingang (OUT) zu der einen oder den mehreren leitenden Elektroden; und
 - mindestens eine Erdungselektrode (212), die von der einen oder den mehreren leitenden Elektroden (106) getrennt ist, wobei die Erdungselektrode (212) so positioniert ist, dass sie von einem zweiten Körperteil (222) berührt wird, der sich von jedem des mindestens einen zu stimulierenden Körperteils (120; 220A, 220B, 220C) unterscheidet.
6. Vorrichtung nach einem der vorhergehenden Ansprüche, wobei die Vorrichtung eine leitende Elektrode für jeden räumlich unterschiedlichen zu stimulierenden Körperteil (120; 220A, 220B, 220C) umfasst.
 7. Vorrichtung nach einem der vorhergehenden Ansprüche, wobei die Vorrichtung eine leitende Elektrode (206A, 206B, 206C) für jeden von mehreren räumlich unterschiedlichen zu stimulierenden Körperteilen (220A, 220B, 220C) umfasst.
 8. Vorrichtung nach einem der vorhergehenden Ansprüche, wobei der elektrische Eingang eine Niederfrequenzkomponente (114) in einem Frequenzbereich zwischen 10 Hz und 1000 Hz und eine Hochfrequenzkomponente (112) mit einer Frequenz aufweist, die höher als die Frequenz der Niederfrequenzkomponente (114) und niedriger als 500 kHz ist.
 9. Vorrichtung nach Anspruch 8, umfassend eine Einrichtung (110) zum Modulieren der Hochfrequenzkomponente (112) durch die Niederfrequenzkomponente (114).
 10. Vorrichtung nach einem der vorhergehenden Ansprüche, wobei der elektrische Eingang der einen oder der mehreren leitenden Elektroden (106) eine Spitze-Spitze-Spannung von 750 bis 100.000 Volt aufweist.
 11. Vorrichtung nach einem der vorhergehenden Ansprüche, wobei der Isolator eine Dicke von zwischen 0,1 mm und 50 mm aufweist.
 12. Vorrichtung nach einem der vorhergehenden Ansprüche, wobei mindestens ein Isolator eine erste Schicht und eine zweite Schicht umfasst, wobei die erste Schicht näher an der leitenden Elektrode liegt als die zweite Schicht, und wobei die zweite Schicht eine niedrigere Oberflächenleitfähigkeit aufweist als die erste Schicht.
 13. Verfahren zum Hervorrufen einer elektrosensori-

schen Empfindung für mindestens einen zu stimulierenden Körperteil (120), wobei das Verfahren umfasst:

- Bereitstellen einer Berührungsbildschirm-Oberfläche mit einer oder mehreren leitenden Elektroden (106), wobei jede leitende Elektrode mit einem Isolator (108) versehen ist, wobei, wenn sich der mindestens eine zu stimulierende Körperteil (120) in der Nähe der leitenden Elektrode befindet, der Isolator den Fluss von Gleichstrom von der leitenden Elektrode zu dem zu stimulierenden Körperteil verhindert, und eine kapazitive Kopplung über den Isolator (108) zwischen der leitenden Elektrode (106) und dem zu stimulierenden Körperteil (120) gebildet wird, und wobei die eine oder die mehreren leitenden Elektroden (106) und der jeweils eine oder die mehreren Isolatoren transparent sind;
- Bereitstellen einer Hochspannungsquelle (100, 102, 104) zum Anlegen eines elektrischen Eingangs (OUT) an die eine oder die mehreren leitenden Elektroden, wobei der elektrische Eingang mindestens einen Teil seines Energieinhalts in einem Frequenzbereich zwischen 10 Hz und 1000 Hz aufweist;
- wobei die kapazitive Kopplung und der elektrische Eingang so bemessen sind, dass sie eine elektrosensorische Empfindung hervorrufen; und
- wodurch die elektrosensorische Empfindung unabhängig von einer mechanischen Vibration der einen oder der mehreren leitenden Elektroden (106) oder Isolatoren (108) hervorgerufen wird;

wobei das Verfahren ferner umfasst:

- Verwenden von Positionsinformation zu einer Position des mindestens einen Körperteils (120), um die elektrosensorische Empfindung zeitlich zu variieren;
- wodurch die elektrosensorische Empfindung mindestens teilweise auf der Position des mindestens einen Körperteils im Verhältnis zur Berührungsbildschirm-Oberfläche basiert.

Revendications

1. Appareil pour produire une sensation électrosensorielle sur au moins une partie corporelle (120) à stimuler, l'appareil comprenant :
 - une surface d'écran tactile, et
 - une ou plusieurs électrodes conductrices (106) disposées sur la surface d'écran tactile, chaque électrode conductrice étant pourvue d'un isolant

- (108), dans lequel, lorsque ladite au moins une partie corporelle (120) à stimuler est à proximité de l'électrode conductrice, l'isolant empêche la circulation d'un courant continu de l'électrode conductrice vers la partie corporelle à stimuler et un couplage capacitif sur l'isolant (108) est formé entre l'électrode conductrice (106) et ladite au moins une partie corporelle (120) à stimuler, et dans lequel lesdites une ou plusieurs électrodes conductrices (106) et lesdits un ou plusieurs isolants respectifs sont transparents ;
- une source haute tension (100, 102, 104) pour appliquer une entrée électrique (OUT) auxdites une ou plusieurs électrodes conductrices, dans lequel l'entrée électrique a au moins une partie de son contenu d'énergie dans une plage de fréquence entre 10 Hz et 1000 Hz ;
 - dans lequel le couplage capacitif et l'entrée électrique sont dimensionnés pour produire une sensation électrosensorielle ; et
 - moyennant quoi la sensation électrosensorielle est produite indépendamment de toute vibration mécanique desdites une ou plusieurs électrodes conductrices (106) ou des isolants (108) ;
- dans lequel l'appareil comprend en outre :
- un contrôleur (1406, 1506) configuré pour utiliser des informations de position concernant une position de ladite au moins une partie corporelle (120) pour modifier temporellement la sensation électrosensorielle ;
 - moyennant quoi la sensation électrosensorielle est basée au moins partiellement sur la position de ladite au moins une partie corporelle par rapport à la surface d'écran tactile.
2. Appareil selon la revendication 1, dans lequel la surface d'écran tactile comporte une seule électrode conductrice.
 3. Appareil selon la revendication 1 ou 2, dans lequel le contrôleur (1506) est en outre configuré pour utiliser :
 - des informations de zones concernant une pluralité de zones prédéfinies (A1, A2, A3) sur la surface d'écran tactile ;
 - des informations d'importance indiquant l'importance des zones prédéfinies ;
 moyennant quoi la sensation électrosensorielle est basée sur une position détectée de ladite au moins une partie corporelle dans l'une des zones prédéfinies, et sur l'importance de cette zone prédéfinie.
 4. Appareil selon la revendication 3, dans lequel le contrôleur (1506) est en outre configuré pour utiliser :

- des informations concernant une fonction attribuée à chacune des zones prédéfinies ;
- des informations concernant une activation détectée d'une fonction par ladite au moins une partie corporelle ;

moyennant quoi la sensation électrosensorielle dépend du fait que ladite au moins une partie corporelle a activé ou non une fonction attribuée à la zone prédéfinie dans laquelle ladite au moins une partie corporelle est actuellement.

5. Appareil selon l'une quelconque des revendications précédentes, comprenant en outre une connexion de masse (210) entre :

- une tension de référence (REF) de la source haute tension (100, 102, 104) autre que l'entrée électrique (OUT) vers lesdites une ou plusieurs électrodes conductrices ; et
- au moins une électrode de masse (212) séparée desdites une ou plusieurs électrodes conductrices (106), dans lequel l'électrode de masse (212) est positionnée de manière à être touchée par une deuxième partie corporelle (222) distincte de chacune de ladite au moins une partie corporelle à stimuler (120 ; 220A, 220B, 220C).

6. Appareil selon l'une quelconque des revendications précédentes, dans lequel l'appareil comprend une électrode conductrice pour chaque partie corporelle spatialement distincte à stimuler (120 ; 220A, 220B, 220C).

7. Appareil selon l'une quelconque des revendications précédentes, dans lequel l'appareil comprend une électrode conductrice (206A, 206B, 206C) pour chacune d'une pluralité de parties corporelles spatialement distinctes à stimuler (220A, 220B, 220C).

8. Appareil selon l'une quelconque des revendications précédentes, dans lequel l'entrée électrique comprend une composante basse fréquence (114) dans une plage de fréquence entre 10 Hz et 1000 Hz et une composante haute fréquence (112) ayant une fréquence qui est supérieure à la fréquence de la composante basse fréquence (114) et inférieure à 500 kHz.

9. Appareil selon la revendication 8, comprenant des moyens (110) pour moduler la composante haute fréquence (112) par la composante basse fréquence (114).

10. Appareil selon l'une quelconque des revendications précédentes, dans lequel l'entrée électrique vers lesdites une ou plusieurs électrodes conductrices

(106) a une tension crête à crête de 750 à 100 000 volts.

11. Appareil selon l'une quelconque des revendications précédentes, dans lequel l'isolant a une épaisseur entre 0,1 mm et 50 mm. 5

12. Appareil selon l'une quelconque des revendications précédentes, dans lequel au moins un isolant comprend une première couche et une deuxième couche de sorte que la première couche soit plus près de l'électrode conductrice que la deuxième couche, et dans lequel la deuxième couche a une conductivité de surface inférieure à celle de la première couche. 10
15

13. Procédé pour provoquer une sensation électrosensorielle dans au moins une partie corporelle (120) à stimuler, le procédé comprenant :
 - la fourniture d'une surface d'écran tactile avec une ou plusieurs électrodes conductrices (106), chaque électrode conductrice étant pourvue d'un isolant (108), dans lequel, lorsque ladite au moins une partie corporelle (120) à stimuler est à proximité de l'électrode conductrice, l'isolant empêche la circulation d'un courant continu de l'électrode conductrice vers la partie corporelle à stimuler et un couplage capacitif sur l'isolant (108) est formé entre l'électrode conductrice (106) et la partie corporelle (120) à stimuler, et dans lequel lesdites une ou plusieurs électrodes conductrices (106) et lesdits un ou plusieurs isolants respectifs sont transparents ; 20
25
30
 - la fourniture d'une source haute tension (100, 102, 104) pour appliquer une entrée électrique (OUT) auxdites une ou plusieurs électrodes conductrices, dans lequel l'entrée électrique a au moins une partie de son contenu d'énergie dans une plage de fréquence entre 10 Hz et 1000 Hz ; 35
40
 - dans lequel le couplage capacitif et l'entrée électrique sont dimensionnés pour produire une sensation électrosensorielle ; et
 - moyennant quoi la sensation électrosensorielle est produite indépendamment de toute vibration mécanique desdites une ou plusieurs électrodes conductrices (106) ou des isolants (108) ; 45

dans lequel le procédé comprend en outre : 50

 - l'utilisation d'informations de position concernant une position de ladite au moins une partie corporelle (120) pour modifier temporellement la sensation électrosensorielle ;
 - moyennant quoi la sensation électrosensorielle est basée au moins partiellement sur la position de ladite au moins une partie corporelle par rapport à la surface d'écran tactile. 55

Fig. 1

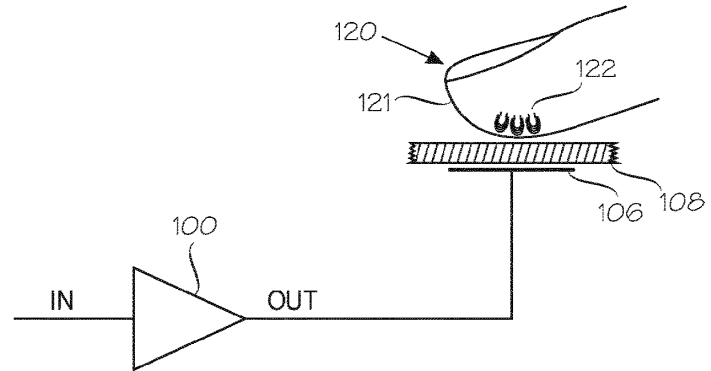


Fig. 2

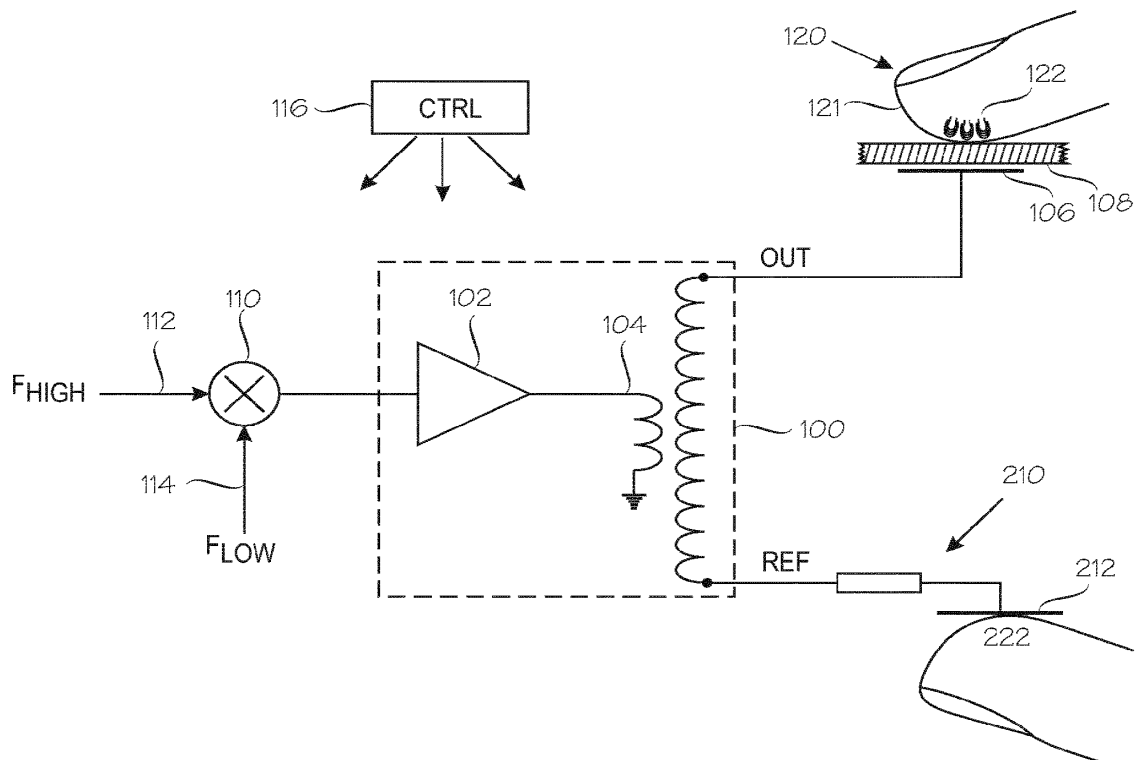


Fig. 3

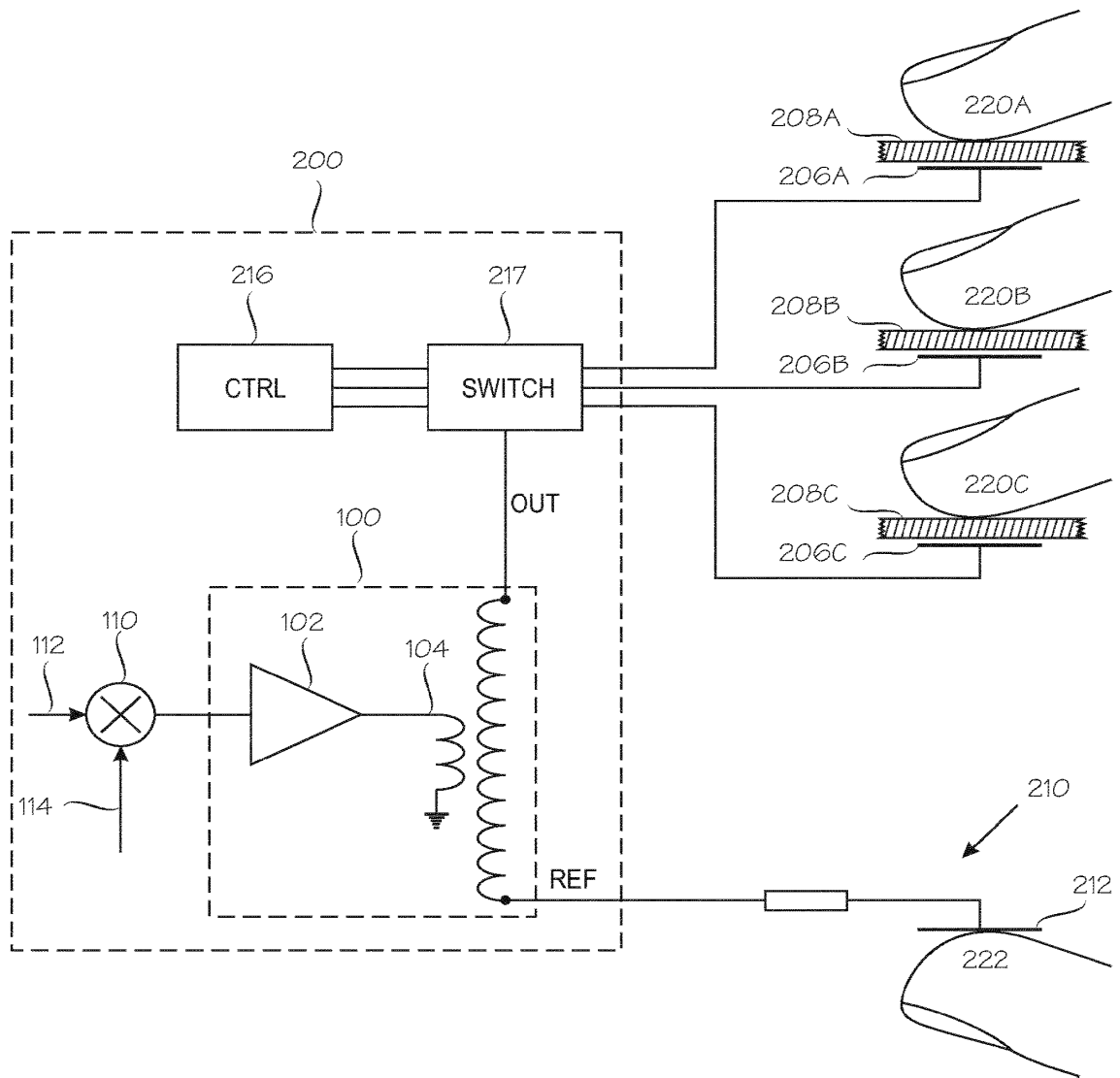


Fig. 4

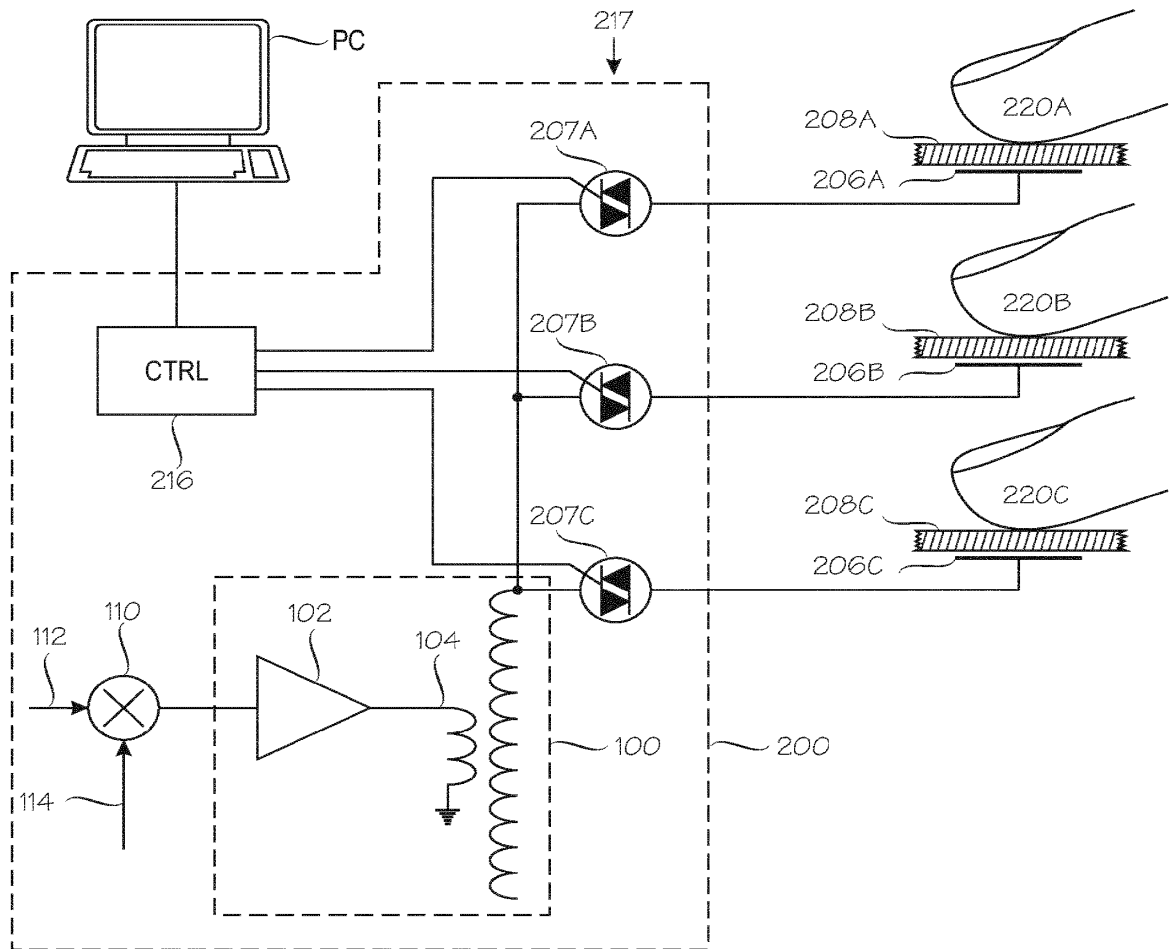


Fig. 5

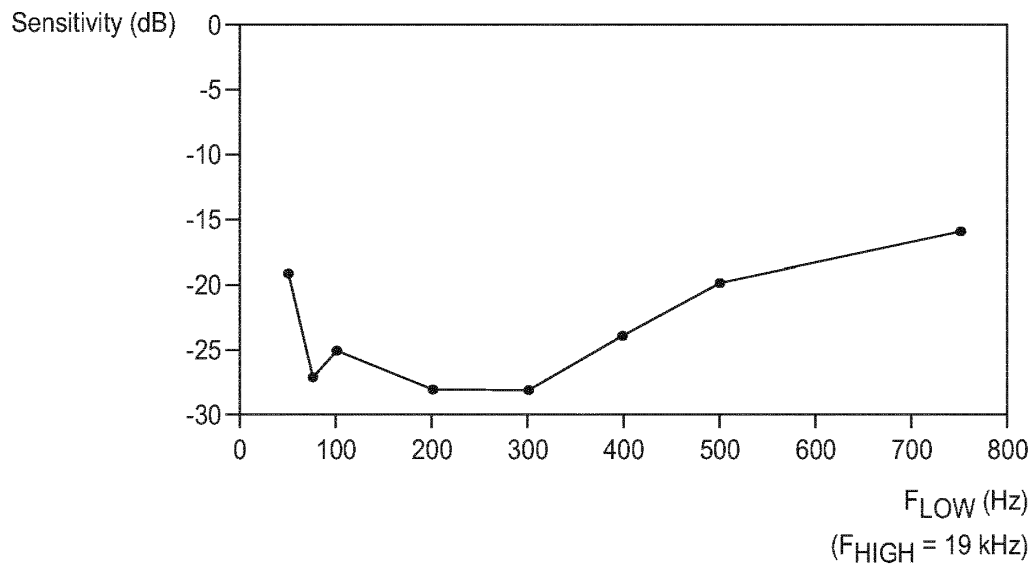


Fig. 6

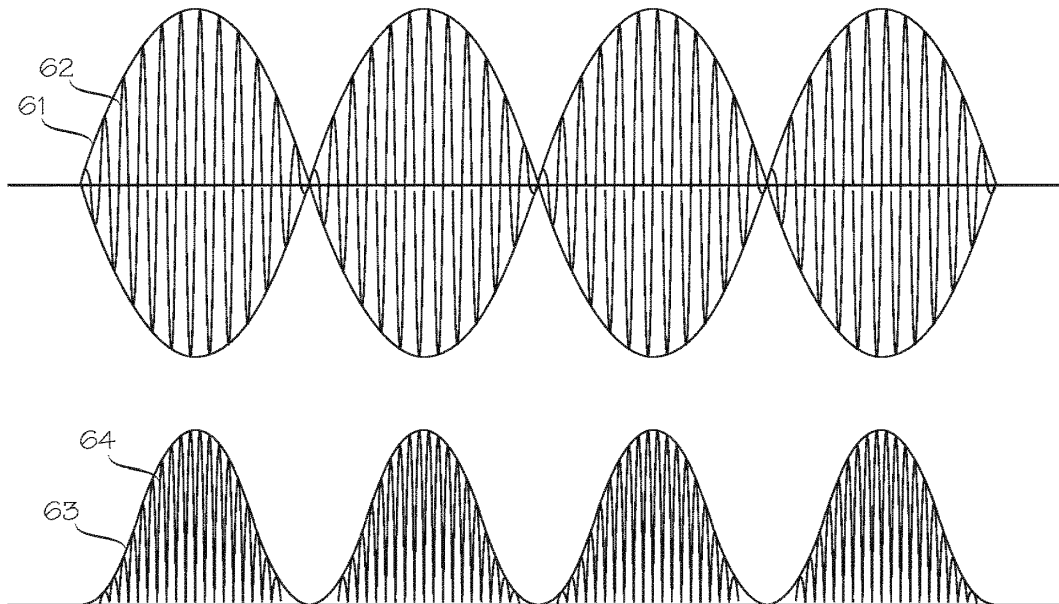


Fig. 7A

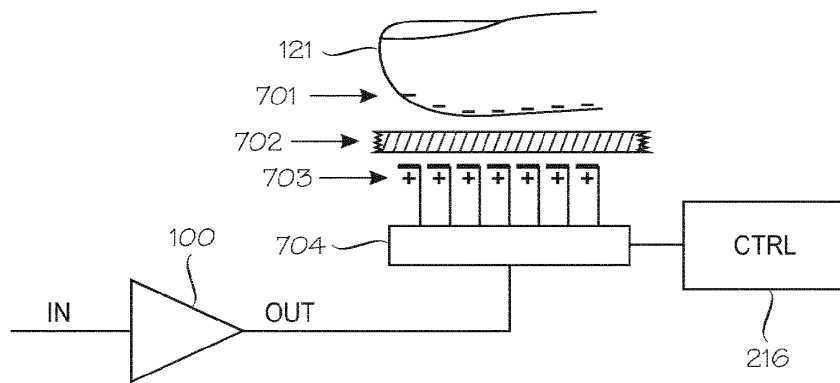


Fig. 7B

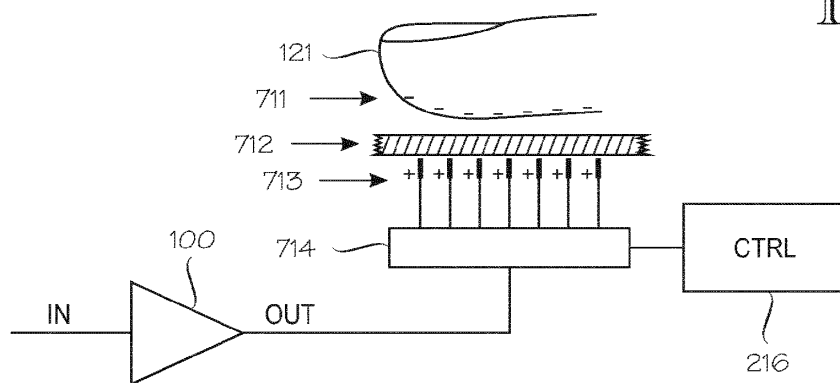


Fig. 8

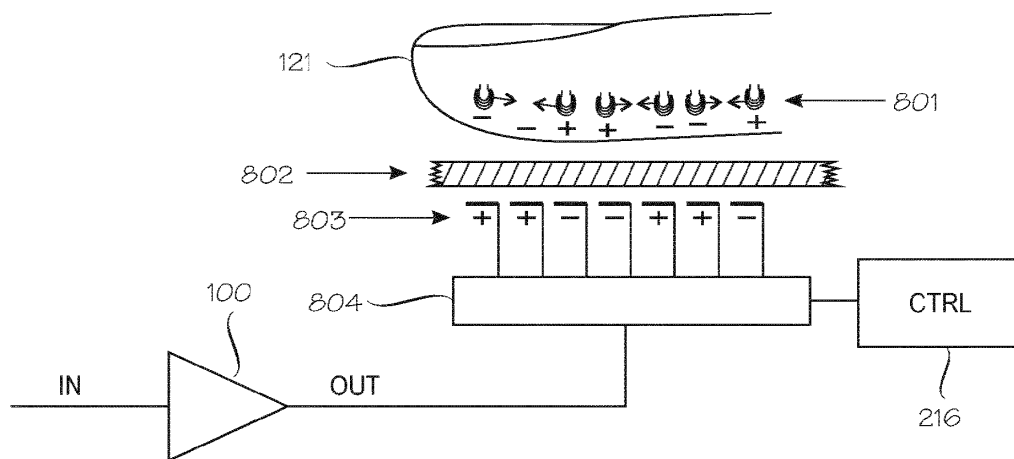


Fig. 9

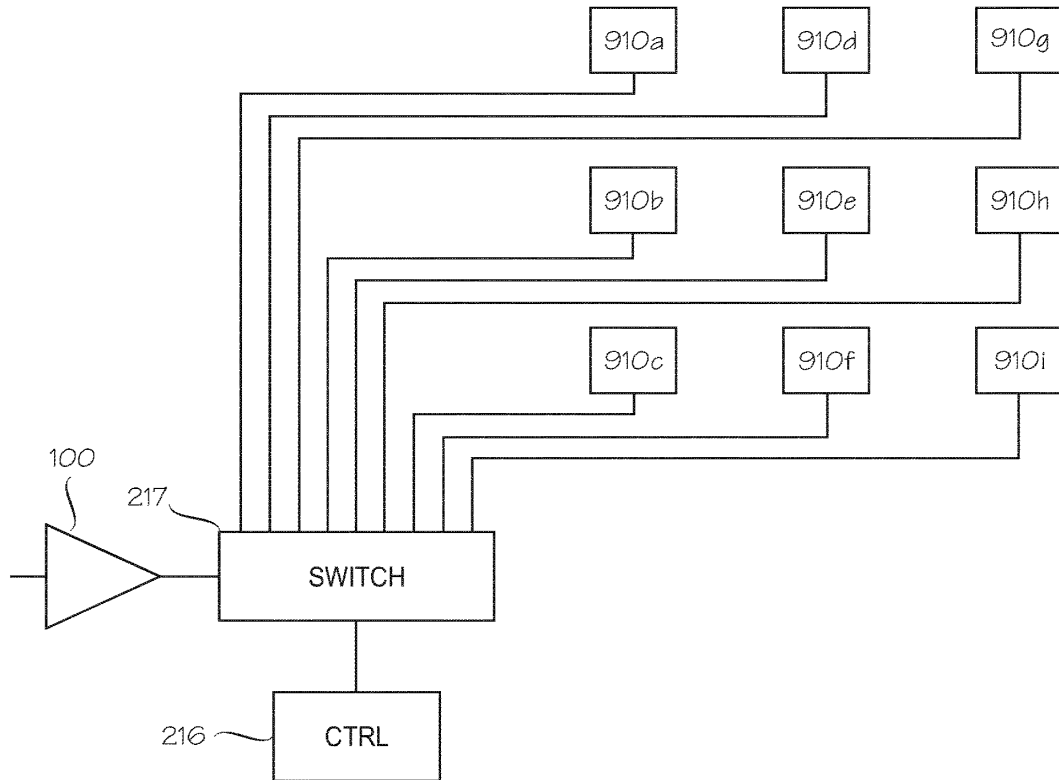


Fig. 10

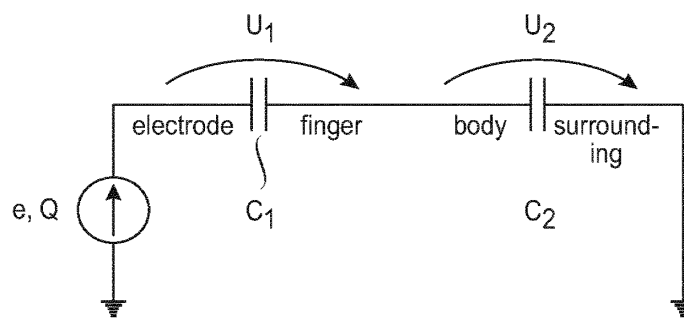


Fig. 11

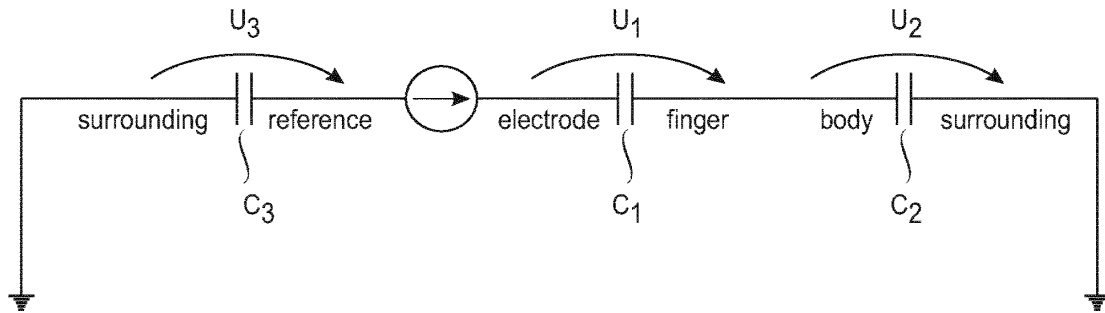


Fig. 12

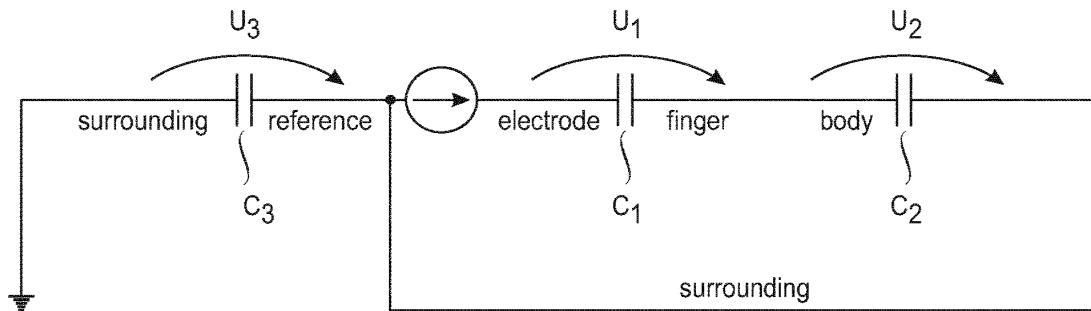


Fig. 13

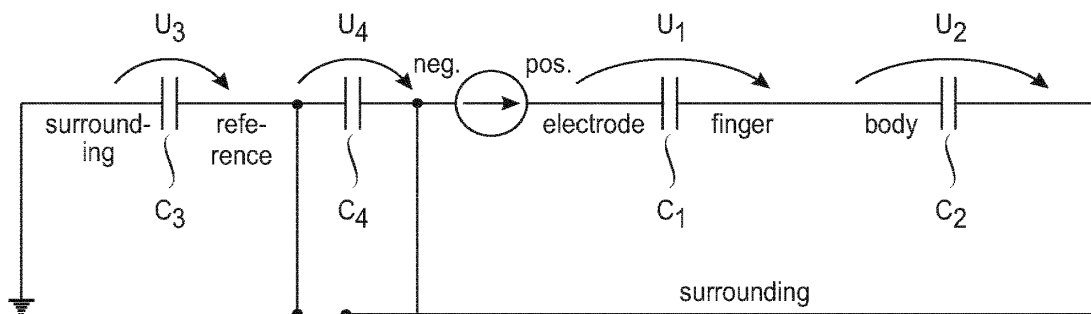


Fig. 14

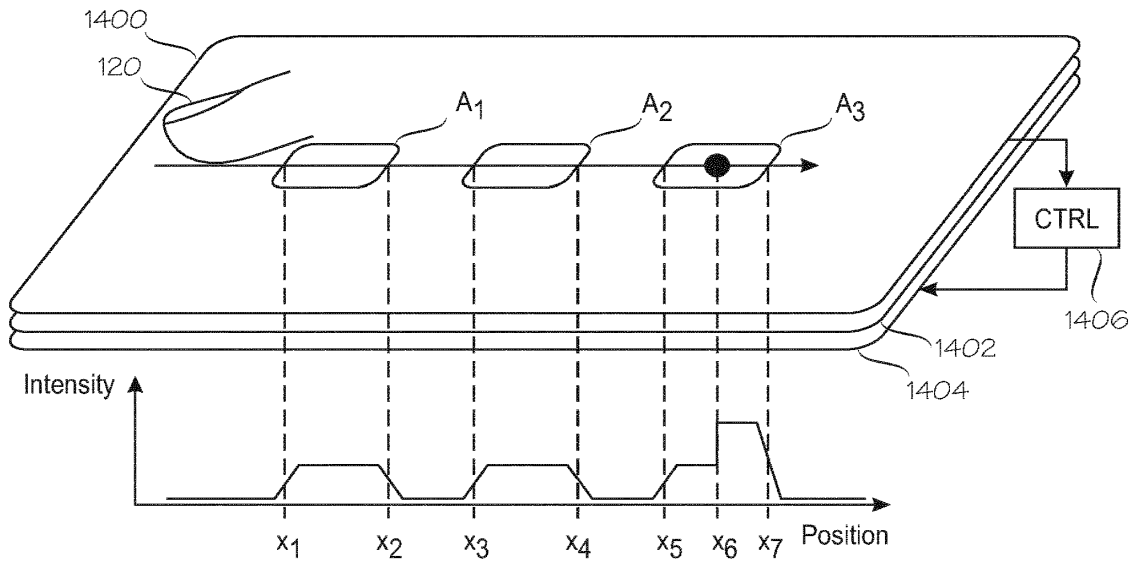
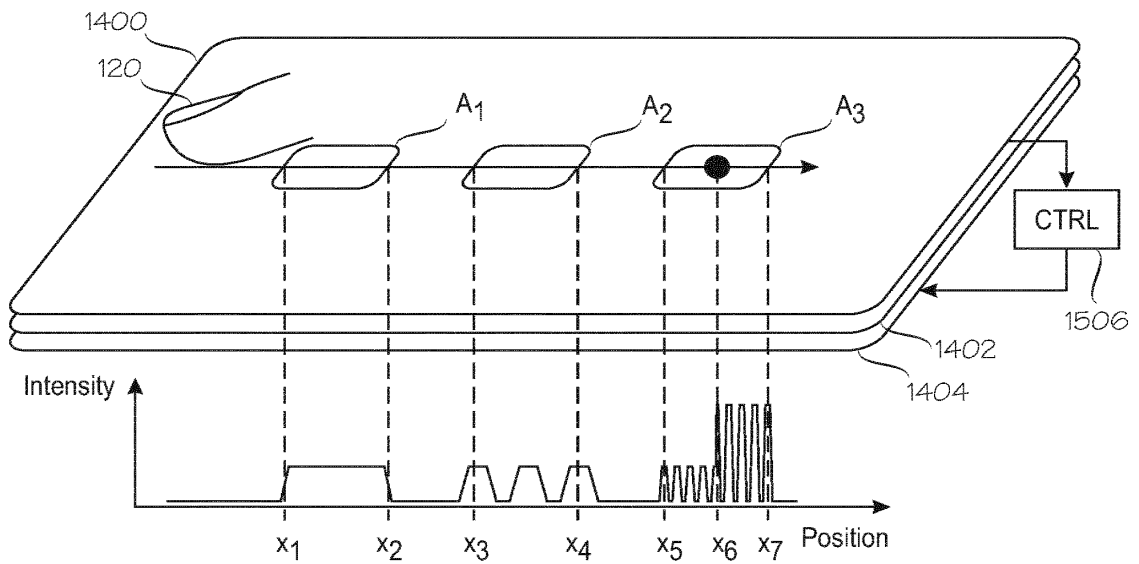


Fig. 15



REFERENCES CITED IN THE DESCRIPTION

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Non-patent literature cited in the description

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- Skinscape: A Tool for Composition in the Tactile Modality. **GUNTHER ; ERIC**. Master's thesis. Massachusetts Institute of Technology, 2001 [0088]

ASSIGNMENT AND DECLARATION

ASSIGNMENT

WHEREAS, I, **MATTHEW ROBERT LEAPER**, have invented certain new and useful improvements as described in a U.S. nonprovisional patent application entitled “**COMMUNICATION DEVICES, METHODS, AND SYSTEMS**” and identified by the United States Patent and Trademark Office ("USPTO") as Application No. _____ filed **December 1, 2023** (the "Invention").

WHEREAS, **DATAFEEL INC.**, a corporation existing under the laws of the State of Delaware, and having a mailing address of 1629 K Street NW, Suite 300, Washington, D.C., 20006 (together with its successors and assigns, the "Assignee") seeks to memorialize its ownership of the entire right, title, and interest in and to the Invention.

NOW, THEREFORE, in exchange for good and valuable consideration, the receipt and adequacy of which are hereby acknowledged, I transfer to Assignee my entire right, title, and interest in and to the Invention, including all inventions disclosed or claimed in the above-identified patent application, including any improvements thereof, any corresponding domestic applications, and any other corresponding provisional, non-provisional, divisional, continuation, continuation-in-part, reexamination, and/or reissue patent), any corresponding international applications, any corresponding foreign applications, all patents issuing thereon, or other patent applications based off or claiming priority to the above-identified patent application, and all rights and benefits under any applicable treaty or convention authorize the USPTO (or foreign equivalent thereof) to issue any patent (or similar legal protection) to the Assignee.

I hereby authorize the Assignee (or its designee) to apply for patent (or similar legal protection) in its own name if desired, in any and all countries.

I represent to the Assignee that I have not and shall not execute any writing or do any act whatsoever conflicting with this Assignment. I agree when requested, without additional consideration, but at the expense of the Assignee, to provide additional reasonable assistance necessary to memorialize this assignment, to execute all oaths, declarations, assignments, powers of attorney and other papers necessary to perfect and vest title to the rights assigned herein to the Assignee.

I shall render all assistance in filing, obtaining, maintaining, and enforcing any patent (or similar legal protection) on the invention in any and all countries.

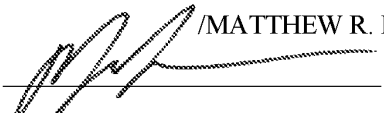
DECLARATION

I have reviewed and understand the contents of the above-identified patent application including the claims, and I believe I am an original or an original joint inventor of a claimed invention in the above-identified patent application. The above-identified patent application was made or authorized to be made by me. I am aware of and acknowledge my duty to disclose to the USPTO all information known to me

to be material to patentability of the claims in the above-identified patent application. I acknowledge that any willful false statement made in this declaration is punishable under 18 U.S.C. § 1001 by fine or imprisonment of not more than five (5) years, or both.

SIGNATURES

To evidence my agreement to the ASSIGNMENT and DECLARATION set forth above, I have executed and delivered this Agreement on the date set forth below.

Signature:  /MATTHEW R. LEAPER/

Name: Matthew Leaper

Date: December 1, 2023

Address 1039 South 21st Street
Unit #1
Omaha, NE 68108
USA

(12) STANDARD PATENT APPLICATION (11) Application No. **AU 2015202395 A1**
(19) AUSTRALIAN PATENT OFFICE

(54) Title
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(51) International Patent Classification(s)
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(62) Divisional of:
2009288135

(71) Applicant(s)
McNeil-PPC, Inc.

(72) Inventor(s)
Robinson, Ronni L.; Sowden, Harry S.; Kriksunov, Leo B.

(74) Agent / Attorney
Shelston IP, Level 21, 60 Margaret Street, Sydney, NSW, 2000

2015202395 05 May 2015

Abstract

The present invention is directed to a reusable pain relieving treatment device, such as a belt, and a disposable thermal insert comprising one or more thermally conductive component that extend from an inner surface of the device and are capable of transferring heat, cold and vibrations from disposable or reusable inserts.

Nil

Combined Portable Thermal and Vibratory Treatment Device

Background of the Invention

[0001] The application of heat to the human body can decrease the viscosity of body fluids, loosen stiff muscles, improve blood flow to an affected area, facilitate tissue repair, and create a feeling of relaxation for many suffers of general joint and muscle pain. For some acute injuries, the immediate application of cold can numb pain, constrict blood vessels and mitigate an inflammatory response. The application of heat to the skin as a means to penetrate deeper into tissues has historically been used for pain relief of muscles and joints, as well as for the treatment of certain inflammatory conditions. The application of cold materials to the skin has also been used for similar treatments, especially for treating inflammatory responses such as joint inflammation. The application of vibratory materials to the skin has also been used for similar treatments.

[0002] Any discussion of the prior art throughout the specification should in no way be considered as an admission that such prior art is widely known or forms part of common general knowledge in the field.

[0003] Traditional heating devices have, in many instances, generated heat using chemical formulations, such as iron powder formulations, that oxidize when exposed to air. Commercially available thermal chemical formulation products are mainly categorized with disposable heat patches, which are available in loosely formed fabric that is filled with an exothermic composition. An alternate means of producing heat is by way of electrical heating elements that are attached to a power source. Since the desired time of treatment is often longer than 4 hours, in the case of an electrical source, the power source typically used in these types of devices is either an electrical wall outlet or a battery.

[0004] Other chemical heating devices include those products that incorporate heating portions into fabrics that can conform or are shaped to fit various parts of the body, such as the knee or the back, as shown in U.S. Patent No. 6,074,413. In these cases, typically the entire product, including the garment and the heat providing exothermic formulation materials, is a disposable, unitary product. The chemical heating portion is not removable from such a unitary product, and therefore, the entire device is designed to be disposed of following use. Each use can typically last for between 6 to 12 hours, and a user can use 2 or 3 of these products over a 24-hour period. These types of products have the disadvantage of having loose powder

formulations that do not always adequately conform to parts of the skin and do not conduct heat thoroughly to the skin since a woven or non-woven fabric surface is in contact with the skin.

[0005] Other types of devices, such as those shown in U.S. Patent 5,484,366, exemplify elements that are not disposable, such as using a back belt with gel insert containers. In such a device the gel-inserts must be manually re-heated or cooled, taking more active participation by the user in order to be reusable. Similarly, the device shown in U.S. Patent No. 6,416,534 uses a back belt with a flexible fabric, and a gel insert that is reheated using electrical heat. This type of device also involves active participation on the part of the user and a potential lag time in order to heat the gel-insert. U.S. Patent No. 6,074,413 is directed to a disposable thermal back wrap having one or more thermal inserts comprising a plurality of heat cells, wherein heat is applied to specific areas of the user's back for pain relief. U.S. Patent No. 5,605,144 is directed to a heating garment with a pouch for accommodating inserted chemical heating inserts that are air activated.

[0006] U.S. Patent No. 5,484,366 is directed to an aerobic/cross training exercise belt. The belt comprises a straight piece of material having a fastener on each end whereby the ends can be fastened together to form a closed belt. A back lumbar support is connected to the rear body of the belt. The back lumbar support has at least one pocket to mount chemical gel-inserts whereby the user would have a thermal application to the lumbar area while wearing the belt. The gel inserts can be heated or cooled to the desired temperature. U.S. Patent No. 6,623,419 is directed to a therapeutic back belt and related method of manufacture. The belt includes magnets that are secured to the belt and thermally active gel material. U.S. Patent No. 5,179,942 is directed to a lumbar support therapeutic heat/cooling/air belt. The support has one pocket in the lower back section that is capable of receiving an insert to create a thermal change or provide air for support purposes.

[0007] U.S. Patent 5,925,072 is directed to a disposable elastic thermal insert wherein iron powder based exothermic compositions are segmented into individual portions and integrated into a back belt. In this composition, the thermal conductivity is not optimized since the composition is separated from the skin by a fabric barrier. US Patent 5,918,590 is directed to a specific heat cell unit comprising an iron powder based exothermic composition, wherein a specific exothermic formulation and pocket fill volume are defined.

[0008] U.S. Patent No. 6,146,342 is directed to massage pad having a plurality of randomly actuated pressure inducing elements. The apparatus massages the body by subjecting the body to impacts from reciprocating plungers. The plungers are secured in a flat array within a flexible pad. Each plunger has an associated solenoid device that alternately causes the plunger to project from the pad and to retract within the pad. An electrical circuit includes a power cord and plug assembly, manual controls disposed serially on the cord and plug assembly, and a controller generating operating signals randomly to the solenoids. A heating element is optionally included in the flexible pad, with a suitable controller provided among the controls.

[0009] Still other types of devices, as shown in U.S. Patent No. 7,077,858, include those that use flexible heat exchangers to distribute cooling and heating agents to the skin utilizing electrical heat. U.S. Patent No. 6,409,748 is directed to a heating pad with removable gel insert that provides rapid initial warming. U.S. Patent No. 4,846,176 is directed to a thermal bandage having a conformable region that can be placed against the skin to uniformly heat or cool the contacted skin area.

[0010] Battery or plug-in powered vibratory devices have also been traditionally employed to deliver pain relief, relax tight muscles, relieve muscles soreness, and joint stiffness. Devices have also been disclosed, as shown in U.S. Patent No. 7,147,610, that incorporate massaging elements with the heating elements so that they are conveniently available in a single device. Such a device has excess bulk, is non-discreet and requires the use of external power sources (i.e. a junction box) because the heating and massaging elements require electrical power. In addition, although the parts are reusable, electrical elements tend to be non-washable. Published U.S. Patent Application 2004/0082886 is directed to a therapeutic device for relieving pain and stress in the hands and feet. The portable device provides heat and vibratory therapies for the hand or foot.

Summary of the Invention

[0011] Accordingly the invention provides a thermal device for topical application on humans that comprises:

- a) a thermal insert containing a thermal composition;
- b) a vibrational means that transmits vibrational energy to and through the thermal insert; and
- c) a power source having capacity to power the vibratory element from at least

about 10 minutes to a maximum duration of about 12 hours;

wherein the vibratory element has a maximum dimension not greater than about 7 centimeters; and the thermal device is a unitary system having a thickness of not greater than about 10 millimeters.

[0012] Unless the context clearly requires otherwise, throughout the description and the claims, the words “comprise”, “comprising”, and the like are to be construed in an inclusive sense as opposed to an exclusive or exhaustive sense; that is to say, in the sense of “including, but not limited to”.

[0013] Advantageously, the present invention relates to a device to be worn in close contact with the skin of a human, and includes methods for providing a vibration and heating sensation to human skin, and methods for treating muscle aches and pains in a human, as well as a therapeutic device comprising a thermal insert. The thermal and vibratory inserts, devices, and methods of the present invention are useful in managing muscle and joint pain.

[0014] The present invention also relates to the combination of thermal and vibratory components for wearing in a garment in close contact with the skin of a human. The present invention also provides a therapeutic device comprising a combined thermal and vibratory insert and a garment. The present invention also provides methods for treating muscle aches and pains in a human.

[0015] The present invention relates to a thermal device for topical application on humans that includes a thermal insert containing a thermal composition; a vibrational means that transmits vibrational energy to and through the thermal insert; and a power source having capacity to power the vibratory element from at least about 10 minutes to a maximum duration of about 12 hours. The vibratory element has a maximum dimension not greater than about 7 centimeters. Additionally, the thermal device is a unitary system having a thickness of not greater than about 10 millimeters. Thermal insert can be an air-activated exothermic powder mixture. The thermal device can further maintains a temperature differential of from about 3 to about 10 degrees Celsius for at least about 8 hours, as between the surface of the thermal insert and the skin. The vibrational means can be, at least in part, powered by an electric-powered motor, which optionally can operate on a direct current. The vibrational means can preferably transmit vibrational energy at a frequency of from about 5 Hz to about 1000 Hz. The thermal insert can additionally comprises at least one thermally conductive component. Such a thermally conductive component can have a hardness as measured using a durometer of

greater than or equal to 40 on an A scale. The surface of the vibratory component can have a hardness as measured by durometer of greater than or equal to 40 on an A scale.

[0016] The present invention is directed to a method of treating pain in a human patient by providing a device described above, wherein said device delivers both heat sufficient to raise the skin surface temperature to between about 39.5°C and about 42°C for at least about 8 hours, and vibration sufficient to be sensed by the patient for at least about 10 minutes to a maximum of about 12 hours. The vibration can be activated by removing a pull-tab or by a switch and can be turned off by the patient. The device is preferably substantially inaudible to the patient while delivering vibration. For example, the vibration can be delivered with a loudness of less than 60 decibels.

[0017] The present invention is directed to a system for providing wearable pain relief therapy to a consumer by providing the consumer with a self contained thermal device described above, together with a reusable wrap having pockets for inserting the self contained thermal device. In one embodiment, the wrap is shaped to fit a particular body part, such as the lower back, knee, wrist, neck, shoulder, elbow, ankle.

[0018] The present invention is also directed to a system for providing wearable pain relief therapy to a consumer by providing the consumer with a device as described that has been integrally incorporated into a disposable garment that comprises a non-woven fabric.

[0019] The present invention is also directed to a method for treating muscle aches and pains in a human by wearing the device described above for a period of time of about 1 hour to about 16 hours.

Detailed Description of the Invention

[0020] The thermal and vibratory device of the present invention will typically be worn in a garment. Suitable garments include belts, back belts, back wraps, sleeves, knee sleeves, elbow sleeves, knee or elbow wraps or supports, neck wraps, neck sleeves, shoulder vest, shoulder support, wrist sleeve, wrist support, ankle sleeve, ankle wrap, foot support, sock, glove, hand support, or other braces and supports typically used to stabilize a joint. Suitable garments also include articles designed to adhere to the skin, such as a patch. The garment can be re-usable, e.g. constructed from washable fabric, such as a nylon-spandex fabric. Alternately, the garment can be disposable, e.g. constructed from non-woven materials. The

garment preferably comprises a pocket for holding the thermal and vibratory insert. The pocket is preferably constructed of a breathable and porous fabric, and attached to the garment on the surface that will be worn next to the skin. In one particular embodiment, the pocket shape is contoured similarly to the shape of the thermal insert. In embodiments wherein the garment is designed to adhere to the skin, adhesive can be applied continuously over one surface of the patch-style garment, or adhesive can be applied discontinuously to the edges of the garment. The adhesive can be designed to adhere to the skin, or alternately can be designed to adhere to the interior of the user's clothing. The patch-style garment can be shaped like a sleeve or tube for inserting the thermal insert, or can be a flat piece of fabric with an attached pocket. In one embodiment, the patch-style garment is constructed from a disposable, breathable, non-woven fabric.

[0021] The present invention describes a unitary system. As used herein "unitary" defines a device with an integrated thermal insert and a vibratory element.

[0022] The thermal insert of the present invention comprises a thermally active component and a thermally conductive component. The thermally active component generates heat or cold for purposes of this invention, preferably including therapeutic purposes. The thermally conductive component improves the efficiency of delivery of said heat or cold, and thereby, improving the experience of the user. In one embodiment, the thermal insert can comprise a thermally active composition, which is a component, material or combination of materials that activates upon the addition of heat or cold, thereby produces the heat or cold; a thermal fill composition, or combinations thereof. In one embodiment, the thermal insert comprises an enclosure for said thermally active composition.

[0023] The thermal insert can comprise a thermal composition that can be any material suitable for either generating, or holding heat or for maintaining a low (cold) temperature. In one embodiment, the thermal composition emits heat from about 1 to about 10 degrees Celsius above the skin surface temperature of a human. In an alternate embodiment, the thermal composition maintains a temperature from about 1 to about 20 or 50 or up to 100 degrees Celsius lower than the skin surface temperature of a human.

[0024] In one particular embodiment, the thermal insert comprises a thermal composition that is a mixture of substances that react exothermically. For example, several commercial hand warmers and therapeutic heat products contain an iron powder based mixture that liberates heat as the iron is oxidized upon exposure to air. These types of systems are

described in detail in for example, U.S. Patent No. 5,918,590. It is known in the art to formulate these mixtures to maintain a temperature of at least about 40 degrees Celsius for at least 4 hours, and up to 24 hours, for example, for at least about 8 hours, e.g. for at least about 10 hours, say for at least about 12 hours, or for at least about 16 hours.

[0025] In another embodiment, the thermal insert comprises a thermal fill material that is capable of absorbing microwave energy and retransmitting such energy as heat energy. Suitable microwave energy retaining fill materials include rice, corn, barley, cherry stones, starch-based synthetic pellets, and the like. Such materials typically retain a suitable level of heat for about 20 to about 60 minutes.

[0026] In another embodiment, the thermal insert comprises electrically heated or electrically cooled articles, such as a resistive heater, or a thermoelectric based cooling and heating element such as Peltier element.

[0027] In certain embodiments, the temperature measured by a thermocouple inserted between the individual's skin and the thermally conductive component of the thermal insert of this invention is 37°C, 38°C, 40°C, 41°C, 45°C, or 50°C.

[0028] In another embodiment, the thermal insert comprises a thermal composition that is a liquid that changes phase, such as solidifies or gels at a desired temperature. Upon storage in a freezer, for example, the material solidifies and maintains a temperature of less than about 5 degrees Celsius for about 20 to about 90 minutes. In one such embodiment, the temperature measured by a thermocouple inserted between the individual's skin and the thermally conductive member of the thermal insert of this invention is 5°C, 10°C, 20°C, 25°C, 30°C, or 35°C.

[0029] In one embodiment, the thermal insert is a material or combination of materials that are solid from about -2°C to 20°C, or at about 0°C. In one embodiment, the thermal insert is substantially free of a material that is combustible, flammable, or volatile. As used herein, "substantially free" is defined as less than 1 percent by weight of the thermal insert. Combustible materials include but are not limited to fuels such as alcohols, such as ethanol, methanol and butanol; or fuels, such as lighter fluids, kerosene, lantern oils, and mixtures thereof.

[0030] In one embodiment, the thermal insert comprises an enclosure. The optional enclosure for the thermal insert can be any material that contains the thermal composition within the thermal insert. In one embodiment, the enclosure is a pouch constructed of breathable non-woven fabric. In another embodiment, the enclosure is a water-tight polymer film pouch for holding a freezable liquid. In another embodiment, the enclosure is constructed from woven textile fabric. In certain embodiments, the enclosure is a pouch having one surface formed from a relatively non-conductive fabric, and a second surface comprising the thermally conductive component.

[0031] The thermally conductive component has a thermal conductivity of at least about 10 W/mK, such as at least about 100 W/mK, say from about 150 W/mK to about 250 W/mK. For the sake of comparison, the thermal conductivities for some representative materials are shown below:

Polypropylene:	0.12 W/mK
Stainless steel:	21 W/mK
Aluminum:	221 W/mK

[0032] Suitable materials for forming the thermally conductive component include metals, such as aluminum, copper, silver, steel, and metal alloys of aluminum, copper, silver, steel, and combinations thereof; non-metallic thermally conductive materials, such as carbon-based materials, including graphite, glassy carbon, thermally conductive plastics, polymers, rubber, or such as conductive textiles, composites, ceramics, and mixtures thereof. Optionally, these thermally conductive components can contain wires or fibers comprising the metals described above in order to make them more thermally conductive. Preferably, the thermally conductive component is non-reactive with the thermal composition, or with air and moisture.

[0033] In embodiments in which the thermal insert comprises a material that is activated by microwave, the thermally conductive component must be designed accordingly. For example, in one version of this embodiment, the thermally conductive component comprises a non-metallic substance such as ceramic. In another version of this embodiment, the thermally conductive component comprises a plastic portion that has a metallic surface underneath that does not expose metal to the microwave. In yet another version of this embodiment, the thermally conductive component is packaged separately from the thermally active component, along with means (such as an adhesive) for attaching the thermally conductive component to the thermally active component after microwave heating.

[0034] In certain preferred embodiments, the thermally conductive component has a portion of its surface that extends from and above the plane of the thermally active component. In certain such embodiments, the raised portions have a rounded shape. As used herein, rounded shape is defined as elliptical, semi-elliptical, semi-circular, or circular. In certain such embodiments, the raised portions of the thermally conductive component are raised by from about 2 millimeters to about 3 centimeters above the surface of the thermally active component or enclosure for such thermally active component. The raised portions of the thermally conductive component can advantageously provide a massaging sensation when held against the skin. For example, when the thermal insert of the present invention is worn in a back belt, with the raised portions of the thermally conductive component in close contact with the skin, the raised portions can give the sensation of fingers, massaging the skin as the wearer moves. In one particular embodiment, all or a portion of the thermally conductive component can be configured to rotate around a supporting element, or within a socket. In this embodiment, the thermally conductive massaging element can be shaped as a cylinder, sphere, octahedron, dodecahedron, or any suitable rotatable shape.

[0035] In a broader embodiment, the thermally conductive component can be of a various shapes, including round, semi-spherical, elongated, ellipsoidal, cylindrical, star shaped, mushroom shaped, or similar shapes. According to an embodiment of the present invention, the shapes of the thermally conductive component at the interfaces to the individual's body can be flat or non-flat, including but not limited to semi-spherical, pyramidal, conical, concave, convex, bumped, or contain an array of smaller shapes, e.g. semi-spherical protrusions.

[0036] In certain embodiments, the thermally conductive component can form a single, continuous layer on the surface of the thermally active component. For example, the thermally conductive component can be a single piece of foil having deep drawn protrusions in its surface. In certain other embodiments, the thermally conductive component can be discontinuously arranged upon a surface of the thermally active component. For example, the thermally conductive component can be a single piece of foil having cut-outs to enhance aesthetics or breathability of the thermal insert, or the thermally conductive component can comprise a plurality of individual metallic parts, individually adhered to the surface of the enclosure for the thermal fill composition. In embodiments where the thermally conductive component is a piece of foil, the thickness of the foil can be from about 0.006 mm to about 0.5 mm, or about 0.01mm to about 0.2 mm. The foil can be present on a single surface of the thermal insert, on two or more surfaces or surrounding the entire thermal insert.

[0037] In certain embodiments, the thermally conductive component can itself form a portion of the enclosure for the thermal fill composition. For example, the thermal fill composition can be a powder enclosed in a pouch-type structure, one surface of which comprises a porous non-woven fabric, and another surface of which comprises a metallic thermally conductive material, or the thermal fill composition can be a freezable liquid or gel enclosed in a pouch-type structure, one surface of which comprises a polymeric water-tight film, and another surface of which comprises a metallic film.

[0038] In another such embodiment, the thermal insert can be configured so that a portion of the thermally conductive component is in contact with the thermal fill material and the interior of the enclosure, while another portion of the thermally conductive component protrudes through openings in the enclosure to form an exterior surface.

[0039] The thermally conductive component can be rigid, or soft and compressible. In embodiments employing the thermally conductive component to deliver a massaging sensation, the massaging elements of the thermally conductive component are preferably rigid enough to maintain their shape when pressed against the skin. The raised portions of the thermally conductive component can be solid, hollow, or filled with conductive or non-conductive material. In one embodiment, the interior surface of the raised portions of the thermally conductive component are in contact with the thermal fill material. In one embodiment, the thermally conductive component is filled with metal pellets.

[0040] Another aspect of the present invention relates to methods for treating or managing pain, particularly muscle or joint pain, in humans. While heat, and massage have long been recognized as effective modalities for managing pain, the thermal insert of the present invention, in the embodiment wherein the thermally conductive component has at least a portion of its surface raised above the plane of the thermally active component, provides a means for delivering heat, along with a massaging sensation to the user. Compared to other methods of providing heat and massage, the method of the present invention is advantageously portable, wearable, and long lasting, with minimal effort required on the part of the user.

[0041] Yet another benefit of the massaging action of the thermal insert of the present invention is the sensory cue to remind the user the product is working. Sensory cues can improve patient compliance with a treatment regimen. One such regimen includes the wearing of the thermal insert of the present invention in close contact with the skin (either via a garment

or patch) for from about 1 to about 16 hours. For example, a user can wear the thermal insert for from about 4 hours to about 8 hours, or from about 8 hours to about 12 hours, or from about 8 hours to about 16 hours, providing heat to the affected muscles or joints while simultaneously engaging in work or leisure activities.

[0042] In the therapeutic use of the thermal inserts of the present invention, the thermally conductive components are in contact with the body of the user, either directly contacting the skin, or contacting the body through clothing or garments worn by the user. Simultaneously the thermally conductive components are in contact with the thermal insert. The thermally conductive component serves to effectively transfer or re-distribute heat or cold from the thermal inserts to the individual's body. In addition, thermally conductive component create a non-uniform thermal sensations on the body or on the skin in case of direct application to skin, whereby body or skin areas in immediate contact with the thermally conductive component experience much stronger sensations of heat or cold relative to the adjacent areas.

[0043] In one embodiment, the thermally conductive member is substantially free of activated carbon, e.g. less than 0.1% by weight of the fill of the thermally conductive component.

[0044] In one embodiment (not shown), the interior cavities created by raised portions of the thermally conductive component are filled with substances that are capable of retaining heat for extended periods of time, such as thermal beads, encapsulated water, wax, phase changing materials, ceramics, sand, grains, rice, wheat, corn, etc. Even after the chemical formulation inside the thermally active component stops delivering or generating heat, the substances that are capable of retaining heat for extended periods of time filled inside the thermally conductive component can continue releasing or absorbing heat for extended periods of time. Additionally, in case of accidental overheating of the chemical formulation inside the thermally active component, said substances are capable of absorbing the excess heat thus providing protection form overheating.

[0045] Advantageously and beneficially, the space around the raised portions of the thermally conductive component is available for removal and evaporation of sweat and provides for areas of the body or skin not in contact or not covered by any implement. Additionally, thermal contrast delivered to the body can be much higher whereby thermally conductive component transferring heat and transferring cold can be immediately adjacent to each. This is also achieved without significant losses of thermal energy due to heat transfer.

[0046] In one embodiment, the thermal insert is a thermal pack.

[0047] The number of the thermally conductive component(s) per single thermal pack can vary from one to several. In one embodiment, from 6 to 30 or more thermally conductive components are installed on the thermal pack. In one embodiment, the dimensions of the thermally conductive components have a width from about 5 millimeters to about 50 millimeters, e.g. from about 7 millimeters to about 20 millimeters. In one embodiment, the dimensions of the thermally conductive components have a height from about 5 millimeters to about 50 millimeters, e.g. from about 7 millimeters to about 20 millimeters.

[0048] In embodiments wherein the shape of the thermally conductive components are semi-spherical, the diameter, which is equal to the width of the component, is from about 5 millimeters to about 50 millimeters, e.g. from about 10 millimeters to about 30 millimeters. In this embodiment, the radius of the semi-spherical component, which is equal to the height, is from about 2.5 millimeters to about 25 millimeters, e.g. from about 5 millimeters to about 20 millimeters.

[0049] In certain embodiments, the thermally conductive components can be defined by the volume of the internal space of the component. In certain embodiments, the internal volume of a thermally conductive component can be from about 0.01 milliliters to about 50.00 milliliters, e.g. from about 0.03 milliliters to about 33.00 milliliters, e.g. from about 0.10 milliliters to about 2.00 milliliters.

[0050] In one embodiment wherein more than one thermally conductive components is present in the device, all thermally conductive components have the same height, while in another embodiment, some thermally conductive components are higher and some are lower, for example a first portion of the thermally conductive components are about 5 millimeters to about 10 millimeters high, while a second portion are about 10 millimeters to about 15 millimeters high, while an optional third portion are about 15 millimeters to about 20 millimeters high.

[0051] In one embodiment, the surface of the thermally conductive component is harder than the surface of the skin as measured by a Shore Durometer on the Type A scale. The term durometer as used herein refers to the measurement as well as the instrument itself. In this embodiment, the durometer of the surface of the thermally conductive component is greater than or equal to 40 on the Type A scale, or greater than or equal to 80 on the Type A scale.

[0052] The thermal device can be of any shape and size suitable for wearing next to the skin of a human, and can be produced commercially in any shape and size that can be die cut. For example, the thermal insert can be round, triangular, square rectangular, pentagonal, hexagonal, etc. In one embodiment, at least one dimension of the thermal devices is from about 1 inch to about 30 inches. In one particular embodiment, the thermal insert of the device has a triangular shape with a width from about 2 to about 6 inches, and overall length from about 2 to about 12 inches. In one particular embodiment, the thermal insert of the device has a hexagonal shape.

[0053] In certain embodiments, the thermal device can be substantially flat with the thickness of the device ranging from about 2 millimeters to about 30 millimeters, and the other dimensions of the insert ranging from about 24 millimeters to about 720 millimeters.

[0054] The vibratory massaging element can be any vibrating mechanism, including an electric motor with offset weight located on the rotor, stop-and-go electric motor, linear motors operated in a back and forth fashion, piezo-electric vibrator, electric solenoid vibrator, air or water pump based vibrator, inflatable flexible pulsating bulb, or other vibrator type known in the art.

[0055] The term vibration as used herein refers to mechanical oscillations about or from an equilibrium point or starting point. The oscillations can be periodic such as the motion of a pendulum, random, or pulsatile with variable dwell and pulse periods and variable amplitudes.

[0056] Vibration, as used herein, is intended to be desirable. For example, the motion of a tuning fork, the reed in a wood wind instrument, or the cone of a loudspeaker is desirable vibration, necessary for the correct functioning of the various devices. In certain types of devices, vibration is undesirable, can waste energy and can create unwanted sound noise. For example, the vibrational motions of electric motors, and engines or any mechanical device in operation are typically unwanted. Such vibrations can be caused by imbalances in the rotating parts, uneven friction, the meshing of gear teeth, etc. Careful design in these types of devices usually minimizes unwanted vibrations.

[0057] The science of sound and vibration are closely related. Sound and pressure waves are generated by vibrating structures (e.g. vocal cords) and pressure waves can generate vibration of structures (e.g. ear drum). Hence, a reduction in noise emanating from a device is

most often achieved by reducing the associated vibration. In the case of this invention, it is desirable to increase vibration without increasing audible undesirable sounds.

[0058] The traditional definitions of vibration are categorized as either Free Vibration, or Forced Vibration. "Free vibration", as used herein, occurs when a mechanical system is set off with an initial input and then allowed to vibrate freely. Examples of this type of vibration are pulling a child back on a swing and then letting go or hitting a tuning fork and letting it ring. The mechanical system will then vibrate at one or more of its natural frequencies and damp down to zero.

[0059] Forced vibration as used herein is defined as an alternating force or motion that is applied to a mechanical system. Examples of this type of vibration include shaking washing machine due to an imbalance, transportation vibration (caused by truck engine, springs, road, etc), or the vibration of a building during an earthquake. In forced vibration, the frequency of the vibration is the frequency of the force or motion applied, but the magnitude of the vibration is strongly dependent on the mechanical system itself.

[0060] In one embodiment of the present invention, the vibratory element can function as a free vibration system. In one embodiment, the vibratory element can function as a forced vibration system. In another embodiment, the vibratory element can function as a combination of forced and free vibration. In one embodiment, the combination of a forced and free system incorporates a resonating element such as a tuning fork, tuning rod, tuning plate, spinning eccentric mass on a shaft, resonating cavity etc. that is energized with forced vibration or rotational input and allowed to vibrate or rotate freely. After the vibration has stopped, it is energized again and allowed to decay. In this way energy is conserved in the conversion from kinetic to potential energy, thus maximizing force and conserving input energy which is desirable in portable battery powered embodiments.

[0061] There are two means whereby the sensation of a vibrational massage are achieved. "Vibrational massage", as used herein, is delivered in one embodiment using direct-acting systems and in a second embodiment using coupled systems.

[0062] An embodiment of a direct acting system is comprised of a motive force such as a linear motor, solenoid, or rotary motor with eccentric and connecting rod attached to a linear bearing, all of which is oriented with their axis that is roughly perpendicular to the body. The actuator is constrained at one end portion, whereas the other end portion is in contact with and

presses against the skin or body. The constrained end can be held by mechanical means such as a band, belt, adhesive attachment, hand pressure, or an external surface such as a chair back or seat pad. A periodic or random input is given to the actuator (various wave forms are possible such as sinusoidal, square wave, triangular wave and random amplitude and period wave forms) resulting in an in and out (or extend - retract) motion.

[0063] The coupled vibratory systems are the second classification of embodiments described herein. The function can be easily visualized using the classic mass, spring, damper model cited in physics and vibration analysis texts. In this type of system, the vibrational element provides forced excitation and the human body becomes part of the spring mass damper system. In general, the body is equivalent to the spring and viscous damper of the model as well as an additional mass. In this embodiment, the human body or skin surface is the damper. The damper sees a force that is proportional to the velocity of the moving mass of the vibrational element. The damping is called viscous because it models the effects of an object in a fluid. In one embodiment, the skin sees a force equal to the reaction force of mass moving during the vibration sequence.

[0064] The massage sensation is achieved through the constraint of the moving mass mechanism against the body whereby the damping effect results in a force acting upon the skin. In a preferred embodiment, the thermal insert is a coupling element. The coupling element herein refers to the element generally transmitting at least some of the movement or vibration to the body. That is the coupling element at least in part interfacing between the vibratory element and the body. The coupling element is in direct contact with the body. The coupling element is not generating the vibration itself, but it is vibrating due to the connection to the vibrating element.

[0065] In certain preferred embodiments, the thermally conductive protrusions provide a pathway for vibrational waves to propagate from the device to the skin creating a vibrating sensation.

[0066] In a preferred embodiment of the coupled vibratory system, a rotary motor with an eccentric mass attached to a shaft is employed. The rotation of the eccentric mass about the axis of the motor creates the vibrator effect, the speed of rotation establishing the frequency of vibration. The motor and mass preferably are contained in an enclosure to shield the rotating members from disturbance. The degree of force can be tuned by adjusting or selecting the following parameters: speed (frequency of oscillation) amount of eccentric mass, degree of

offset of mass from centerline and amount of moving mass. The orientation of the motor axis can be either perpendicular or parallel to the skin surface. The mass, the geometry and the frequency of operation of the system can be optimized to take advantage of resonant effects which will beneficially amplify the input frequency to achieve higher amplitudes and massaging force. When the rotational speed of the motor matches the resonant frequency of the motor, mass, and housing structure the resonating effect is produced.

[0067] An example of a vibratory system includes commercially available vibratory elements, such as low voltage direct current (dc) motors with eccentric weights that are designed for commercial products such as mobile phones, electric tooth brushes, toy vehicles, and massagers. They are commercially available from suppliers such as Panasonic, Matsushita, Shicoh and Jin long Machinery. The vibratory element is co-located with the thermal insert, and preferably has a small size, in order to be worn discreetly on the body of the user. Suitable dimensions for the vibratory element are not more than about 7 cm, e.g. not more than about 2 cm, in length, and not more than about 1 cm, e.g. not more than about 0.5 cm in depth. In one embodiment, the vibratory component is incorporated into the thermally conductive component. In one embodiment, the surface of the vibratory component is harder than the surface of the skin as measured by a Durometer on the Type A scale. The term durometer as used herein refers to the measurement as well as the instrument itself. In this embodiment, the durometer of the surface of the vibratory component is greater than or equal to 40 on the Type A scale, or greater than or equal to 80 on the Type A scale.

[0068] In one embodiment, the power source is contained within the thermal device, and has capacity to power the vibratory element for at least about 20 minutes, e.g. at least about 30 minutes, of operation. Preferably the power source is small in size, in order to be contained conveniently and worn discreetly on the body of the user. In certain embodiments, the power source can be a single-use battery, such as either button cell shaped or cylindrical cell shaped or flat-pouch encapsulated battery based on any chemical composition known in the art, including manganese-zinc, metal hydride, lithium, lithium ion, lithium polymer, and other known battery chemistries. Voltage of the battery can range from 1 volts to 3 volts to 12 volts depending on the motor employed. The battery capacity is selected to provide for sufficient time of operation of the vibrating element as described above. Suitable power sources can include primary batteries and secondary (rechargeable) batteries, fuel cells, hydrocarbon fuel cells, printed batteries, and plug-in power sources. In one embodiment, the power source for the vibratory component must have adequate energy density for the vibratory component to vibrate for up to 8 hours, e.g. up to 10 hours, e.g. up to 12 hours.

[0069] In one embodiment, the vibratory element can be activated by completing an electrical circuit with the power source. In certain embodiments, this can be achieved by means of a pull-out tab separating two contacts thus closing the electric circuit and activating the vibrating element, as known in the art. This prevents electrical communication during shipping and storage of the device, but allows electrical communication when removed by the user. In certain other embodiments, the activation of the vibratory element can be achieved by a magnet-based actuator, such as magnet-sensitive proximity switch, by an electric switch, or similar electric circuit activation element. In one embodiment, the vibratory element or thermal device can also optionally incorporate a time-controller, which will switch the vibration off after a pre-set period of time, for example after 20 minutes or 30 minutes or after 1 hour. In another embodiment, the vibratory element may have extensions connected from a central vibratory source that delivers the vibratory sensation over a portion of the surface of the device or over the entire surface of the device, as a means for increasing the surface area of the vibratory sensation over the skin. These extensions may be present as fingers or plates. A vibratory resonance may be incorporated between the source and the extensions to increase the force of the total vibration or to modulate the frequency of the vibration.

[0070] In certain embodiments, the vibratory element is operational for a relatively short time period, compared to the life of the thermal insert. In one particular embodiment, the vibratory element delivers a vibration for the initial 20 minutes to 30 minutes of operation, then stops. Short periods of vibration can enhance the perceived benefit from the heat, especially helping to loosen stiff muscles before the thermal insert reaches its maximum temperature. In one embodiment the ratio of time for the vibratory element to the thermal insert is 1:50 or 1:25 or 1:10 or 1:5.

[0071] In certain embodiments it is desirable to minimize the noise level from the vibratory element. The noise level depends upon the vibrational frequency, the damping provided by the skin of the user or the enclosure; the mass of the vibrational element and eccentric distance traveled by the eccentric mass on the rotary motor. In certain embodiments, the device is substantially inaudible to the patient while delivering vibration. In these embodiments, the frequency of vibration is preferably below about 150 Hz, for example below about 20 Hz., however higher frequencies up to about 10,000 Hz can be utilized as the noise is somewhat dampened by the vibrating element being enclosed and being in contact with sound-dampening soft tissue and heating element.

[0072] Preferred amplitude and frequency ranges of vibration are selected to provide optional patient's relief and to utilize low cost, miniature vibrators. Preferably, the vibration can be sensed at the skin surface, but is substantially inaudible to the patient. In one embodiment, the frequency is from about 1 Hz to about 10,00 Hz, another embodiment from about 5 Hz to about 1,000 Hz, and in yet another embodiment, from about 1 Hz to about 100 Hz. The amplitude of vibratory stimulation as measured on the surface of the device, ranges from 0.1 mm peak-to-peak to 1 mm peak-to-peak and up to 15 mm peak-to-peak. The human auditory system is sensitive to frequencies from about 20 Hz to a maximum of around 20,000 Hz, although the hearing range decreases with age. Within this range, the human ear is most sensitive between 1,000 Hz and 5,000 Hz, largely due to the resonance of the ear canal and the transfer function of the ossicles in the middle ear. One desired function of the vibratory element is to create no perceptibly audible disturbance to the user.

[0073] Equal-loudness contours were first measured by Fletcher and Munson using headphones (1933). In their study, listeners were presented with pure tones at various frequencies and over 10 dB increments in stimulus intensity. For each frequency and intensity, the listener was also presented with a reference tone at 1000 Hz. The reference tone was adjusted until it was perceived to be of the same loudness as the test tone. Loudness, being a psychological quantity, is difficult to measure, so Fletcher and Munson averaged their results over many test subjects to derive reasonable averages. Based on these studies human hearing sensitivity was found to drop off dramatically below 100Hz.

[0074] In a preferred embodiment, the loudness of the noise from the vibratory element is preferably below 60 dB at a distance of 1 foot which is equivalent to human conversation, such as below 50 db at one foot, or below 20 db at 1 foot.

[0075] The voltage of the power supply is selected to be safe and to provide sufficient power to the vibratory element. Typically the voltage is from 1.5 V to 3 V, and in some embodiments up to 12 V DC.

Claims:

1. A thermal device for topical application on humans that comprises:
 - a) a thermal insert containing a thermal composition;
 - b) a vibrational means that transmits vibrational energy to and through the thermal insert; and
 - c) a power source having capacity to power the vibratory element from at least about 10 minutes to a maximum duration of about 12 hours;

wherein the vibratory element has a maximum dimension not greater than about 7 centimeters; and the thermal device is a unitary system having a thickness of not greater than about 10 millimeters.
2. The thermal device of claim 1, wherein the thermal insert comprises an air-activated exothermic powder mixture.
3. The thermal device of claim 1, which maintains a temperature differential from about 3 to about 10 degrees Celsius for at least about 8 hours, as between the surface of the thermal insert and the skin
4. A device according to claim 1 wherein the vibrational means comprises an electric-powered motor.
5. A device according to claim 4 wherein the electric power mower operates as a direct current.
6. A device according to claim 1 wherein the vibrational means transmits vibrational energy at a frequency of from about 5 Hz to about 1000 Hz.
7. A device according to claim 1 wherein the thermal insert additionally comprises at least one thermally conductive component.
8. A device according to claim 7 wherein the thermally conductive component has a durometer of greater than or equal to 40 on a Type A scale.
9. A device according to claim 1 wherein the surface of the vibratory component has a durometer of greater than or equal to 40 on a Type A scale.

10. A method of treating pain in a human patient, comprising providing the patient a device according to claim 6, wherein said device delivers both heat sufficient to raise the skin surface temperature to between about 39.5°C and about 42°C for at least about 8 hours, and vibration sufficient to be sensed by the patient for at least about 10 minutes to a maximum of about 12 hours.

11. The method of claim 10, wherein the vibration is activated by removing a pull-tab.

12. The method of claim 10 wherein the vibration is activated by a switch and can be turned off by the patient.

13. The method of claim 10 wherein the device is substantially inaudible to the patient while delivering vibration.

14. The method of claim 10 wherein the vibration is delivered with a loudness of less than 60 decibels.

15. A system for providing wearable pain relief therapy to a consumer, comprising providing the consumer with the self contained thermal device of claim 1, together with a reusable wrap having pockets for inserting the self contained thermal device.

16. The system of claim 15 wherein said wrap is shaped to fit a particular body part, selected from the group consisting of lower back, knee, wrist, neck, shoulder, elbow, ankle.

17. A system for providing wearable pain relief therapy to a consumer, comprising providing the consumer with the device of claim 1, which has been integrally incorporated into a disposable garment, comprising a non-woven fabric.

18. A method for treating muscle aches and pains in a human comprising wearing the device of claim 1 for a time period of about 1 hour to about 16 hours.



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(72) Inventor: and

(71) Applicant : VERMA, Abhinav S. [IN/IN]; B.TECH (2
nd Year), Chitkara University Punjab campus, Chandigarh
Patiala National Highway, Village Jansla, Tehsil Rajpura,
Distt. Patiala 140401 (IN).

(74) Agent: BANSAL, Kompal; For Corporate Consultants, #
5568, Sector 38 West, Chandigarh 160014 (IN).

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(54) Title: HAND WEARABLE HAPTIC FEEDBACK BASED NAVIGATION DEVICE

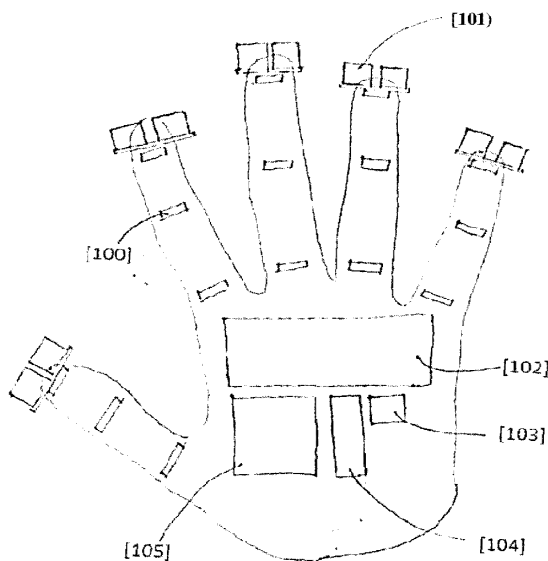


Fig 2

(57) Abstract: The present invention is a hand wearable haptic feedback based navigation device for distance sensing which has the flexibility of attachment and detachment of the navigation sensors (101) and has the flexibility of sensing the distance of the obstacle in multiple directions covering maximum 180 degrees in the direction of pointing of the hand. The device measures the distance of obstacle using sensors (101) at the tip of a finger. The measurement is broken down into categories on the basis of distance. This category is eventually informed to the user via haptic feedback actuators (100) strategically located on the specific finger. The feedback is taken to three dimensions by mapping the hand's spacial orientations using Inertial measurement units (2).

Declarations under Rule 4.17:

- as to the identity of the inventor (Rule 4.1 7(i))
- as to applicant's entitlement to apply for and be granted a patent (Rule 4.1 7(H))
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HAND WEARABLE HAPTIC FEEDBACK BASED NAVIGATION DEVICE

5

FIELD OF INVENTION

The present invention relates to the field of guiding and navigation systems and devices. More specifically, it relates to a hand wearable haptic feedback based navigation device. The device can be used to assist blind people while walking, to access the obstacles and their distances. It can also be used by soldiers to access their enemy in dark night. It can, in fact, be used for applications where a normal vision with eyes is not possible.

BACKGROUND OF THE INVENTION

15

ABOUT NAVIGATION SYSTEMS AND DEVICES: A navigation system is a system that aids in navigation. Navigation systems may be entirely on board a vehicle or vessel, or they may be located elsewhere and communicate via radio or other signals with a vehicle or vessel, or they may use a combination of these methods.

20 Navigation systems may be capable of:

- Containing maps which may be displayed in human readable format via text or in a graphical format.
- determining a vehicle or vessel's location via sensors, maps, or information from external sources
- 25 • providing suggested directions to a human in charge of a vehicle or vessel via text or speech
- providing directions directly to an autonomous vehicle such as a robotic probe or guided missile
- providing information on nearby vehicles or vessels, or other hazards or obstacles
- 30 • providing information on traffic conditions and suggesting alternative directions

Types of navigation systems

- **Automotive navigation system**
- **Marine navigation system**
- 5 • **Global Positioning System**, a group of satellites and computers that can provide information on any person, vessel, or vehicle's location via a GPS receiver
- **GPS navigation device**, a device that can receive GPS signals for the purpose of determining the device's location and possibly to suggest or give directions
- 10 • **Surgical navigation system**, a system which determines the position of surgical instruments in relation to patient images such as CT or **MRI** scans.
- **Inertial guidance system**, a system which continuously determines the position, orientation, and velocity (direction and speed of movement) of a moving object without the need for external reference
- 15 • **Robotic mapping**, the methods and equipment by which an autonomous robot is be able to construct (or use) a map or floor plan and to localize itself within it
- **Web navigation**
- **XNAV for Deep Space**

ABOUT HAPTIC TECHNOLOGY:

- 20 **Haptic technology** is a tactile feedback technology which takes advantage of the sense of touch by applying forces, vibrations, or motions to the user. This mechanical stimulation can be used to assist in the creation of virtual objects in a computer simulation, to control such virtual objects, and to enhance the remote control of machines and devices (telerobotics).

25 **Applications of Haptic technology**

- **Tactile electronic displays**

A tactile electronic display is a kind of display device that presents information in tactile form. The two most popular kinds of tactile electronic displays are various refreshable braille displays and the Optacon.

- 30 A **refreshable braille display** or **braille terminal** is an electro-mechanical device for displaying braille characters, usually by means of round-tipped pins raised through holes in a

flat surface. Blind computer users, who cannot use a normal computer monitor, use it to read text output. Speech synthesizers are also commonly used for the same task, and a blind user may switch between the two systems or use both at the same time depending on circumstances.

- 5 The **Optacon** (OPTical to TActile CONverter) is an electromechanical device that enables blind people to read printed material that has not been transcribed into Braille.

- **Tele operators and simulators**

- 10 Teleoperators are remote controlled robotic tools—when contact forces are reproduced to the operator, it is called *haptic teleoperation*. When such devices are simulated using a computer (as they are in operator training devices) it is useful to provide the force feedback that would be felt in actual operations. Since the objects being manipulated do not exist in a physical sense, the forces are generated using haptic (force generating) operator controls. Data representing touch sensations may be saved or played back using such haptic technologies.

- 15 Haptic simulators are used in medical simulators and flight simulators for pilot training.

There are many other applications of haptic feedback such as their use in video games, personal computers, mobile devices, medical field, robotics and art design.

(Ref: Wikipedia)

- 20 Many navigation systems and devices have been designed and developed based on haptic feedback . They suffer from the following limitations.

LIMITATIONS OF EXISTING NAVIGATION SYSTEMS AND DEVICES:

1. **High Cost-** The available navigation systems are very expensive.
- 25 2. **Less portability-** The available devices once fitted, are difficult to remove hence making them less portable
3. **Maintenance problems-** The existing devices being technically complex, are difficult and expensive to manufacture to provide them to grass root people. At the same time, these are difficult to repair on breakdown.

4. **Multi direction sensing not possible-** No existing device provides a multi-directional realistic and relative data covering an angle upto 180 degree using distance sensors.

5. **Lack of open source capability-** Since the circuitry and designing of existing devices is very complex, none of them provides the capability to customize the same as per the

5 requirement of a specific individual .

INNOVATIVE SOLUTION PROPOSED BY INVENTOR:

10 The inventor has designed and developed a hand wearable haptic feedback based navigation device which overcomes the above limitations of existing devices.

The design and concept makes the device utter reliable, ergonomic, simple and reasonable.

The device senses the 'distance' and 'direction' of the obstacles in 0-180 degree field of view and 4-6 directions in all. This information is communicated via Haptic feedback vibration motors on the surface of the hand and embedded in the glove.

15

PRIOR ART AND ITS DRAWBACKS:

Patent application No.	Difference with present invention
WO2013025823 A2	<p>The device in the referred patent application is a wearable tactile stimulation device which includes a facial mask, an air-suit, a pair of gloves, integrated conduits and nozzles configured to deliver tactile stimulation to portions of users face, hands, and/or body. The tactile stimulation can be delivered via puffs of air transmitted through the conduits and nozzles. A controller can be configured to control tactile stimulation by controlling the generation and delivery of puffs of air. The puffs can be delivered individually, or in combination.</p> <p>In comparison, the present invention uses removable and detachable sensors along with arduino controller. The circuit and software are simple and realistic as compared to the above application.</p>
EP 2629241 A1 and EP 2629242 A1	<p>The device in the referred patent application is a wearable device including a camera, a processor and a control interface between the wearable device and a user of</p>

	<p>the wearable device.</p> <p>In comparison, the present invention uses removable and detachable sensors along with arduino controller . No camera is used as input device.</p>
WO2007105937 A1	<p>The invention in the referred patent application relates to a tactile device comprising a plurality of actuators for producing navigation instructions. The tactile device is formed by an article of clothing wearable by a user. The tactile device is formed in such a way that, when being worn by a user, the plurality of actuators are positioned in a substantially closed path, surrounding part of a body of the user.</p> <p>In comparison, the present invention uses removable and detachable sensors along with arduino controller. The circuit and software are simple and realistic as compared to the above application.</p>
CN 102614068 A	<p>The invention in the referred patent application discloses an accompanying robot system for assisting a visually impaired person in walking. The accompanying robot system comprises a vibrational touch waistband arranged on the waist of the visually impaired person, and four tracked robots positioned on the front, back, left and right of the visually impaired person; the four tracked robots and the vibrational touch waistband form a wireless sensor network through an Ad Hoc Network; each tracked robot comprises a body and a control module; the control module comprises an ultrasonic distance measurement sensor, a laser distance measurement sensor, a motion control module, a wireless communication module, a central processing module and a power supply; the ultrasonic distance measurement sensor and the laser distance measurement sensor are arranged at the back and front ends of the body, and outputs of the ultrasonic distance measurement sensor and the laser distance measurement sensor are connected with the central processing module; the output of the central processing module is connected with the motion control module; the output of</p>

	<p>the central processing module is bi directionally connected with the wireless communication module.</p> <p>Although the system disclosed above uses sensors but the overall system is very complex and hence expensive which makes it unsuitable for grass root user.</p> <p>In contrast, the present device is low cost, fulfills the objective of being affordable and industrially applicable.</p>
CN201 076033 Y ES2367059 (A1)	<p>The devices of the patent applications as referred are only capable of telling 'distance' from only 'one' direction due to presence of only 'one' ultrasonic sensor.</p> <p>In comparison, in the present invention, sensors are detachable and attachable with the help of spring fit arrangement or the like, thus can be mounted at the fingertips, thumb or at any area in the hand, thereby making the device capable of covering any angle.</p>
US20130039152	<p>The device of the patent application has a fixed and defined plane for mounting two sensors.</p> <p>In comparison, in the present invention, sensors are detachable and attachable with the help of spring fit arrangement or the like, thus can be mounted at the fingertips, thumb or at any area in the hand, thereby making the device capable of covering any angle.</p>
CN 202844047 U	<p>The devices of the patent application is based on multiple sensors connected with the blind walking aid especially a hat which has embedded circuit device comprising of a base plate power supply module, an ultrasonic module main control module, voice outputting module to transmit voice information to the user.</p> <p>In comparison, in the present invention, sensors are detachable and attachable with the help of spring fit arrangement or the like, thus can be mounted at the fingertips, thumb or at any area in the hand, thereby making the device capable of covering any angle. The device uses haptic feedback system and no voice outputting module is</p>

	required.
US5047994 (A)	<p>The patent application referred here is a supersonic bone conduction hearing aid that receives conventional audiometric frequencies and converts them to supersonic frequencies for connection to the human sensory system by vibration bone conduction.</p> <p>In contrast, the device of the present application uses haptic feedback system and no voice outputting module is required. It uses sensors and no audio frequencies are received or transmitted.</p>
US2010278012 (A1) and US4761770 (A)	<p>Both the referred patent uses audio frequency range as receiver or transmitter.</p> <p>In contrast, the device of the present application uses haptic feedback system and no voice outputting module is required. It uses sensors and no audio frequencies are received or transmitted.</p>
CN201591719 (U) WO2006074993 (A2) US6671226 (B1) US6198395 (B1) WO9740403 (A1) WO9600401 (A1) US4712003 (A) US4280204 (A) EP0008455 (B1)	<p>The utility models referred here provide intelligent blind aid system and an intelligent blind aid either in the form of cane or goggles or waist bands. Most of these provide intelligent blind aid cane; a first ultrasonic range acquisition module is arranged at the middle of the cane; the ultrasonic transmitting head of the first ultrasonic range acquisition module faces to the front for detecting obstacles ahead; a second ultrasonic range acquisition module is arranged at the upper part of the cane; the ultrasonic transmitting head of the second ultrasonic range acquisition module faces upwards to the front for detecting obstacles in a front upper place; an infrared range acquisition module is arranged at the lower part of the cane at the vertical distance of 2-30 cm to the ground; and the infrared transmitting head faces to the front for detecting low obstacles on the ground.</p> <p>In contrast, the device of the present application uses haptic feedback system. It neither is a cane nor uses infrared frequencies.</p>
WO9740403 (A1)	The device of the patent application is a personal object detector

	<p>using continuous transmission frequency modulation and an audio output device.</p> <p>In contrast, the device of the present application uses haptic feedback system.</p>
MX2009001705 (A) and GB2448166 (A)	<p>The devices of the patent applications have fixed and defined plane for mounting two sensors.</p> <p>In comparison, in the present invention, sensors are detachable and attachable with the help of spring fit, clip fit arrangement or the like, thus can be mounted at the fingertips, thumb or at any area in the hand, thereby making the device capable of covering any angle.</p>
WO2007084122 (A3) and US2006098533 (A1)	<p>The devices of the patent applications are used for determining the direction of an acoustic highlight, comprising receiving backscattered, analog, ultrasonic sound-pressure pulses at the microphones of said acoustic vector probe; converting said backscattered analog ultrasonic sound-pressure pulses simultaneously into digital form and inputting these signals into said digital signal processor; lowering the frequency of said backscattered ultrasonic sound-pressure pulses to the audible range by heterodyning thereby highlighting the source of backscattered ultrasonic pulses.</p> <p>In contrast, the device of the present application uses haptic feedback system rather than audio output.</p>
US2009122648 (A1), WO2008086178 (A1) and US6469956 (B1)	<p>The referred patent applications use wide-band sonar system as a mobility aid by the visually impaired. The system includes an acoustic source and a pair of miniature microphone arrays with frequency-dependent beam patterns designed to mimic the properties of the human ear. Each microphone is preferably mounted near a respective ear of the user. The acoustic source and microphone arrays are mounted on the user's head so that the system will always be aligned therewith-as an example, they may be mounted near the user's ears on conventional eyeglass frames or a similar mounting device. Then each ear of the human receives measurement</p>

	<p>information.</p> <p>In contrast, the device of the present application uses haptic feedback system rather than audio output.</p>
CN201076033 (Y)	<p>The utility model relates to a glove which uses ultrasound to achieve obstacle prompt for blind, the structure comprises a first isolation sheet metal , an ultrasound emission probe , an ultrasound receiving transducer and a vibration motor , wherein the first isolation sheet metal is sleeved on a fourth and a fifth finger portions of the glove , the ultrasound emission probe, the ultrasound receiving transducer and the vibration motor are arranged on the first isolation sheet metal, one end of a connecting line is connected with the ultrasound emission probe, the ultrasound receiving transducer and the vibration motor, and the other end is connected with a circuit board which is equipped with a power interface. The device is capable of probing the distance of an obstacle on a road and transforms the distance messages of the obstacle into vibration to prompt the blind. He is capable of judging the distance of the obstacle in accordance with change in strength of the probe.</p> <p>Although the system disclosed above uses ultrasonic sensors as well as haptic feedback but the present device has sensors that are detachable and attachable with the help of spring fit arrangement or the like, thus can be mounted at the fingertips, thumb or at any area in the hand, thereby making the device capable of covering any angle and any direction.</p>

Hence it is clear that none of the available patents are able to achieve the desired results of the present invention.

OBJECT OF THE PRESENT INVENTION:

1. The main object of the present invention is to disclose a hand wearable haptic feedback based navigation device which has the flexibility of attachment and detachment of the navigation sensors.
2. Another object of the invention is to disclose a hand wearable haptic feedback based navigation device which has the flexibility of sensing the distance of the obstacle in multiple directions covering a maximum of 180 degree field of view in the direction in which the hand is pointing.
3. Yet another object of the present invention is to disclose a hand wearable haptic feedback based navigation device which constantly transmits the distance of an obstacle to an external high performance device via wired or wireless communication after combining it with a 10 degrees of freedom Inertial measurement sensor that senses the special orientation of the hand with respect to the distance measured. Hence producing a 3D image of the objects/area in front in the form of a 3D graph.

SUMMARY OF THE INVENTION:

In the present exemplary embodiment, the present invention consists of distance sensors mounted on the gloves at the position of the finger tips. These sensors sense the distance of any hindrance, obstacles etc. from the finger's tip and transmit them to the microcontroller which is embedded in the glove itself. The microcontroller accordingly drives the vibration motors embedded in the glove. Since there are 5 fingers; all in different direction which when opened in full stretch make an angle of roughly 180 degrees, every finger tells the distance of obstacle in its direction.

BRIEF DESCRIPTION OF DRAWINGS:

FIGURE 1: Block diagram of present invention
Numbering :

1. Distance sensor unit, it may be ultrasonic based, infrared based, laser based or any distance sensing device. For 5 fingers there are five such sensors.

2. 10 degrees of freedom Inertial measurement sensor
3. Arduino or any low power based microcontroller unit
4. Wireless or wired transmission device
5. High performance device (IOS, android based mobile platforms, computers, laptops or any other high performance device).
6. 3D output device
7. A wireless signal transmitter
8. Arduino or any other MCU
9. Distance calibrator
10. Logic circuit for Distance = 0-33% of the maximum distance or any set category.
11. First Vibrator
12. Logic circuit for Distance = 33-66 of the maximum distance or any set category.
13. Vibrator 2 powered **ON** on that particular finger.
14. Logic circuit for Distance 66-99% of the maximum distance or any set category.
15. Vibrator 3 powered **ON** on that particular finger.

20 **FIGURE 2:** Present embodiment as a glove

Numbering :

100. Vibrators or any other haptic feedback generating device.
101. Distance sensors
102. Battery pack, may or may not be disposed on hand though
- 25 103. Bug and error detection unit
104. Arduino or any other capable microcontroller unit or even a circuit
105. 10 degrees of freedom Inertial measurement sensor along with wireless or wired transmission unit.

30 **FIGURE 3:** Hand pointing in two axis at a time

FIGURE 4: Hand pointing in three axis at a time

FIGURE 5: Hand pointing in one axis 180 degrees

35 **FIGURE 6:** Hand pointing in downward direction

DETAILED DESCRIPTION OF THE INVENTION:

When a person is not using his eyes for sensing distance, there are two practical alternate means to achieve distance sensing i.e. hearing or touch. Auditory (hearing) system, generally being able to process only one sound at a time makes it difficult for the user to understand
5 any auditory signal that informs the presence of more than one obstacle and it's direction at the very same time.

Also if the person is using a pair of headphones as a part of the obstacle detection device, he might not be able to hear the horn of an approaching car or a whistle of a police man etc. at the same point of time resulting in accidents or injuries. Hence we may conclude that
10 headphones set a barter agreement somewhere between sight and hearing as the user is neither able to hear clearly not able to see (if he is blind).

Speaker based audio feedback is evidently not practical in already noisy places and may prove to be disturbing in places where silence needs to be maintained.

15 The present invention uses the other alternative of using touch sense to detect distance.

Referring fig 2, in the present exemplary embodiment, the inventor has designed and developed special pair of gloves which is provided with attachable and detachable distance sensors (101) along with a microcontroller (104) embedded in the glove itself. The present invention is powered by a battery pack (102) which may or may not be disposed on hand
20 though, a bug and error detection unit (103) for detecting any electronic, mechanical or software malfunction. Also provided is a 10 degrees of freedom Inertial measurement sensor unit (105) along with wireless or wired transmission unit.

The mechanism used for attachment and detachment can be any mechanism like stretchable
25 wire loop fitted with sensor and made of elastic or any other suitable material or clip fit mechanism or any other mechanism that can let the distance sensing unit to be fixed on the finger and may or may also allow the user to rotate them about the fixed point. In the present embodiment, the inventor has shown already stretched and fitted sensors (101) at the position of the finger tips. These sensors sense the distance of any hindrance, obstacles etc.
30 from the fingers tip and signals the microcontroller (104). Since there are 5 fingers all in different direction which when opened in full stretch, cover an angle of approximately 180 degrees, every finger is capable of sensing the distance of obstacle in its direction thereby covering multiple directions. Since the direction of the sensors can be fully controlled by the

user by pointing his finger to any direction, there is no limitation of sensing any particular direction.

WORKING OF THE DEVICE WITH REFERENCE TO FIG 1 AND 2:

5

1. Every finger is equipped with distance sensors **(101)** and three vibrators **(100 of fig 2 or 11, 13, 15 of fig 1)** for providing haptic feedback to the user; the user may use more or less vibrators on the finger depending on his sensing capability. To improve the reliability and ruggedness, every finger has a dedicated on board microcontroller **(104)** so that in case of
10 failure of one, the rest can work.

2. The vibrators **(100 of fig 2 or 11, 13, 15 of fig 1)** are calibrated with respect to the distance of an obstacle from the user with the help of logic circuits **(10, 12, 14 of Fig 1)** in the MCU **(104)**. Thus the following logic works:

15 a) When the obstacle is 0-50 cm (or any distance category assigned by the user), is close and is about to hit the user, logic circuit **(10)** gives output which powers up first vibrator **(11 of Fig 1)** and it starts vibrating.

b) When the obstacle is 50-200 cm (or any distance category assigned by the user) , is close to the user, logic circuit **(12)** gives output which powers up first vibrator **(13 of Fig 1)** and it
20 starts vibrating.

c) When the obstacle is 200-400 cm (or any distance category assigned by the user), far away from the user, logic circuit **(14)** gives output which powers up first vibrator **(15 of Fig 1)** and it starts vibrating.

25 3. In a preferred embodiment, input from 10 degrees of freedom Inertial measurement sensor unit **(105 of Fig 2 or 2 of fig 1)** is also fed to the onboard microcontroller **(104 of Fig 2)**. This performs the usual task with the vibrators but along with it also sends the data of distance sensed by all the distance sensors and the direction and position of the hand sensed via 10 degrees of freedom Inertial measurement sensor **(105 of Fig 2 or 2 of fig 1)** to a
30 wireless or wired signal transmitter (**4 of fig 1**) working as a high performance device. This device may be a mobile, laptop or any other high performance portable or non-portable.

4. The high performance device (**4 of fig 1**) receives the 'direction and spacial orientation of hand' and the distance of the obstacle from the distance sensors and plots that in the form of

a graph on 3D output device (6 of fig 1) . The hand now works like a bionic scanner. As the user moves the hand in random directions the graph gets plotted. Every direction has a coordinate on the 10 degrees of freedom Inertial measurement sensor therefore speed, randomness etc. does not affect the graph.

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5. This graph can be saved or plotted on a high performance machine by sending the data through wireless signal transmitter (7 of fig 1) to an external display, projector etc.

10 The above description makes this device applicable to be used by soldiers or police also who have to work in dark at times to fight the enemy. Since the valuable data including direction, distance, shape, size etc in the form of 2D or 3D graph , can be transmitted to distant location also using wireless transmission unit (7 of fig 1), it may be received at a distant location using a receiver.

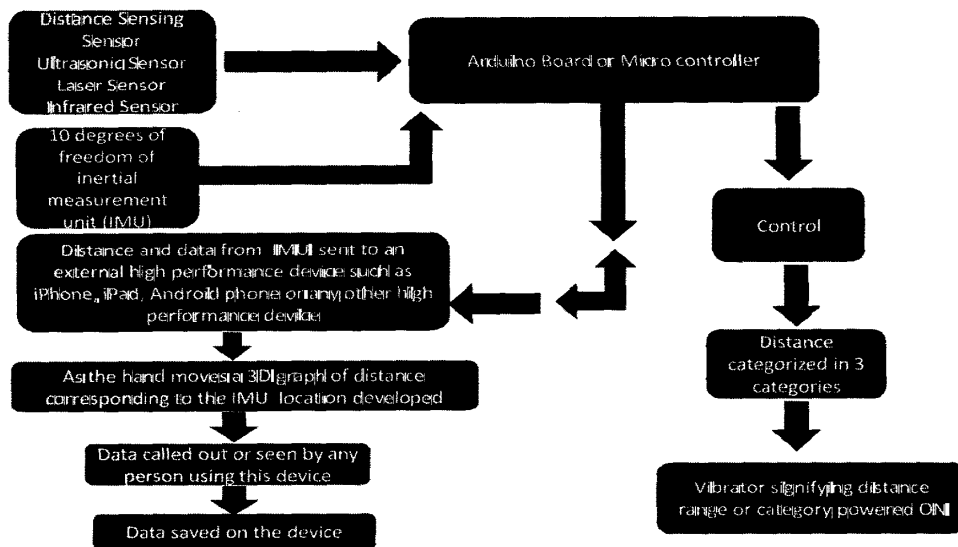
15 More detailed view can be achieved by combining sensors such as infrared sensors, PIR sensors and night vision. The distance may be also be mapped via high performance laser sensors and the user may be able to map an entire locality from a suitable height with greatest accuracy.

20 6. In yet another embodiment, two sensors can be mounted , one each at the top and bottom of the hand to sense stairs (ascending/descending), pits and sudden irregularities in the path. These sensors mounted on the top and bottom work in a similar manner and share a single MCU. There are two vibrators (100), one for the upper part of the hand and the other for lower part of the hand respectively. The vibrators (100) on the lower hand are calibrated in such a way so as to indicate an ascending stair, descending stair, sudden pit or a sudden
25 elevation. Similarly, the upper vibrators are calibrated in such a way so as to indicate a thin obstacle or a major big obstacle at the head level.

7. In one more embodiment, the sensors may have on board micro controller and may be integrally strapped on two or more individual fingers.

30

The present invention can be best understood with the help of following flow chart.



NOVELTY:

- As is clear from the above discussion that none of the prior art patents have overcome the drawbacks of being non portable, workable only in closed system environment, direction sensing possibility of either one or two axis and high complexity and high cost of the device. The inventor came out with a novel solution to these problems by designing and developing a hand wearable haptic feedback based navigation device for distance sensing which has the flexibility of attachment and detachment of the navigation sensors and has the flexibility of sensing the distance of the obstacle in multiple directions covering a span of 0-180 degrees in the direction in which the hand is pointed.
- The microcontroller used is Arduino which is an open source chip thereby making the device workable in any generic mode and customizable according to the user's demand. The device of present invention is less complex, easy to manufacture, is low cost and is user friendly.
- Also, the unique concept of using a 10 degrees of freedom Inertial measurement sensor in combination with sensors and vibrators, converting the data received into graphs and maps, providing capability of transmitting the data to a remote location, makes it a versatile device for navigation .
- None of the available prior art patents have provided solution of this kind, thus the invention is novel in itself.

INVENTIVE STEP:

The first inventive step lies in haptic feedback which is not specific to the hand but to every finger. This renders obstacles 5 directions to be sensed at a time. The second inventive step
5 is to incorporate a 10 degrees of freedom Inertial measurement sensor to sense the spacial orientation of the hand. This eventually makes it possible to 3D map the view in front just by random hand movements. The third inventive step involves making the sensors detachable. This ensures that while the user needs lower accuracies in distance measurement he can free up fingers for normal use.

10

The final inventive step is the design. Firstly all the components are SMD and no moving parts are there such as servos etc. This manifests a robust design. Secondly the whole setup is wearable so the person need not carry it. Thirdly there is no tasking on the locomotive and auditory dexterity of the user as there is no audio feedback involved.

15

INDUSTRIAL APPLICATION:

The distance sensing device can be used successfully by blind as an aid while walking on road or on staircase. The same device can also be used by the soldiers in dark war field. They
20 can simply wear this device and feel the vibration or view a 3D or 2D graph of what is in front.

Another application is in the field of animal study where the researchers have to watch the movement of animals in a jungle during night.

Therefore, the present invention finds application in any field where distance sensing is
25 required without use of normal eye sight. The device is low cost and can be manufactured at an industrial scale with great ease.

Hence the industrial applicability of the present invention is quite obvious.

In the preceding detailed description, the invention is described with reference to exemplary
30 drawings thereof. Various modifications and changes may be made thereto without departing from the broader spirit and scope of the invention as set forth in the description. The specification and drawings are accordingly, to be regarded in an illustrative rather than a restrictive sense. Thus without analysis, the foregoing will so fully reveal the gist of the present invention that others can, by applying current knowledge, readily adapt it for various

applications without omitting features that from the standpoint of prior art, fairly constitute essential characteristics of the generic or specific aspects of this invention.

I claim:

1. A hand wearable haptic feedback based navigation device comprising:
 - 5 - distance sensing unit (1) mounted at the finger tip of each finger;
 - Arduino microcontroller (3), one for each finger, embedded in the device itself;
 - haptic feedback generating device (100) , one for each finger to produce haptic output in the finger of the user;
 - a 10 degrees of freedom Inertial measurement sensor (IMU) (2);
 - 10 - wireless or wired signal transmitter(4);
 - a battery pack (102);
 - a bug and error detection unit (103)
- wherein the same is capable of :

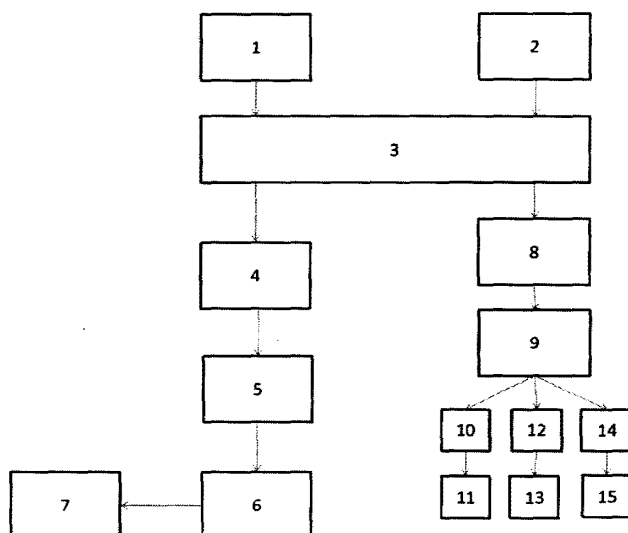
 - 15 - multi directional distance sensing covering maximum of 180 degrees;
 - sensing different distance ranges;
 - providing wireless or wired signals to remote locations.
2. A hand wearable haptic feedback based navigation device as claimed in claim 1 wherein multi directional distance sensing covering **180** degrees is achieved by using an attachment and detachment system with each sensor.
3. A hand wearable haptic feedback based navigation device as claimed in claim 1 wherein
 - 25 different distance ranges are achieved by calibrating each distance sensing unit (1) at a different distance sensing range.
4. A hand wearable haptic feedback based navigation device as claimed in claim 1 wherein wireless or wired signals to remote locations is achieved using wireless or wired signal
 - 30 transmitter (4) along with a 10 degrees of freedom Inertial measurement sensor (IMU) (2).
5. An attachment and detachment system as claimed in claim 2 wherein the same can be in the form of stretchable wire loop fitted with each distance sensing unit (1) or a clip fit mechanism or any other workable mechanism to attach and detach the distance sensing unit
 - 35 (1) to the part of hand.

6. An attachment and detachment system as claimed in claim 2 wherein this system can be made of elastic or any other material suitable for such functioning.
- 5 7. A hand wearable haptic feedback based navigation device as claimed in claim 1 wherein the distance sensing unit (1) comprises ultrasonic, infrared , PIR , night vision or laser sensors in stand alone or in any combination.
8. A hand wearable haptic feedback based navigation device as claimed in claim 1 wherein
10 additional sensors and vibrators can also be mounted one each at the top and bottom of the hand respectively to sense stairs (ascending/descending), pits and sudden irregularities in the path.
9. A hand wearable haptic feedback based navigation device as claimed in claim 1 wherein
15 the haptic feedback generating device (100) can be a vibrator or any other device capable of producing haptic feedback.
10. A hand wearable haptic feedback based navigation device and attachment and detachment system as claimed in claims 1-9 wherein the sensors may have on board micro
20 controller and may be integrally strapped on two or more individual fingers.

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**Fig 1**

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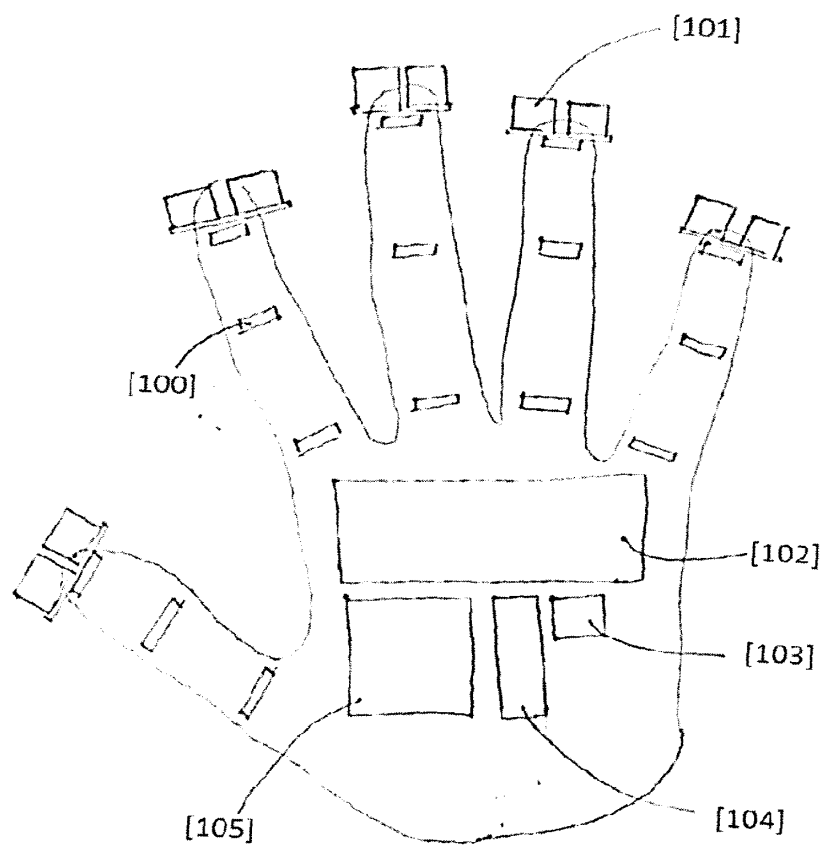


Fig 2



Fig 3



Fig 4

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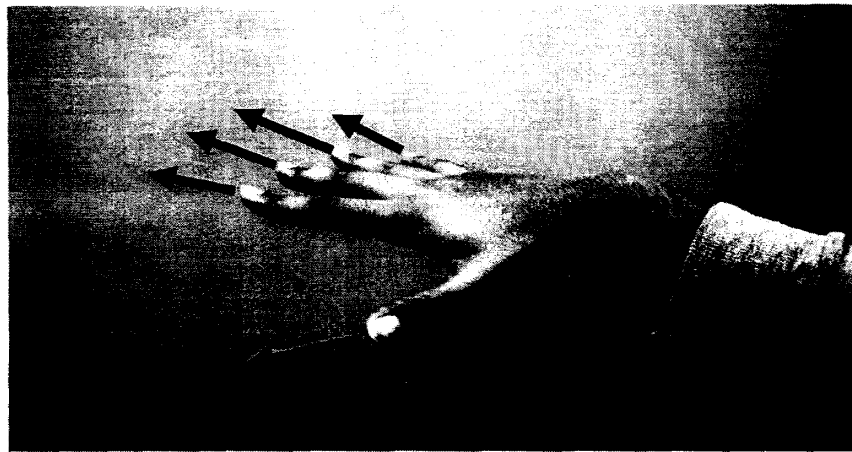


Fig 5



Fig 6

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INTERNATIONAL SEARCH REPORT

International application No
PCT/IN2014/000742

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01C21/36 G06F3/01 A61H3/06
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G01C A61H G06F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal , WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	wo 2008/112519 AI (UNIV PITTSBURGH [US]) 18 September 2008 (2008-09-18) abstract figures 1-5 paragraphs [0001] - [0002] , [0007] , [0017] , [0020] , [0025] , [0028] - [0037] , [0039] , [0040] , [0042] claims 1-20 -----	1-10
X	US 6 115 482 A (SEARS JAMES T [US] ET AL) 5 September 2000 (2000-09-05) abstract figures 5a-5d, 6 column 1, lines 23-29 column 14, lines 56-59 column 24, line 52 - column 25, line 36 column 25, line 51 - column 26, line 6 claims 2-7 , 25-27 ----- -/- .	1-10

☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

13 May 2015

Date of mailing of the international search report

22/05/2015

Name and mailing address of the ISA/
European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Toth , Remy

INTERNATIONAL SEARCH REPORT

International application No
PCT/IN2014/000742

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	<p>US 2002/012014 A1 (MOHRI KOH [JP]) 31 January 2002 (2002-01-31) abstract figures 1-12 paragraphs [0029], [0031] - [0042] claims 1-4 -----</p>	1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/IN2014/000742

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2008112519 A1	18-09-2008	US 2008226134 A1 WO 2008112519 A1	18-09-2008 18-09-2008
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US 2002012014 A1	31-01-2002	NONE	

Form PCT/ISA/210 (patent family annex) (April 2005)



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(54) **TOPICAL NEUROLOGICAL STIMULATION**

TOPIISCHE NEUROLOGISCHE STIMULATION

STIMULATION NEUROLOGIQUE TOPIQUE

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(73) Proprietors:
• **Creasey, Graham H.**
Menlo Park, California 94025 (US)
• **Toong, Hoo-Min**
Cambridge, Massachusetts 02138 (US)

(72) Inventors:
• **Creasey, Graham H.**
Menlo Park, California 94025 (US)

• **Toong, Hoo-Min**
Cambridge, Massachusetts 02138 (US)

(74) Representative: **Cameron, Stewart**
Cameron Intellectual Property Ltd
Moncrieff House
Floor 4
69 West Nile Street
Glasgow G1 2QB (GB)

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US-A1- 2012 109 233

EP 3 003 473 B1

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DescriptionTECHNICAL FIELD

[0001] This invention pertains to the activation of nerves by topical stimulators to control or influence muscles, tissues, organs, or sensation, including pain, in humans and mammals. No claim is made to a therapeutic method for treatment of the human body, and any descriptive text relating to such a method is to be understood and being of an explanatory nature only.

BACKGROUND

[0002] Nerve disorders may result in loss of control of muscle and other body functions, loss of sensation, or pain. Surgical procedures and medications sometimes treat these disorders but have limitations. US2009182393 (Bachinski) discloses a patch for a therapeutic electrical stimulation device comprising a number of separate detachable components including a patch 104, a shoe 120, a controller 102, among other components. US2010/0204538 (Burnett) and WO2011/053607 (Burnett) each disclose apparatus for magnetic induction therapy which comprise a sensor to provide feedback about the efficacy of the applied electromagnetic induction therapy. This invention pertains to a system for offering other options for treatment and improvement of function.

[0003] The invention is defined in the appended claims. Aspects, embodiments and examples disclosed of the present disclosure which do not fall under the scope of the appended claims do not form part of the invention and are merely provided for illustrative purposes.

[0004] According to the present invention there is provided a topical nerve stimulator/sensor system comprising: at least one flexible dermal patch configured to be adhered to the dermis of user and to stimulate one or more nerves of the user in proximity to the patch; the dermal patch comprising one or more electrodes for contact with the skin; an internal power supply; an electrical stimulus generator integrated within the dermal patch; a nerve feedback sensor; a signal transceiver configured to activate the electrical stimulus generator and provide electrical stimulus via the electrode(s); an antenna in communication with the signal transceiver; and a remote electrical signal activation device wherein: (i) each of the internal power supply, the nerve feedback sensor, the signal transceiver, and the antenna are integrated within the dermal patch; and (ii) the antenna is also in communication with the remote electrical signal activation device to enable a user to activate the electrical stimulus generator from a remote location. Optionally, the topical nerve stimulator/sensor system further comprises an integrated circuit comprising the stimulus generator and the signal transceiver.

BRIEF DESCRIPTION OF THE DRAWINGS**[0005]**

Figure 1 is a depiction of a neuron activating a muscle by electrical impulse.

Figure 2 is a representation of the electrical potential activation time of an electrical impulse in a nerve.

Figure 3 is a cross section of a penis.

Figure 4 is an illustration of a Topical Nerve Stimulator/Sensor (TNSS) component configuration including a system on a chip (SOC).

Figure 5 is an illustration of the upper side of a Smart Band Aid™ (SBA) implementation of a TNSS showing location of battery, which may be of various types. Figure 6 is an illustration of the lower side of the SBA of Figure 5.

Figure 7 is TNSS components incorporated into a SBA.

Figure 8 is examples of optional neural stimulator and sensor chip sets incorporated into a SBA.

Figure 9 is examples of optional electrode configurations for a SBA.

Figure 10 is an example of the use of TNSS with a Control Unit as a System, in a population of Systems and software applications.

Figure 11 shows a method for forming and steering a beam by the user of a plurality of radiators.

Figure 12 is an exemplary beam forming and steering mechanism.

Figure 13 illustrates exemplary Control Units for activating a nerve stimulation device.

Figure 14 are exemplary software platforms for communicating between the Control Units and the TNSS, gathering data, networking with other TNSSs, and external communications.

Figure 15 represents TNSS applications for patients with spinal cord injury. [0020] Figure 16 shows an example TNSS system.

Figure 17 shows communications among the components of the TNSS system of Figure 16 and a user. Figure 18 shows an example electrode configuration for electric field steering and sensing.

Figure 19 shows an example of stimulating and sensing patterns of signals in a volume of tissue.

DETAILED DESCRIPTION

[0006] The invention relates to an apparatus for electrical interaction with a human or mammal nervous system to stimulate and/or record body functions using small electronic devices attached to the skin and capable of being wirelessly linked to and controlled by a cellphone, activator or computer network.

[0007] The body is controlled by a chemical system and a nervous system. Nerves and muscles produce and respond to electrical voltages and currents. Electrical

stimulation of these tissues can restore movement or feeling when these have been lost, or can modify the behavior of the nervous system, a process known as neuro modulation. Recording of the electrical activity of nerves and muscles is widely used for diagnosis, as in the electrocardiogram, electromyogram, electroencephalogram, etc. Electrical stimulation and recording require electrical interfaces for input and output of information.

[0008] Electrical interfaces between tissues and electronic systems are usually one of three types:

a. Devices implanted surgically into the body, such as pacemakers. These are being developed for a variety of functions, such as restoring movement to paralyzed muscles or restoring hearing, and can potentially be applied to any nerve or muscle. These are typically specialized and somewhat expensive devices.

b. Devices inserted temporarily into the tissues, such as needles or catheters, connected to other equipment outside the body. Health care practitioners use these devices for diagnosis or short-term treatment.

c. Devices that record voltage from the surface of the skin for diagnosis and data collection, or apply electrical stimuli to the surface of the skin using adhesive patches connected to a stimulator. Portable battery-powered stimulators have typically been simple devices operated by a patient, for example for pain relief. Their use has been limited by:

i. The inconvenience of chronically managing wires, patches and stimulator, particularly if there are interfaces to more than one site, and

ii. The difficulty for patients to control a variety of stimulus parameters such as amplitude, frequency, pulse width, duty cycle, etc.

[0009] Nerves can also be stimulated mechanically to produce sensation or provoke or alter reflexes; this is the basis of touch sensation and tactile feedback. Nerves can also be affected chemically by medications delivered locally or systemically and sometimes targeted to particular nerves on the basis of location or chemical type. Nerves can also be stimulated or inhibited optically if they have had genes inserted to make them light sensitive like some of the nerves in the eye. The actions of nerves also produce electrical, mechanical and chemical changes that can be sensed.

[0010] The topical nerve stimulator/sensor (TNSS) is a device to stimulate nerves and sense the actions of the body that can be placed on the skin of a human or mammal to act on and respond to a nerve, muscle or tissue. One implementation of the TNSS is the Smart Band Aid™ (SBA). A system, incorporating a SBA, controls neuro

modulation and neuro stimulation activities. It consists of one or more controllers or Control Units, one or more TNSS modules, software that resides in Control Units and TNSS modules, wireless communication between these components, and a data managing platform. The controller hosts software that will control the functions of the TNSS. The controller takes inputs from the TNSS of data or image data for analysis by said software. The controller provides a physical user interface for display to and recording from the user, such as activating or disabling the TNSS, logging of data and usage statistics, generating reporting data. Finally, the controller provides communications with other Controllers or the Internet cloud.

[0011] The controller communicates with the neurostim module, also called TNSS module or SBA, and also communicates with the user. In at least one example, both of these communications can go in both directions, so each set of communications is a control loop. Optionally, there may also be a control loop directly between the TNSS module and the body. So the system optionally may be a hierarchical control system with at least four control loops. One loop is between the TNSS and the body; another loop is between the TNSS and the controller; another loop is between the controller and the user; and another loop is between the controller and other users via the cloud, which may be located in the TNSS, the controller or the cloud, has several functions including: (1) sending activation or disablement signals between the controller and the TNSS via a local network such as Bluetooth; (2) driving the user interface, as when the controller receives commands from the user and provides visual, auditory or tactile feedback to the user; (3) analyzing TNSS data, as well as other feedback data such as from the user, within the TNSS, and/or the controller and/or the cloud; (4) making decisions about the appropriate treatment; (5) system diagnostics for operational correctness; and (6) communications with other controllers or users via the Internet cloud for data transmission or exchange, or to interact with apps residing in the Internet cloud.

[0012] The control loop is closed. This is as a result of having both stimulating and sensing. The sensing provides information about the effects of stimulation, allowing the stimulation to be adjusted to a desired level or improved automatically.

[0013] Typically, stimulation will be applied. Sensing will be used to measure the effects of stimulation. The measurements sensed will be used to specify the next stimulation. This process can be repeated indefinitely with various durations of each part. For example: rapid cycling through the process (a-b-c-a-b-c-a-b-c); prolonged stimulation, occasional sensing (aaaa-b-c-aaaa-b-c-aaaa-b-c); or prolonged sensing, occasional stimulation (a-bbbb-c-a-bbbb-c-a-bbbb). The process may also start with sensing, and when an event in the body is detected this information is used to specify stimulation to treat or correct the event, for example, (bbbbbbbb-c-

a-bbbbbbb-b-c-a-bbbbbbb). Other patterns are possible and contemplated within the scope of the application.

[0014] The same components can be used for stimulating and sensing alternately, by switching their connection between the stimulating circuits and the sensing circuits. The switching can be done by standard electronic components. In the case of electrical stimulating and sensing, the same electrodes can be used for both. An electronic switch is used to connect stimulating circuits to the electrodes and electric stimulation is applied to the tissues. Then the electronic switch disconnects the stimulating circuits from the electrodes and connects the sensing circuits to the electrodes and electrical signals from the tissues are recorded.

[0015] In the case of acoustic stimulating and sensing, the same ultrasonic transducers can be used for both (as in ultrasound imaging or radar). An electronic switch is used to connect circuits to the transducers to send acoustic signals (sound waves) into the tissues. Then the electronic switch disconnects these circuits from the transducers and connects other circuits to the transducers (to listen for reflected sound waves) and these acoustic signals from the tissues are recorded.

[0016] Other modalities of stimulation and sensing may be used (e.g. light, magnetic fields, etc) The closed loop control may be implemented autonomously by an individual TNSS or by multiple TNSS modules operating in a system such as that shown below in Fig 16. Sensing might be carried out by some TNSSs and stimulation by others.

[0017] Stimulators are protocol controlled initiators of electrical stimulation, where such protocol may reside in either the TNSS and/or the controller and/or the cloud. Stimulators interact with associated sensors or activators, such as electrodes or MEMS devices.

[0018] The protocol, which may be located in the TNSS, the controller or the cloud, has several functions including:

(1) Sending activation or disablement signals between the controller and the TNSS via a local network such as Bluetooth. The protocol sends a signal by Bluetooth radio waves from the smartphone to the TNSS module on the skin, telling it to start or stop stimulating or sensing. Other wireless communication types are possible.

(2) Driving the user interface, as when the controller receives commands from the user and provides visual, auditory or tactile feedback to the user. The protocol receives a command from the user when the user touches an icon on the smartphone screen, and provides feedback to the user by displaying information on the smartphone screen, or causing the smartphone to beep or buzz.

(3) Analyzing TNSS data, as well as other feedback data such as from the user, within the TNSS, and/or

the controller and/or the cloud. The protocol analyzes data sensed by the TNSS, such as the position of a muscle, and data from the user such as the user's desires as expressed when the user touches an icon on the smartphone; this analysis can be done in the TNSS, in the smartphone, and/or in the cloud.

(4) Making decisions about the appropriate treatment. The protocol uses the data it analyzes to decide what stimulation to apply.

(5) System diagnostics for operational correctness. The protocol checks that the TNSS system is operating correctly.

(6) Communications with other controllers or users via the Internet cloud for data transmission or exchange, or to interact with apps residing in the Internet cloud. The protocol communicates with other smartphones or people via the internet wirelessly; this may include sending data over the internet, or using computer programs that are operating elsewhere on the internet.

[0019] A neurological control system and apparatus are configured in an ecosystem or modular platform that uses potentially disposable topical devices to provide interfaces between electronic computing systems and neural systems. These interfaces may be direct electrical connections via electrodes or may be indirect via transducers (sensors and actuators). It may have the following elements in various configurations: electrodes for sensing or activating electrical events in the body; actuators of various modalities; sensors of various modalities; wireless networking; and protocol applications, e.g. for data processing, recording, control systems. These components are integrated within the disposable topical device. This integration allows the topical device to function autonomously. It also allows the topical device along with a remote control unit (communicating wirelessly via an antenna, transmitter and receiver) to function autonomously.

[0020] Referring to Figure 1, nerve cells are normally electrically polarized with the interior of the nerve being at an electric potential 70mV negative relative to the exterior of the cell. Application of a suitable electric voltage to a nerve cell (raising the resting potential of the cell from -70mV to above the firing threshold of -55mV) can initiate a sequence of events in which this polarization is temporarily reversed in one region of the cell membrane and the change in polarization spreads along the length of the cell to influence other cells at a distance, e.g. to communicate with other nerve cells or to cause or prevent muscle contraction.

[0021] Referring to Figure 2, graphically represents a nerve impulse from a point of stimulation resulting in a wave of depolarization followed by a repolarization that travels along the membrane of a neuron during the meas-

ured period. This spreading action potential is a nerve impulse. It is this phenomenon that allows for external electrical nerve stimulation.

[0022] Referring to Figure 3, the dorsal genital nerve on the back of the penis or clitoris just under the skin is a purely sensory nerve that is involved in normal inhibition of the activity of the bladder during sexual activity, and electrical stimulation of this nerve has been shown to reduce the symptoms of the Over Active Bladder. Stimulation of the underside of the penis may cause sexual arousal, erection, ejaculation and orgasm.

[0023] A Topical nerve stimulator/sensor (TNSS) is used to stimulate these nerves and is convenient, unobtrusive, self-powered, controlled from a smartphone or other control device. This has the advantage of being non-invasive, controlled by consumers themselves, and potentially distributed over the counter without a prescription.

[0024] Referring to Figure 4, the TNSS has one or more electronic circuits or chips that perform the functions of: communications with the controller, nerve stimulation via one or more electrodes 408 that produce a wide range of electric field(s) according to treatment regimen, one or more antennae 410 that may also serve as electrodes and communication pathways, and a wide range of sensors 406 such as, but not limited to, mechanical motion and pressure, temperature, humidity, chemical and positioning sensors. One arrangement would be to integrate a wide variety of these functions into an SOC, system on chip 400. Within this is shown a control unit 402 for data processing, communications and storage and one or more stimulators 404 and sensors 406 that are connected to electrodes 408. An antenna 410 is incorporated for external communications by the control unit. Also present is an internal power supply 412, which may be, for example, a battery. An external power supply is another variation of the chip configuration. It may be necessary to include more than one chip to accommodate a wide range of voltages for data processing and stimulation. Electronic circuits and chips will communicate with each other via conductive tracks within the device capable of transferring data and/or power.

[0025] In one or more examples, a Smart Band Aid™ incorporating a battery and electronic circuit and electrodes in the form of adhesive conductive pads may be applied to the skin, and electrical stimuli is passed from the adhesive pads into the tissues. Stimuli may typically be trains of voltage-regulated square waves at frequencies between 15 and 50Hz with currents between 20 and 100 mA. The trains of stimuli are controlled from a smartphone operated by the user. Stimuli may be either initiated by the user when desired, or programmed according to a timed schedule, or initiated in response to an event detected by a sensor on the Smart Band Aid™ or elsewhere. Another implementation for males may be a TNSS incorporated in a ring that locates a stimulator conductively to selected nerves in a penis to be stimulated.

[0026] Referring to Figure 5, limited lifetime battery

sources will be employed as internal power supply 412, to power the TNSS deployed in this illustration as a Smart Band Aid™. These may take the form of Lithium Ion technology or traditional non-toxic MnO2 technologies. Figure 5 illustrates different battery options such as a printable Manganese Oxide battery 516 and a button battery 518. A TNSS of different shapes may require different battery packaging.

[0027] Figure 6 shows an alternate arrangement of these components where the batteries 616- 618 are positioned on the bottom side of the SBA between the electrodes 610 and 620. In this example, battery 616 is a lithium ion battery, battery 617 is a MnO2 battery and battery 618 is a button battery. Other types of batteries and other battery configurations are possible within the scope of this application in other examples.

[0028] Aside from the Controller, the Smart Band Aid™ Packaging Platform consists of an assembly of an adhesive patch capable of being applied to the skin and containing the TNSS Electronics, protocol, and power described above.

[0029] Referring to Figure 7 is a TNSS deployed as a Smart Band Aid™ 414. The Smart Band Aid™ has a substrate with adhesive on a side for adherence to skin, the SOC 400 previously described in Figure 4, or electronic package, and one or more electrodes 408 disposed between the dermis and the adhesive surface. The electrodes provide electrical stimuli through the dermis to nerves and other tissue and in turn may collect electrical signals from the body, such as the electrical signals produced by muscles when they contract (the electromyogram) to provide data about body functions such as muscle actions.

[0030] Referring to Figure 8, different chips may be employed to design requirements. Shown are sample chips for packaging in a TNSS in this instance deployed as a SBA. For example, neural stimulator 800, sensor 802, processor/communications 804 are represented. The chips can be packaged separately on a substrate, including a flexible material, or as a system-on-chip (SOC) 400. The chip connections and electronics package are not shown but are known in the art.

[0031] Referring to Figure 9 SBAs with variations on arrangements of electrodes are shown. Each electrode may consist of a plurality of conductive contacts that give the electrode abilities to adjust the depth, directionality, and spatial distribution of the applied electric field. For all the example electrode configurations shown, 901-904, the depth of the electrical stimulation can be controlled by the voltage and power applied to the electrode contacts. Electric current can be applied to various electrode contacts at opposite end of the SBA, or within a plurality of electrode contacts on a single end of the SBA. The phase relationship of the signals applied to the electrode contacts can vary the directionality of the electric field. For all configurations of electrodes, the applied signals can vary over time and spatial dimensions. The configuration on the left, 901, shows a plurality of con-

centric electrode contacts at either end of the SBA. This configuration can be used to apply an electric stimulating field at various tissue depths by varying the power introduced to the electrode contacts. The next configuration, 902, shows electrodes 404 that are arranged in a plurality of parallel strips of electrical contacts. This allows the electric field to be oriented perpendicular or parallel to the SBA. The next configuration, 903, shows an example matrix of electrode contacts where the applied signal can generate a stimulating field between any two or more electrode contacts at either end of the SBA, or between two or more electrode contacts within a single matrix at one end of the SBA. Finally, the next configuration on the far right, 904, also shows electrodes that are arranged in a plurality of parallel strips of electrical contacts. As with the second configuration, this allows the electric field to be oriented perpendicular or parallel to the SBA. There may be many other arrangements of electrodes and contacts.

[0032] One or more TNSSs with one or more Controllers form a System. Systems can communicate and interact with each other and with distributed virtualized processing and storage services. This enables the gathering, exchange, and analysis of data among populations of systems for medical and non-medical applications.

[0033] Referring to Figure 10, a system is shown with two TNSS units 1006, with one on the wrist, one on the leg, communicating with its controller, a smartphone 1000 or other control device. The TNSS units can be both sensing and stimulating and can act independently and also work together in a Body Area Network (BAN). Systems communicate with each other over a communication bridge or network such as a cellular network. Systems also communicate with applications running in a distributed virtualized processing and storage environment generally via the Internet 1002. The purpose for communications with the distributed virtualized processing and storage environment is to communicate large amounts of user data for analysis and networking with other third parties such as hospitals, doctors, insurance companies, researchers, and others. There are applications that gather, exchange, and analyze data from multiple Systems 1004. Third party application developers can access TNSS systems and their data to deliver a wide range of applications. These applications can return data or control signals to the individual wearing the TNSS unit 1006. These applications can also send data or control signals to other members of the population who employ systems 1008. This may represent an individual's data, aggregated data from a population of users, data analyses, or supplementary data from other sources.

[0034] Referring to Figure 11, shown is an example of an electrode array to affect beam forming and beam steering. Beam forming and steering allows a more selective application of stimulation energy by a TNSS to nerves and tissue. Beam steering also provides the opportunity for lower power for stimulation of cells including nerves by applying the stimulating mechanism direction-

ally to a target. In the use of an electrical beam lower power demand lengthens battery life and allows for use of low power chip sets. Beam steering may be accomplished in multiple ways for instance by magnetic fields and formed gates. Figure 11 shows a method for forming and steering a beam by the use of a plurality of radiators 1102 which are activated out of phase with each other by a plurality of phase shifters 1103 that are supplied power from a common source 1104. Because the radiated signals are out of phase they produce an interference pattern 1105 that results in the beam being formed and steered in varying controlled directions 1106. Electromagnetic radiation like light shows some properties of waves and can be focused on certain locations. This provides the opportunity to stimulate tissues such as nerves selectively. It also provides the opportunity to focus the transmission of energy and data on certain objects, including topical or implanted electronic devices, thereby not only improving the selectivity of activating or controlling those objects but also reducing the overall power required to operate them.

[0035] Figure 12 is another example of a gating structure 1200 used for beam shaping and steering 1202. The gating structure 1200 shows an example of an interlocked pair of electrodes that can be used for simple beam forming through the application of time-varying voltages. The steering 1202 shows a generic picture of the main field lobes and how such beam steering works in this example. Figure 12 is illustrative of a possible example that may be used.

[0036] The human and mammal body is an anisotropic medium with multiple layers of tissue of varying electrical properties. Steering of an electric field may be accomplished using multiple electrodes, or multiple SBAs, using the human or mammal body as an anisotropic volume conductor. Electric field steering will be discussed below with reference to Figures 18 and 19.

[0037] Referring to Figure 13, the controller is an electronics platform that is a smartphone 1300, tablet 1302, personal computer 1304, or dedicated module 1306 that hosts wireless communications capabilities, such as Near Field Communications, Bluetooth, or Wi-Fi technologies as enabled by the current set of communications chips, e.g. Broadcom BCM4334, TI WiLink 8 and others, and a wide range of protocol apps that can communicate with the TNSSs. There may be more than one controller, acting together. This may occur, for example, if the user has both a smartphone control app running, and a key fob controller in his/her pocket/purse.

[0038] TNSS protocol performs the functions of communications with the controller including transmitting and receiving of control and data signals, activation and control of the neural stimulation, data gathering from on board sensors, communications and coordination with other TNSSs, and data analysis. Typically the TNSS may receive commands from the controller, generate stimuli and apply these to the tissues, sense signals from the tissues, and transmit these to the controller. It may also

analyze the signals sensed and use this information to modify the stimulation applied. In addition to communicating with the controller it may also communicate with other TNSSs using electrical or radio signals via a body area network.

[0039] Referring to Figure 14, controller protocol executed and/or displayed on a smartphone 1400, tablet 1402 or other computing platform or mobile device, will perform the functions of communications with TNSS modules including transmitting and receiving of control and data signals, activation and control of the neuro modulation regimens, data gathering from on board sensors, communications and coordination with other controllers, and data analysis. In some cases local control of the neuro modulation regimens may be conducted by controller protocol without communications with the user.

[0040] Fig 15 shows potential applications of electrical stimulation and sensing for the body, particularly for users who may suffer from paralysis or loss of sensation or altered reflexes such as spasticity or tremor due to neurological disorders and their complications, as well as users suffering from incontinence, pain, immobility and aging. Different example medical uses of the present system are discussed below.

[0041] Figure 16 shows the components of one example of a typical TNSS system 1600. TNSS devices 1610 are responsible for stimulation of nerves and for receiving data in the form of electrical, acoustic, imaging, chemical and other signals which then can be processed locally in the TNSS or passed to the Control Unit 1620. TNSS devices 1610 are also responsible for analysis and action. The TNSS device 1610 may contain a plurality of electrodes for stimulation and for sensing. The same electrodes may be used for both functions, but this is not required. The TNSS device 1610 may contain an imaging device, such as an ultrasonic transducer to create acoustic images of the structure beneath the electrodes or elsewhere in the body that may be affected by the neural stimulation.

[0042] In this example TNSS system, most of the data gathering and analysis is performed in the Control Unit 1620. The Control Unit 1620 may be a cellular telephone or a dedicated hardware device. The Control Unit 1620 runs an app that controls the local functions of the TNSS System 1600. The protocol app also communicates via the Internet or wireless networks 1630 with other TNSS systems and/or with 3rd party software applications.

[0043] Figure 17 shows the communications among the components of the TNSS system 1600 and the user. In this example, TNSS 1610 is capable of applying stimuli to nerves 1640 to produce action potentials in the nerves 1640 to produce actions in muscles 1670 or other organs such as the brain 1650. These actions may be sensed by the TNSS 1610, which may act on the information to modify the stimulation it provides. This closed loop constitutes the first level of the system 1600 in this example.

[0044] The TNSS 1610 may also be caused to operate by signals received from a Control Unit 1620 such as a

cellphone, laptop, key fob, tablet, or other handheld device and may transmit information that it senses back to the Control Unit 1620. This constitutes the second level of the system 1600 in this example.

[0045] The Control Unit 1620 is caused to operate by commands from a user, who also receives information from the Control Unit 1620. The user may also receive information about actions of the body via natural senses such as vision or touch via sensory nerves and the spinal cord, and may in some cases cause actions in the body via natural pathways through the spinal cord to the muscles.

[0046] The Control Unit 1620 may also communicate information to other users, experts, or application programs via the Internet 1630, and receive information from them via the Internet 1630.

[0047] The user may choose to initiate or modify these processes, sometimes using protocol applications residing in the TNSS 1610, the Control Unit 1620, the Internet 1630, or wireless networks. This software may assist the user, for example by processing the stimulation to be delivered to the body to render it more selective or effective for the user, and/or by processing and displaying data received from the body or from the Internet 1630 or wireless networks to make it more intelligible or useful to the user.

[0048] Figure 18 shows an example electrode configuration 1800 for Electric Field Steering. The application of an appropriate electric field to the body can cause a nerve to produce an electrical pulse known as an action potential. The shape of the electric field is influenced by the electrical properties of the different tissue through which it passes and the size, number and position of the electrodes used to apply it. The electrodes can therefore be designed to shape or steer or focus the electric field on some nerves more than on others, thereby providing more selective stimulation.

[0049] An example 10x10 matrix of electrical contacts 1860 is shown. By varying the pattern of electrical contacts 1860 employed to cause an electric field 1820 to form and by time varying the applied electrical power to this pattern of contacts 1860, it is possible to steer the field 1820 across different parts of the body, which may include muscle 1870, bone, fat, and other tissue, in three dimensions. This electric field 1820 can activate specific nerves or nerve bundles 1880 while sensing the electrical and mechanical actions produced 1890, and thereby enabling the TNSS to discover more effective or the most effective pattern of stimulation for producing the desired action.

[0050] Figure 19 shows a example of stimulating and sensing patterns of signals in a volume of tissue. Electrodes 1910 as part of a cuff arrangement are placed around limb 1915. The electrodes 1910 are external to a layer of skin 1916 on limb 1915. Internal components of the limb 1915 include muscle 1917, bone 1918, nerves 1919, and other tissues. By using electric field steering for stimulation, as described with reference to Figure 18,

the electrodes 1910 can activate nerves 1919 selectively. An array of sensors (e.g. piezoelectric sensors or micro-electro-mechanical sensors) in a TNSS can act as a phased array antenna for receiving ultrasound signals, to acquire ultrasonic images of body tissues. Electrodes 1910 may act as an array of electrodes sensing voltages at different times and locations on the surface of the body, with software processing this information to display information about the activity in body tissues, e.g. which muscles are activated by different patterns of stimulation. [0051] The SBA's ability to stimulate and collect organic data has multiple applications including bladder control, reflex incontinence, sexual stimulations, pain control and wound healing among others. Examples of SBA's application for medical and other uses follow.

MEDICAL USES

Bladder management

[0052]

1) Overactive bladder: When the user feels a sensation of needing to empty the bladder urgently, he or she presses a button on the Controller to initiate stimulation via a Smart Band Aid™ applied over the dorsal nerve of the penis or clitoris. Activation of this nerve would inhibit the sensation of needing to empty the bladder urgently, and allow it to be emptied at a convenient time.

2) Incontinence: A person prone to incontinence of urine because of unwanted contraction of the bladder uses the SBA to activate the dorsal nerve of the penis or clitoris to inhibit contraction of the bladder and reduce incontinence of urine. The nerve could be activated continuously, or intermittently when the user became aware of the risk of incontinence, or in response to a sensor indicating the volume or pressure in the bladder.

[0053] Erection, ejaculation and orgasm: Stimulation of the nerves on the underside of the penis by a Smart Band Aid™ (electrical stimulation or mechanical vibration) can cause sexual arousal and might be used to produce or prolong erection and to produce orgasm and ejaculation.

[0054] Pain control: A person suffering from chronic pain from a particular region of the body applies a Smart Band Aid™ over that region and activates electrically the nerves conveying the sensation of touch, thereby reducing the sensation of pain from that region. This is based on the gate theory of pain.

[0055] Wound care: A person suffering from a chronic wound or ulcer applies a Smart Band Aid™ over the wound and applies electrical stimuli continuously to the tissues surrounding the wound to accelerate healing and reduce infection.

[0056] Essential tremor: A sensor on a Smart Band Aid™ detects the tremor and triggers neuro stimulation to the muscles and sensory nerves involved in the tremor with an appropriate frequency and phase relationship to the tremor. The stimulation frequency would typically be at the same frequency as the tremor but shifted in phase in order to cancel the tremor or reset the neural control system for hand position.

[0057] Reduction of spasticity: Electrical stimulation of peripheral nerves can reduce spasticity for several hours after stimulation. A Smart Band Aid™ operated by the patient when desired from a smartphone could provide this stimulation.

[0058] Restoration of sensation and sensory feedback: People who lack sensation, for example as a result of diabetes or stroke use a Smart Band Aid™ to sense movement or contact, for example of the foot striking the floor, and the SBA provides mechanical or electrical stimulation to another part of the body where the user has sensation, to improve safety or function. Mechanical stimulation is provided by the use of acoustic transducers in the SBA such as small vibrators. Applying a Smart Band Aid™ to the limb or other assistive device provides sensory feedback from artificial limbs. Sensory feedback can also be used to substitute one sense for another, e.g. touch in place of sight.

[0059] Recording of mechanical activity of the body: Sensors in a Smart Band Aid™ record position, location and orientation of a person or of body parts and transmit this data to a smartphone for the user and/or to other computer networks for safety monitoring, analysis of function and coordination of stimulation.

[0060] Recording of sound from the body or reflections of ultrasound waves generated by a transducer in a Smart Band Aid™ could provide information about body structure, e.g. bladder volume for persons unable to feel their bladder. Acoustic transducers may be piezoelectric devices or MEMS devices that transmit and receive the appropriate acoustic frequencies. Acoustic data may be processed to allow imaging of the interior of the body.

RECORDING OF ELECTRICAL ACTIVITY OF THE BODY

[0061] Electrocardiogram: Recording the electrical activity of the heart is widely used for diagnosing heart attacks and abnormal rhythms. It is sometimes necessary to record this activity for 24 hours or more to detect uncommon rhythms. A Smart Band Aid™ communicating wirelessly with a smartphone or computer network achieves this more simply than present systems.

[0062] Electromyogram: Recording the electrical activity of muscles is widely used for diagnosis in neurology and also used for movement analysis. Currently this requires the use of many needles or adhesive pads on the surface of the skin connected to recording equipment by many wires. Multiple Smart Band Aids™ record the electrical activity of many muscles and transmit this informa-

tion wirelessly to a smartphone.

[0063] Recording of optical information from the body: A Smart Band Aid™ incorporating a light source (LED, laser) illuminates tissues and senses the characteristics of the reflected light to measure characteristics of value, e.g. oxygenation of the blood, and transmit this to a cell-phone or other computer network.

[0064] Recording of chemical information from the body: The levels of chemicals or drugs in the body or body fluids is monitored continuously by a Smart Band Aid™ sensor and transmitted to other computer networks and appropriate feedback provided to the user or to medical staff. Levels of chemicals may be measured by optical methods (reflection of light at particular wavelengths) or by chemical sensors.

SPECIAL POPULATIONS OF DISABLED USERS

[0065] There are many potential applications of electrical stimulation for therapy and restoration of function. However, few of these have been commercialized because of the lack of affordable convenient and easily controllable stimulation systems. Some applications are shown in the figure 15.

[0066] Limb Muscle stimulation: Lower limb muscles can be exercised by stimulating them electrically, even if they are paralyzed by stroke or spinal cord injury. This is often combined with the use of a stationary exercise cycle for stability. Smart Band Aid™ devices could be applied to the quadriceps muscle of the thigh to stimulate these, extending the knee for cycling, or to other muscles such as those of the calf. Sensors in the Smart Band Aid™ could trigger stimulation at the appropriate time during cycling, using an application on a smartphone"tablet, handheld hardware device such as a key fob, wearable computing device, laptop, or desktop computer, among other possible devices. Upper limb muscles can be exercised by stimulating them electrically, even if they are paralyzed by stroke of spinal cord injury. This is often combined with the use of an arm crank exercise machine for stability. Smart Band Aid™ devices are applied to multiple muscles in the upper limb and triggered by sensors in the Smart Band Aids™ at the appropriate times, using an application on a smartphone.

[0067] Prevention of osteoporosis: Exercise can prevent osteoporosis and pathological fractures of bones. This is applied using Smart Band Aids™ in conjunction with exercise machines such as rowing simulators, even for people with paralysis who are particularly prone to osteoporosis.

[0068] Prevention of deep vein thrombosis: Electric stimulation of the muscles of the calf can reduce the risk of deep vein thrombosis and potentially fatal pulmonary embolus. Electric stimulation of the calf muscles is applied by a Smart Band Aid™ with stimulation programmed from a smartphone, e.g. during a surgical operation, or on a preset schedule during a long plane flight.

RESTORATION OF FUNCTION (FUNCTIONAL ELECTRICAL STIMULATION)

Lower limb

[0069]

1) Foot drop: People with stroke often cannot lift their forefoot and drag their toes on the ground. A Smart Band Aid™ is be applied just below the knee over the common peroneal nerve to stimulate the muscles that lift the forefoot at the appropriate time in the gait cycle, triggered by a sensor in the Smart Band Aid™

2) Standing: People with spinal cord injury or some other paralyses can be aided to stand by electrical stimulation of the quadriceps muscles of their thigh. These muscles are stimulated by Smart Band Aids™ applied to the front of the thigh and triggered by sensors or buttons operated by the patient using an application on a smartphone. This may also assist patients to use lower limb muscles when transferring from a bed to a chair or other surface.

3) Walking: Patients with paralysis from spinal cord injury are aided to take simple steps using electrical stimulation of the lower limb muscles and nerves. Stimulation of the sensory nerves in the common peroneal nerve below the knee can cause a triple reflex withdrawal, flexing the ankle, knee and hip to lift the leg, and then stimulation of the quadriceps can extend the knee to bear weight. The process is then repeated on the other leg. Smart Band Aids™ coordinated by an application in a smartphone produce these actions.

Upper limb

[0070]

1) Hand grasp: People with paralysis from stroke or spinal cord injury have simple hand grasp restored by electrical stimulation of the muscles to open or close the hand. This is produced by Smart Band Aids™ applied to the back and front of the forearm and coordinated by sensors in the Smart Band Aids™ and an application in a smartphone.

2) Reaching: Patients with paralysis from spinal cord injury sometimes cannot extend their elbow to reach above the head. Application of a Smart Band Aid™ to the triceps muscle stimulates this muscle to extend the elbow. This is triggered by a sensor in the Smart Band Aid™ detecting arm movements and coordinating it with an application on a smartphone.

[0071] Posture: People whose trunk muscles are paralyzed may have difficulty maintaining their posture even

in a wheelchair. They may fall forward unless they wear a seatbelt, and if they lean forward they may be unable to regain upright posture. Electrical stimulation of the muscles of the lower back using a Smart Band Aid™ allows them to maintain and regain upright posture. Sensors in the Smart Band Aid™ trigger this stimulation when a change in posture was detected.

[0072] Coughing: People whose abdominal muscles are paralyzed cannot produce a strong cough and are at risk for pneumonia. Stimulation of the muscles of the abdominal wall using a Smart Band Aid™ could produce a more forceful cough and prevent chest infections. The patient using a sensor in a Smart Band Aid™ triggers the stimulation.

[0073] Essential Tremor: It has been demonstrated that neuro stimulation can reduce or eliminate the signs of ET. ET may be controlled using a TNSS. A sensor on a Smart Band Aid™ detects the tremor and trigger neuro stimulation to the muscles and sensory nerves involved in the tremor with an appropriate frequency and phase relationship to the tremor. The stimulation frequency is typically be at the same frequency as the tremor but shifted in phase in order to cancel the tremor or reset the neural control system for hand position.

NON-MEDICAL APPLICATIONS

Sports training

[0074] Sensing the position and orientation of multiple limb segments is used to provide visual feedback on a smartphone of, for example, a golf swing, and also mechanical or electrical feedback to the user at particular times during the swing to show them how to change their actions. The electromyogram of muscles could also be recorded from one or many Smart Band Aids™ and used for more detailed analysis.

Gaming

[0075] Sensing the position and orientation of arms, legs and the rest of the body produces a picture of an onscreen player that can interact with other players anywhere on the Internet. Tactile feedback would be provided to players by actuators in Smart Band Aids on various parts of the body to give the sensation of striking a ball, etc.

Motion Capture for film and animation

[0076] Wireless TNSS capture position, acceleration, and orientation of multiple parts of the body. This data may be used for animation of a human or mammal and has application for human factor analysis and design.

SAMPLE MODES OF OPERATION

[0077] A SBA system consists of at least a single Con-

troller and a single SBA. Following application of the SBA to the user's skin, the user controls it via the Controller's app using Near Field Communications. The app appears on a smartphone screen and can be touch controlled by the user; for 'key fob' type Controllers, the SBA is controlled by pressing buttons on the key fob.

[0078] When the user feels the need to activate the SBA s/he presses the "go" button two or more times to prevent false triggering, thus delivering the neuro stimulation. The neuro stimulation may be delivered in a variety of patterns of frequency, duration, and strength and may continue until a button is pressed by the user or may be delivered for a length of time set in the application.

[0079] Sensor capabilities in the TNSS, are enabled to start collecting/analyzing data and communicating with the controller when activated.

[0080] The level of functionality in the protocol app, and the protocol embedded in the TNSS, will depend upon the neuro modulation or neuro stimulation regimen being employed.

[0081] In some cases there will be multiple TNSSs employed for the neuro modulation or neuro stimulation regimen. The basic activation will be the same for each TNSS.

[0082] However, once activated multiple TNSSs will automatically form a network of neuro modulation/stimulation points with communications enabled with the controller.

[0083] The need for multiple TNSSs arises from the fact that treatment regimens may need several points of access to be effective.

[0084] While illustrative systems as described herein embodying various aspects of the present disclosure are shown, it will be understood by those skilled in the art, that the invention is not limited to these embodiments. Modifications may be made by those skilled in the art, particularly in light of the foregoing teachings. For example, each of the elements of the aforementioned embodiments may be utilized alone or in combination or sub-combination with elements of the other embodiments. It will also be appreciated and understood that modifications may be made without departing from the scope of the present disclosure as defined by the accompanying claims. The description is thus to be regarded as illustrative instead of restrictive on the present invention.

Claims

1. A topical nerve stimulator/sensor system comprising:

a flexible dermal patch (414) configured to be adhered to the skin of user and to stimulate one or more nerves of the user in proximity to the patch (414); the dermal patch comprising one or more electrodes (408, 610, 620) for contact with the skin;

an internal power supply (412, 518, 616, 617, 618)
 an electrical stimulus generator (404) integrated within the dermal patch (414); a nerve feedback sensor (406);
 a signal transceiver (402) configured to activate the electrical stimulus generator (404) and provide electrical stimulus via the electrode(s) (408, 610, 620);
 an antenna (410) in communication with the signal transceiver (402); and
 a remote electrical signal activation device (1000, 1300, 1302, 1304, 1306, 1400, 1402);

characterised in that:

(i) each of the internal power supply, the nerve feedback sensor (406), the signal transceiver (402), and the antenna (410) are integrated within the dermal patch (414); and
 (ii) the antenna (410) is also in communication with the remote electrical signal activation device to enable a user to activate the electrical stimulus generator (404) from a remote location.

2. The topical nerve stimulator system of claim 1 further comprising an integrated circuit (400) comprising the stimulus generator (404) and the signal transceiver (402).

Patentansprüche

1. Topisches Nervenstimulations/Sensorsystem, umfassend:

ein flexibles Hautpflaster (414), das konfiguriert ist, um auf die Haut eines Benutzers gehaftet zu werden, und um einen oder mehrere Nerven des Benutzers in der Nähe des Pflasters (414) zu stimulieren; wobei das Hautpflaster eine oder mehrere Elektroden (408, 610, 620) zum Kontakt mit der Haut umfasst;
 eine interne Stromversorgung (412, 518, 616, 617, 618)
 einen elektrischen Stimulusgenerator (404), der im Hautpflaster (414) integriert ist;
 einen Nerven-Feedback-Sensor (406);
 einen Signal-Transceiver (402), der konfiguriert ist, um den elektrischen Stimulusgenerator (404) zu aktivieren und einen elektrischen Stimulus mit Hilfe der Elektrode(n) (408, 610, 620) bereitzustellen;
 eine Antenne (410) in Kommunikation mit dem Signal-Transceiver (402); und
 eine Vorrichtung zur Aktivierung eines entfernten elektrischen Signals (1000, 1300, 1302, 1304, 1306, 1400, 1402);

dadurch gekennzeichnet, dass:

(i) jedes der internen Stromversorgung, des Nerven-Feedback-Sensors (406), des Signal-Transceivers (402) und der Antenne (410) im Hautpflaster (414) integriert ist; und
 (ii) die Antenne (410) auch mit der Vorrichtung zur Aktivierung des entfernten elektrischen Signals in Kommunikation steht, um einem Benutzer zu ermöglichen, den elektrischen Stimulus-Generator (404) von einer entfernten Stelle zu aktivieren.

2. Topisches Nerven-Stimulationssystem nach Anspruch 1, weiter umfassend eine integrierte Schaltung (400), umfassend den Stimulusgenerator (404) und den Signal-Transceiver (402).

Revendications

1. Système de capteur/stimulateur de nerf topique comprenant :

un timbre dermique souple (414) configuré pour être fixé à la peau d'un utilisateur et pour stimuler un ou plusieurs nerfs de l'utilisateur à proximité du timbre (414) ; le timbre dermique comprenant une ou plusieurs électrodes (408, 610, 620) pour le contact avec la peau ;
 une source d'énergie interne (412, 518, 616, 617, 618)
 un générateur de stimulus électrique (404) intégré à l'intérieur du timbre dermique (414) ;
 un capteur de rétroaction nerveuse (406) ;
 un émetteur-récepteur de signal (402) configuré pour activer le générateur de stimulus électrique (404) et fournir un stimulus électrique via l'électrode (les électrodes) (408, 610, 620) ;
 une antenne (410) en communication avec l'émetteur-récepteur de signal (402) ; et
 un dispositif d'activation de signal électrique distant (1000, 1300, 1302, 1304, 1306, 1400, 1402) ;

caractérisé en ce que :

(i) chacun de la source d'énergie interne, du capteur de rétroaction nerveuse (406), de l'émetteur-récepteur de signal (402), et de l'antenne (410) sont intégrés à l'intérieur du timbre dermique (414) ; et
 (ii) l'antenne (410) est également en communication avec le dispositif d'activation de signal électrique distant pour permettre à un utilisateur d'activer le générateur de stimulus électrique (404) d'un emplacement distant.

2. Système de stimulateur de nerf topique selon la revendication 1, comprenant en outre un circuit intégré (400) comprenant le générateur de stimulus (404) et l'émetteur-récepteur de signal (402).

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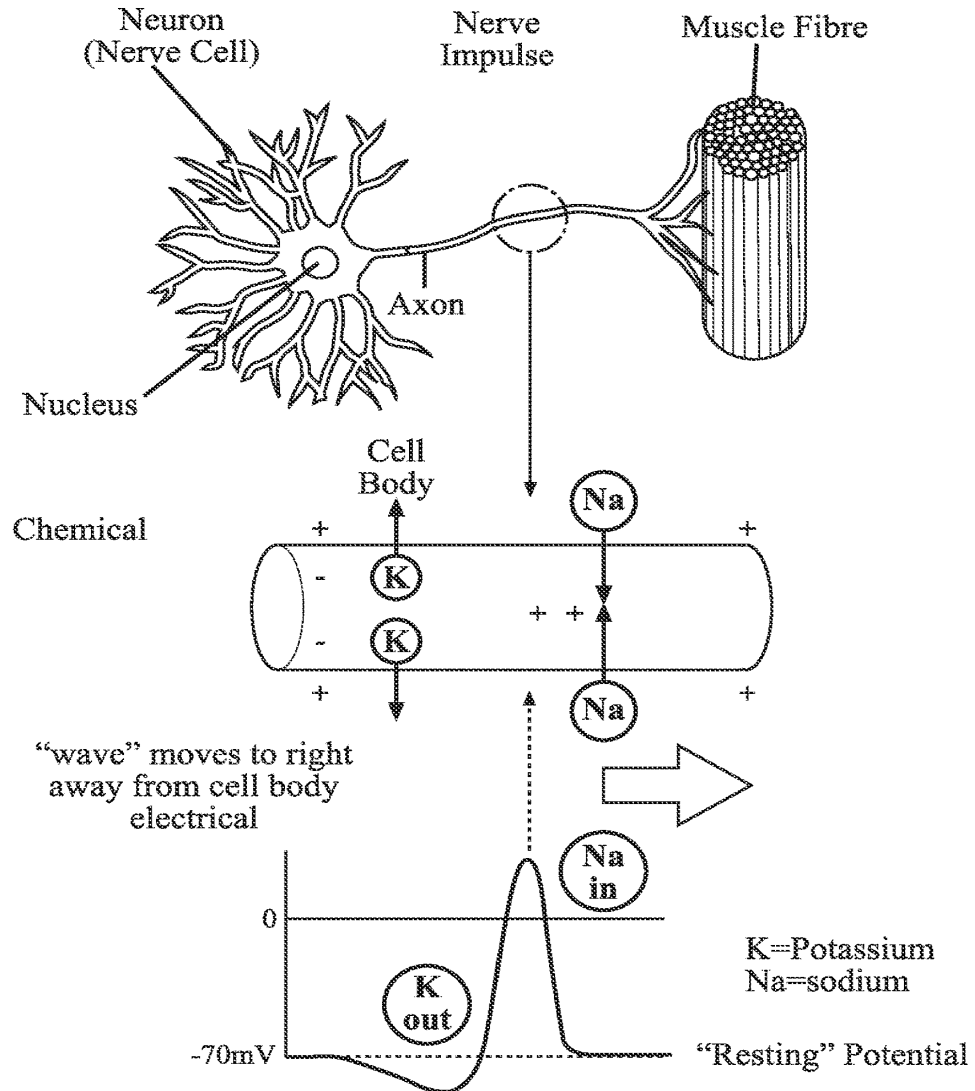


FIG. 1

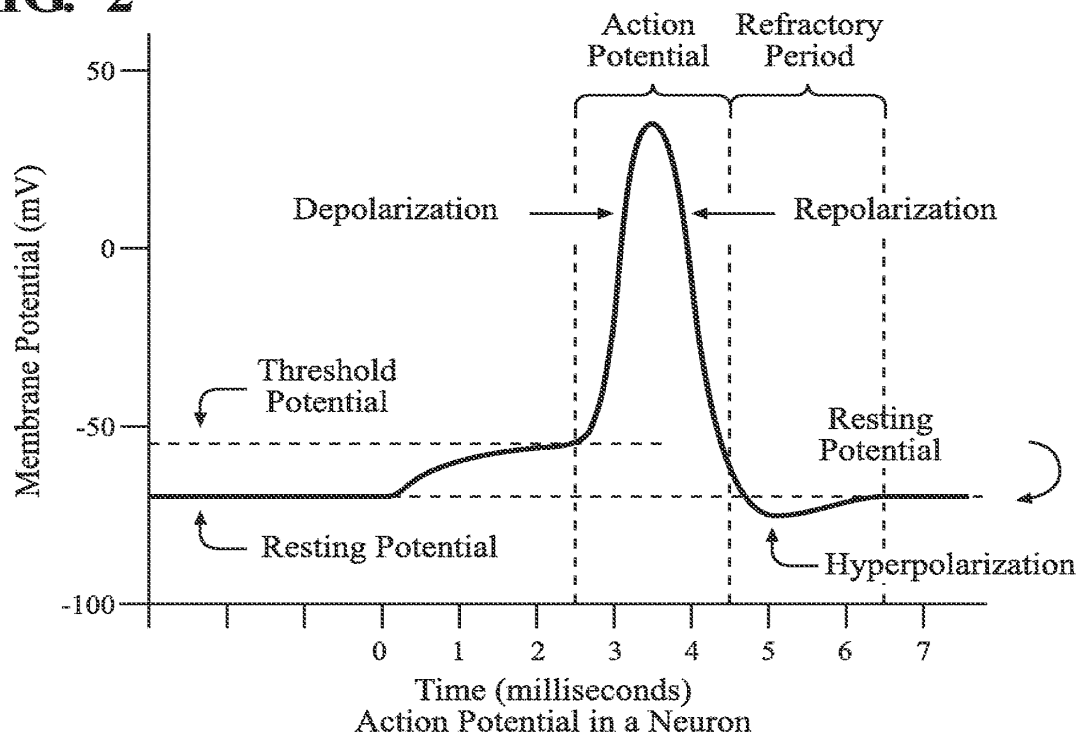
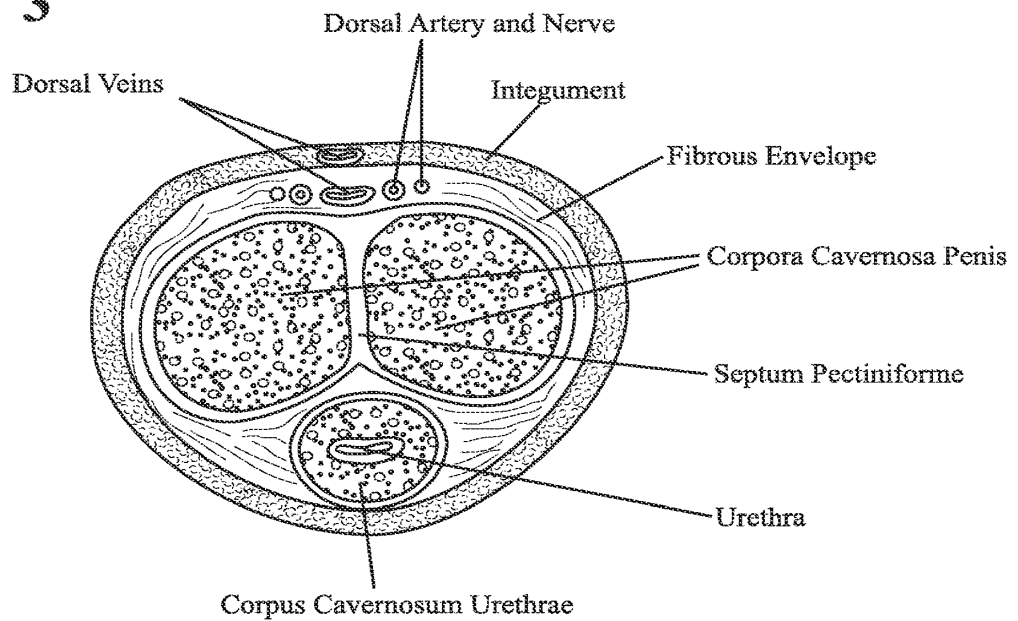
FIG. 2**FIG. 3**

FIG. 4

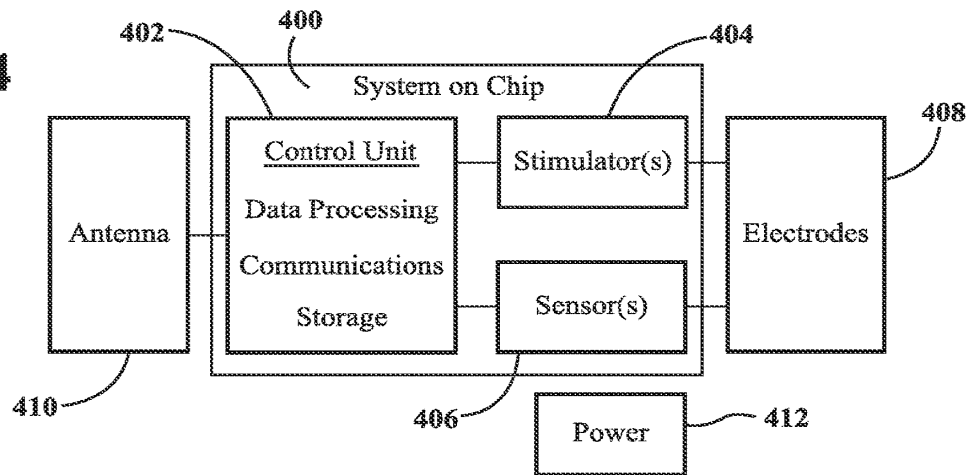


FIG. 5

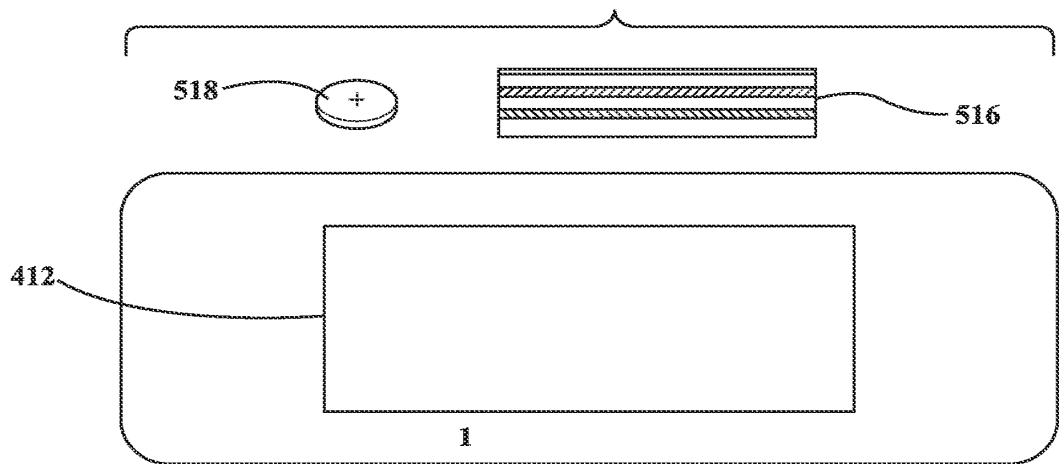


FIG. 6

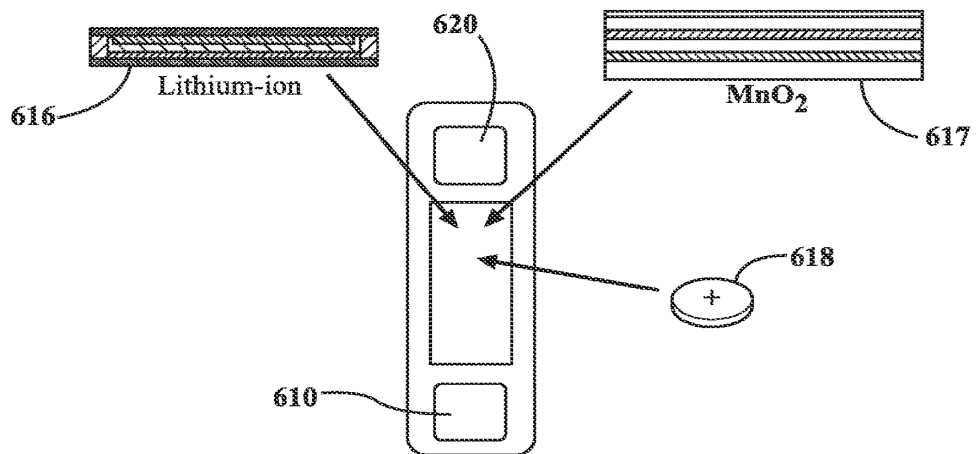


FIG. 7

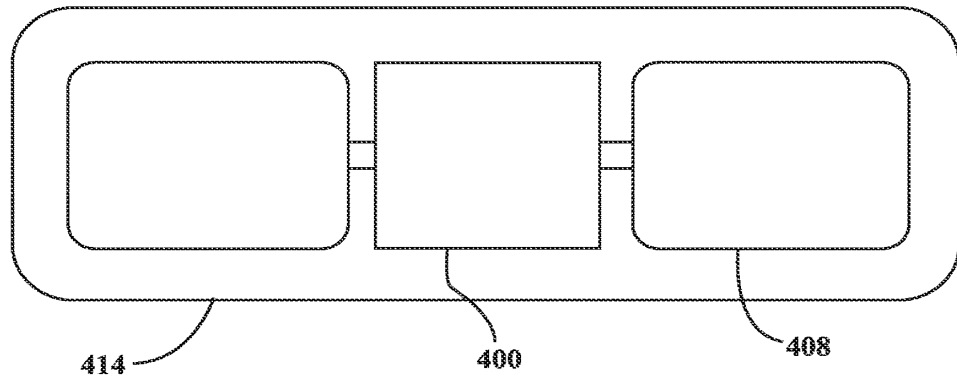


FIG. 8

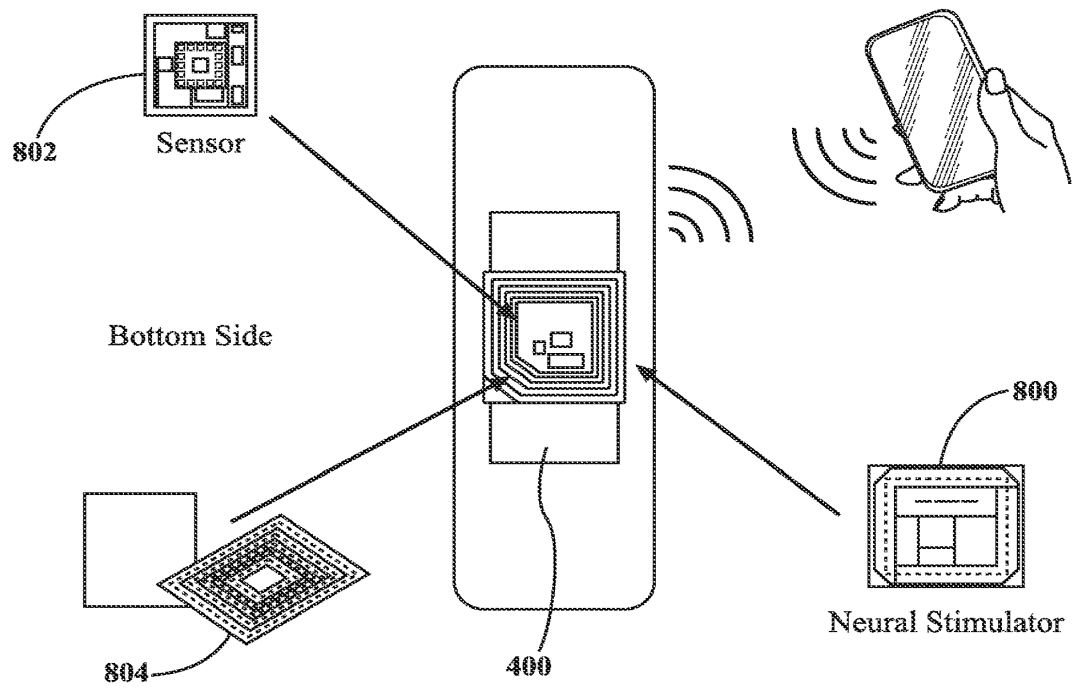


FIG. 9

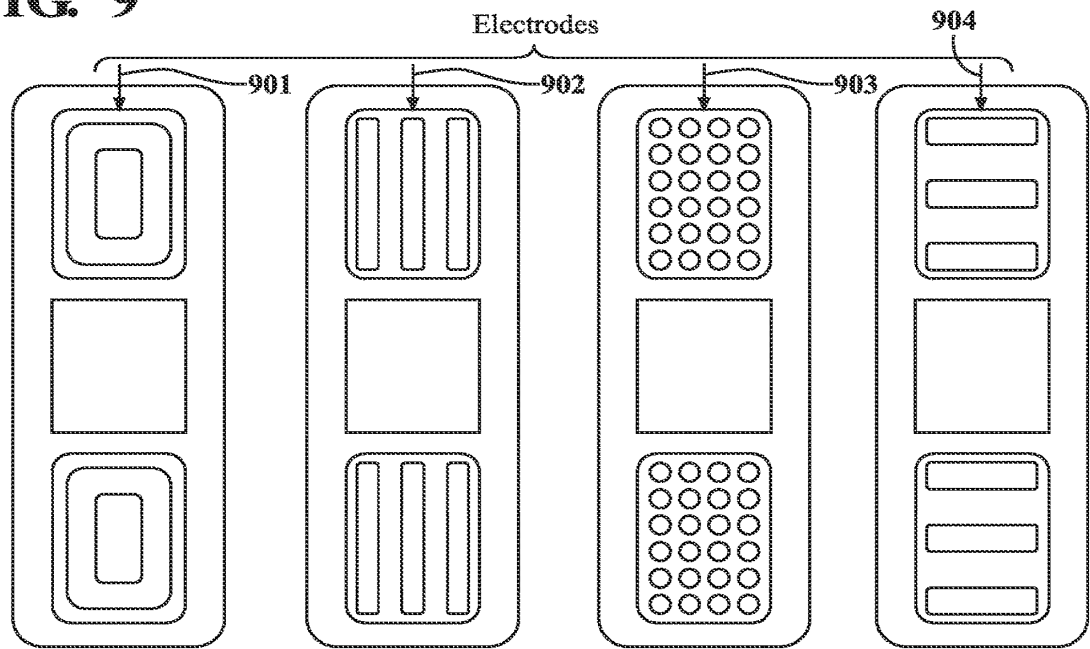
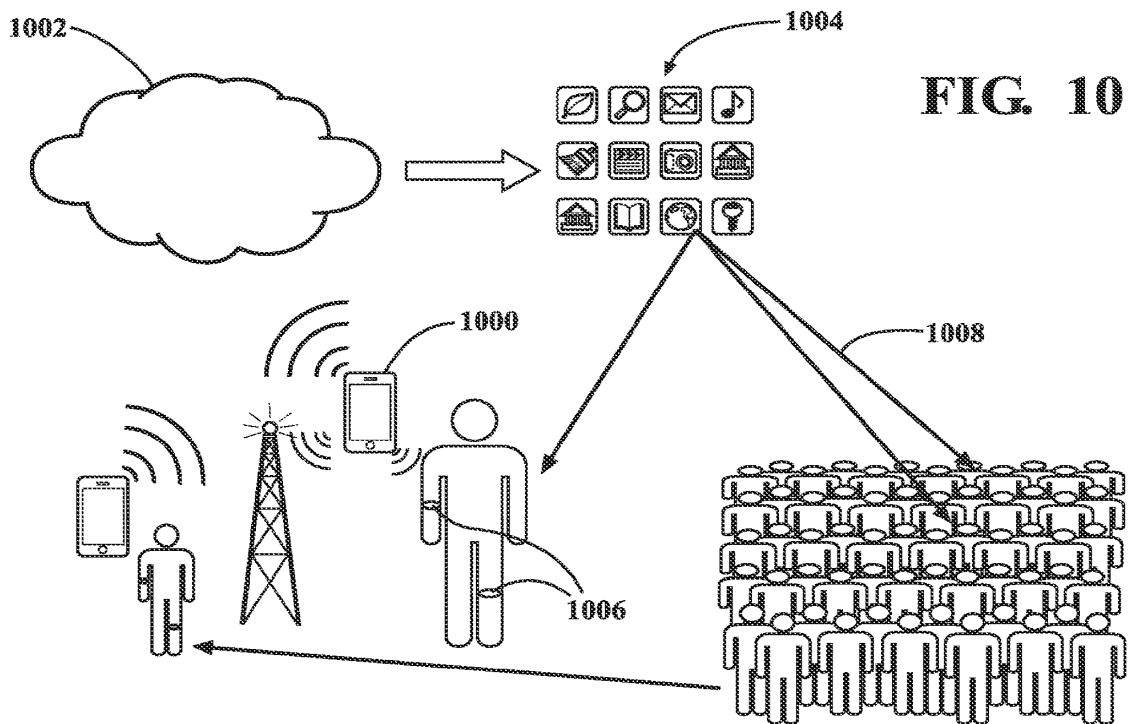


FIG. 11

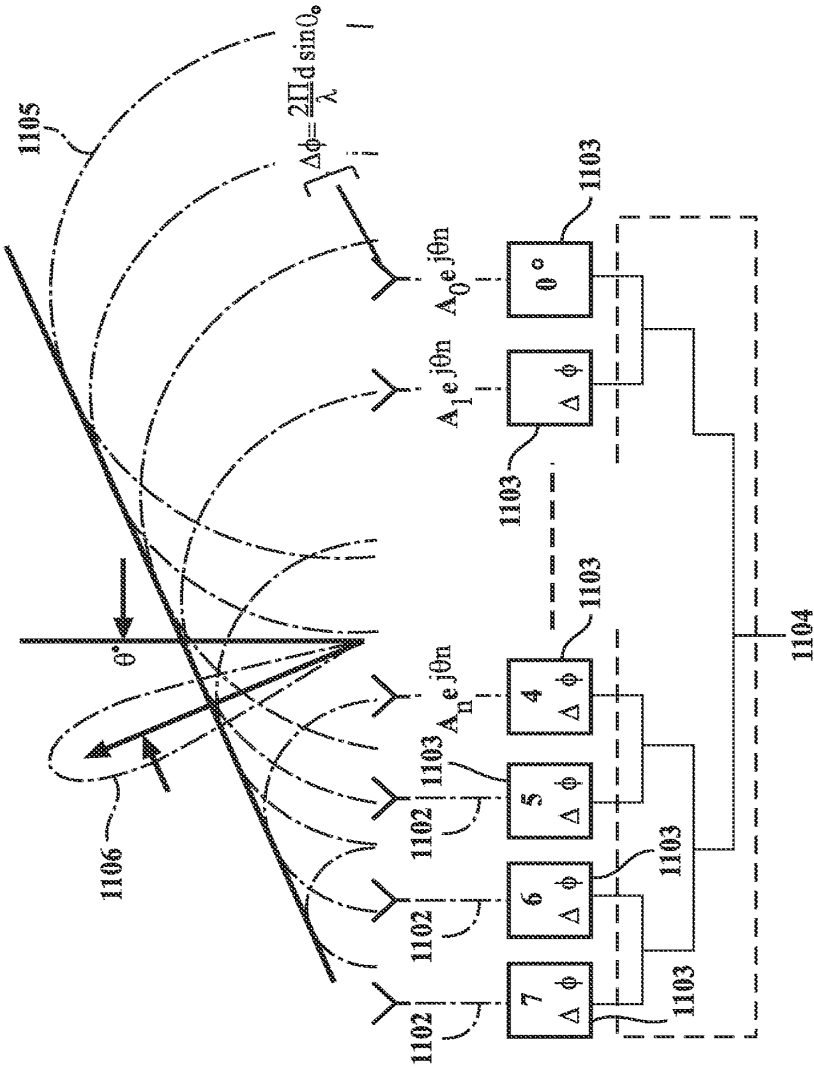


FIG. 12

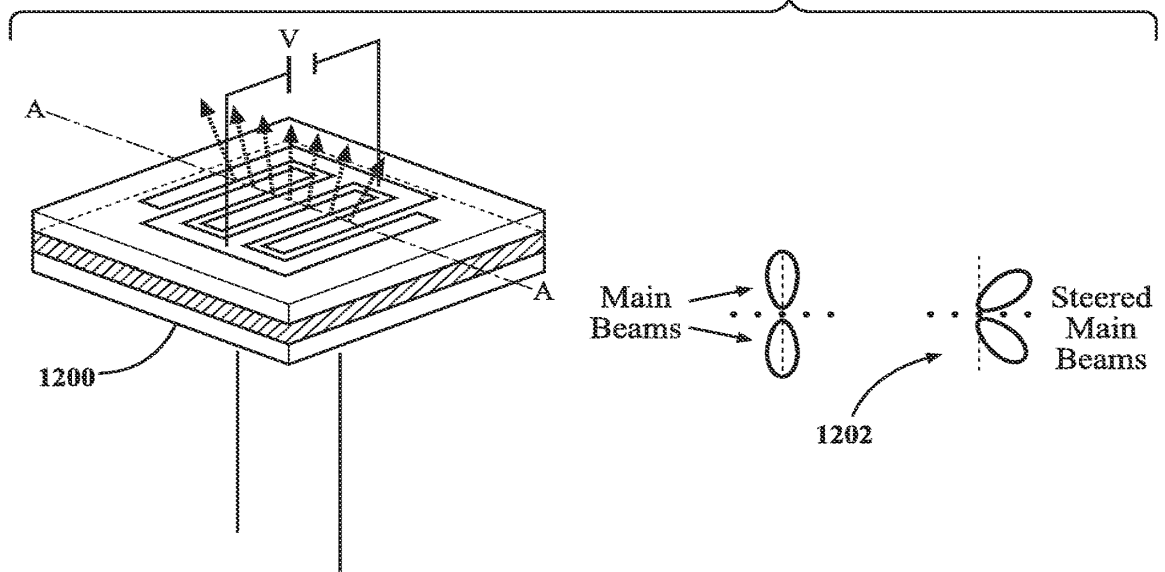
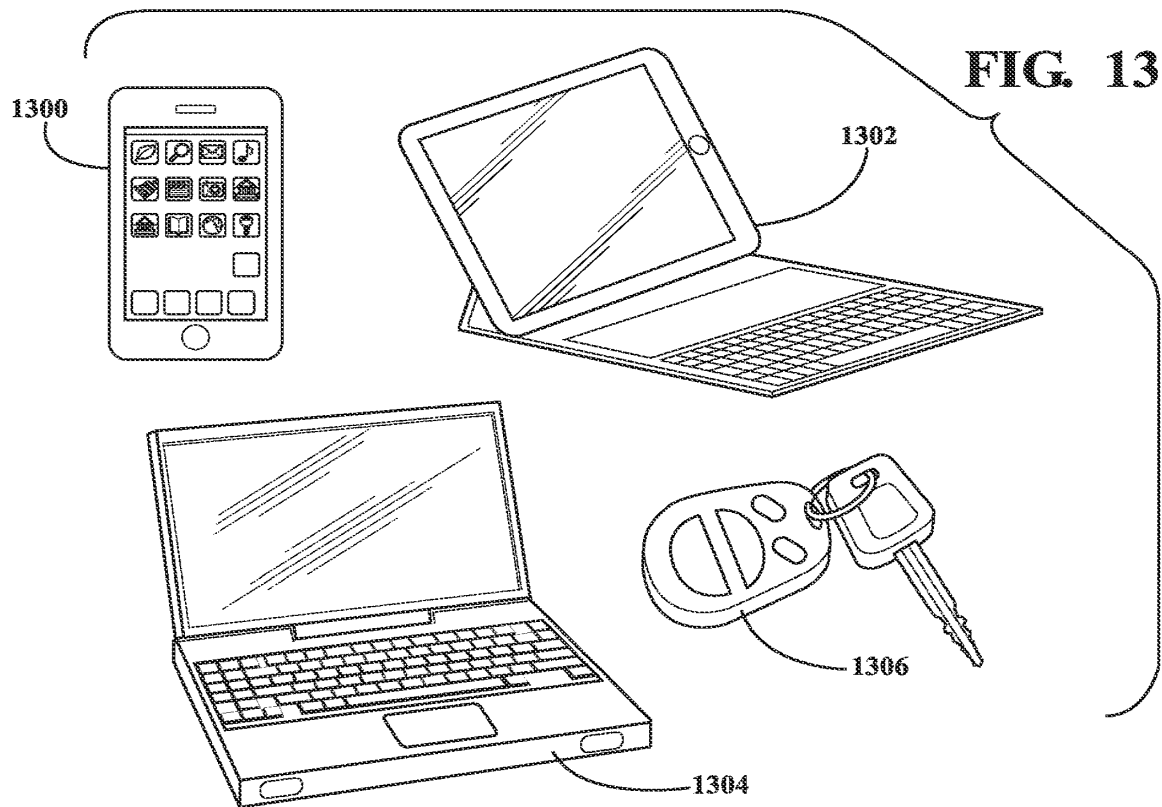


FIG. 13



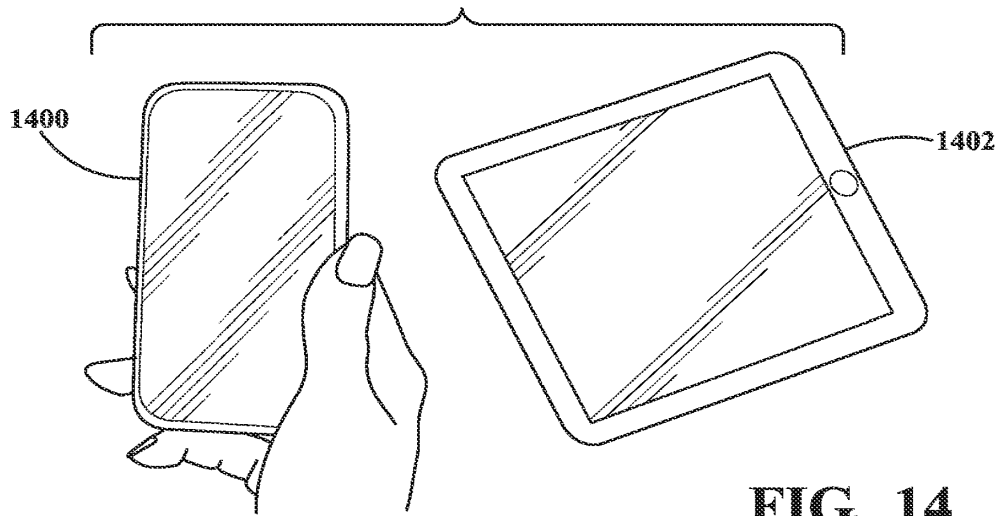
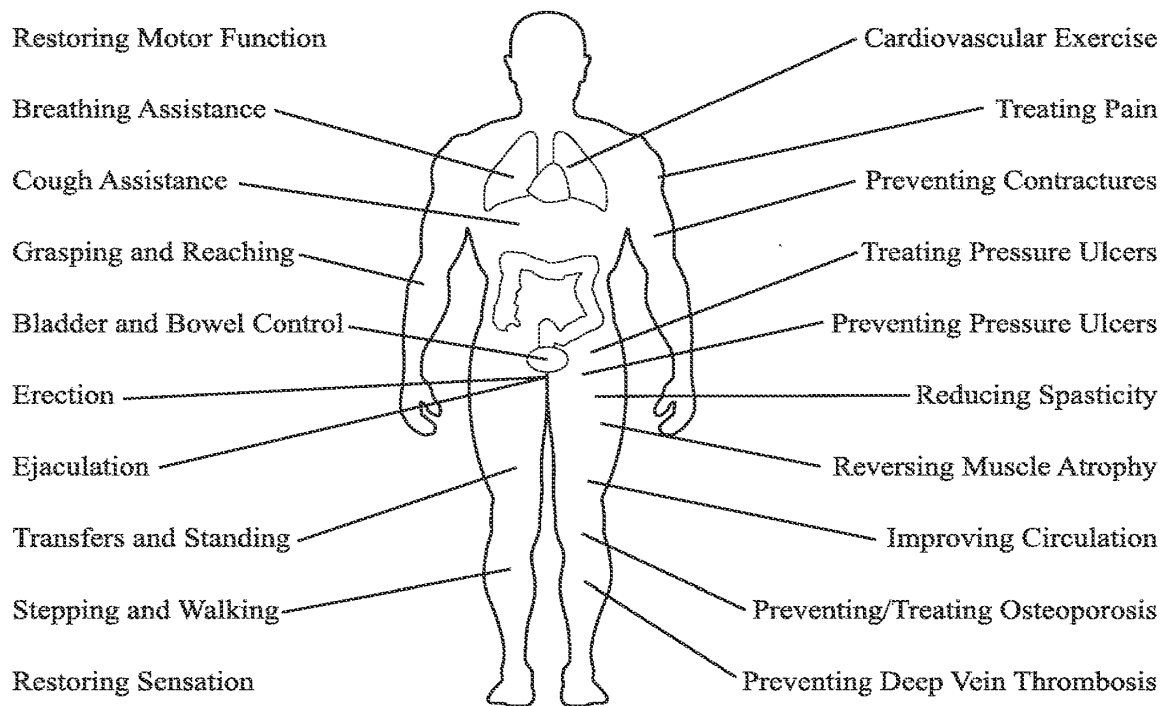


FIG. 15



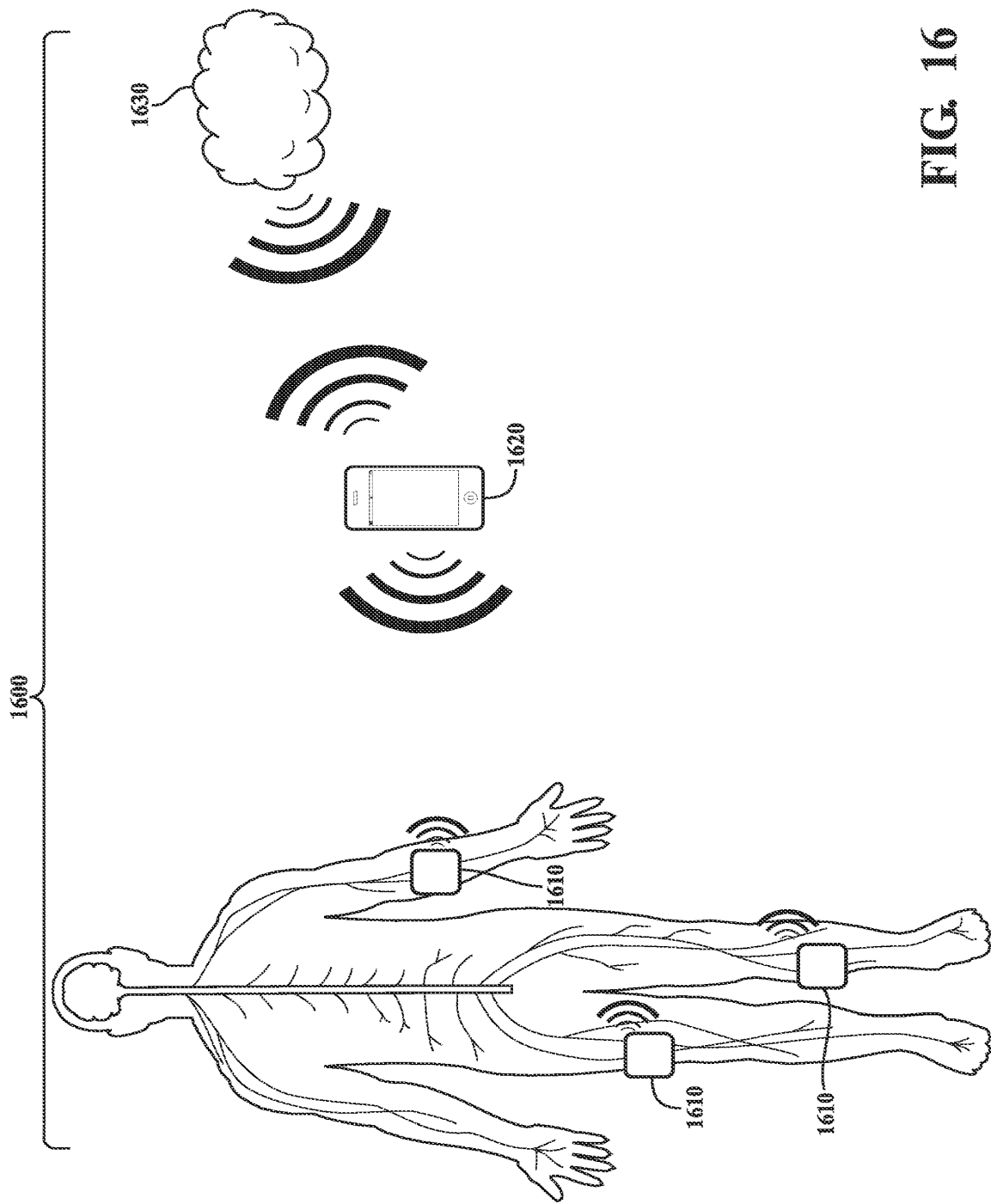


FIG. 16

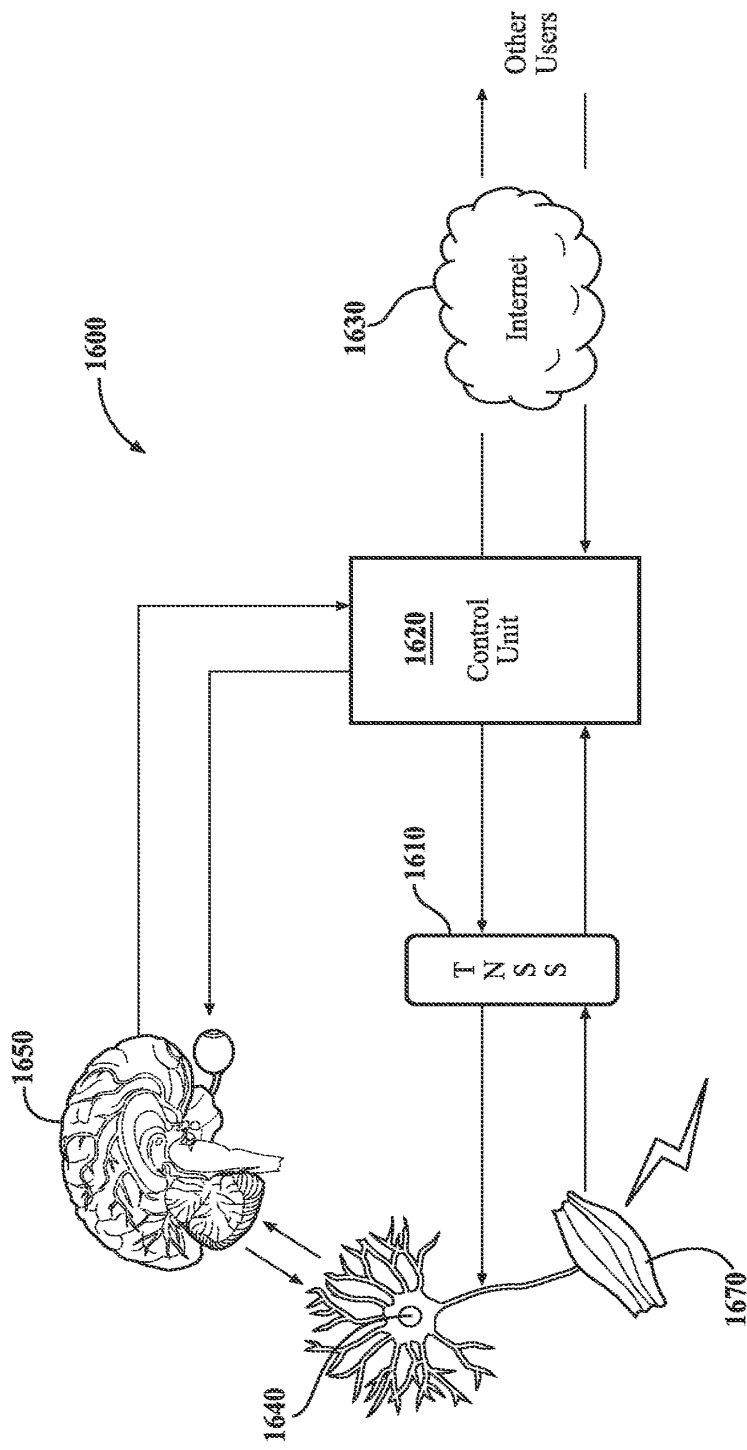


FIG. 17

FIG. 18

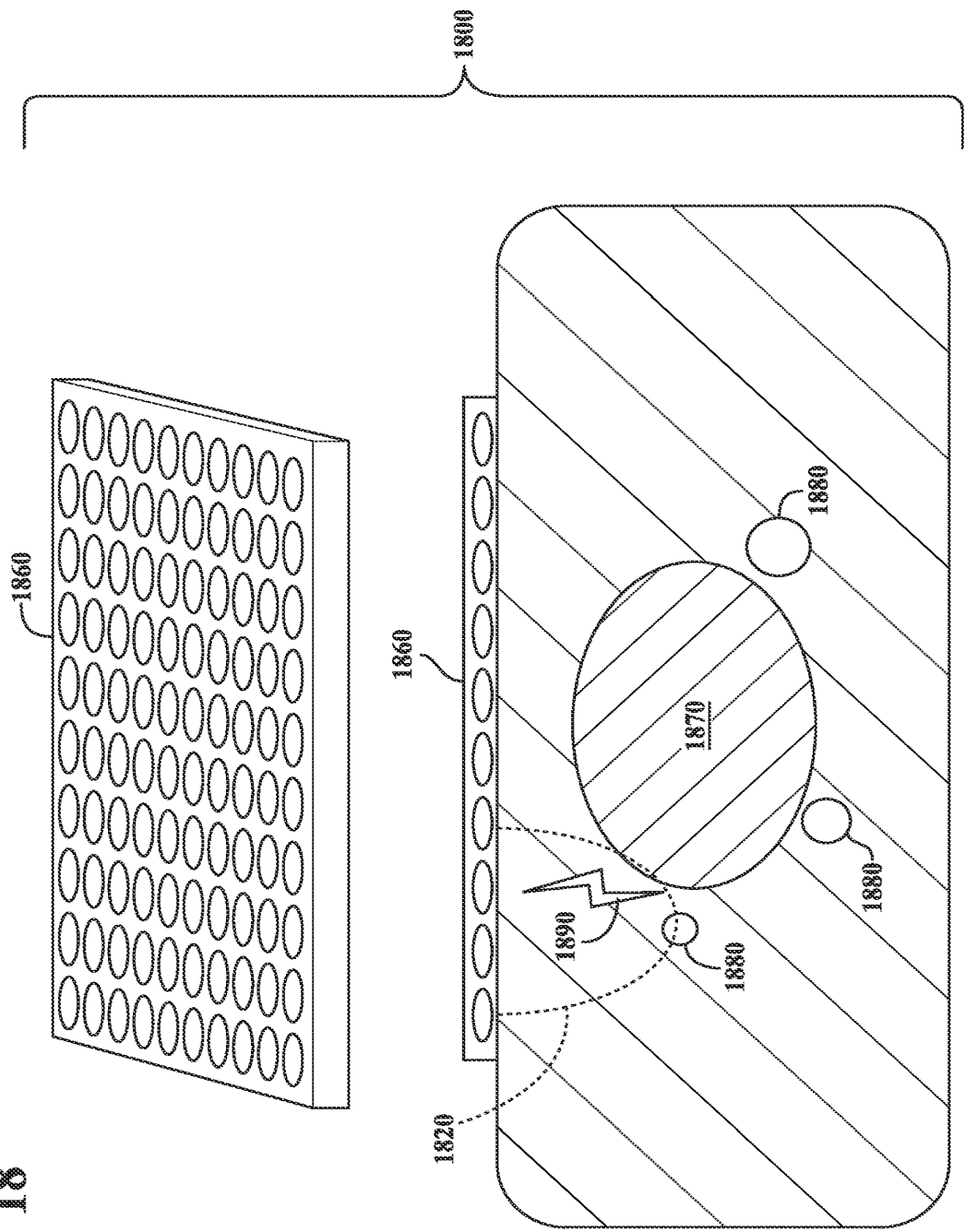
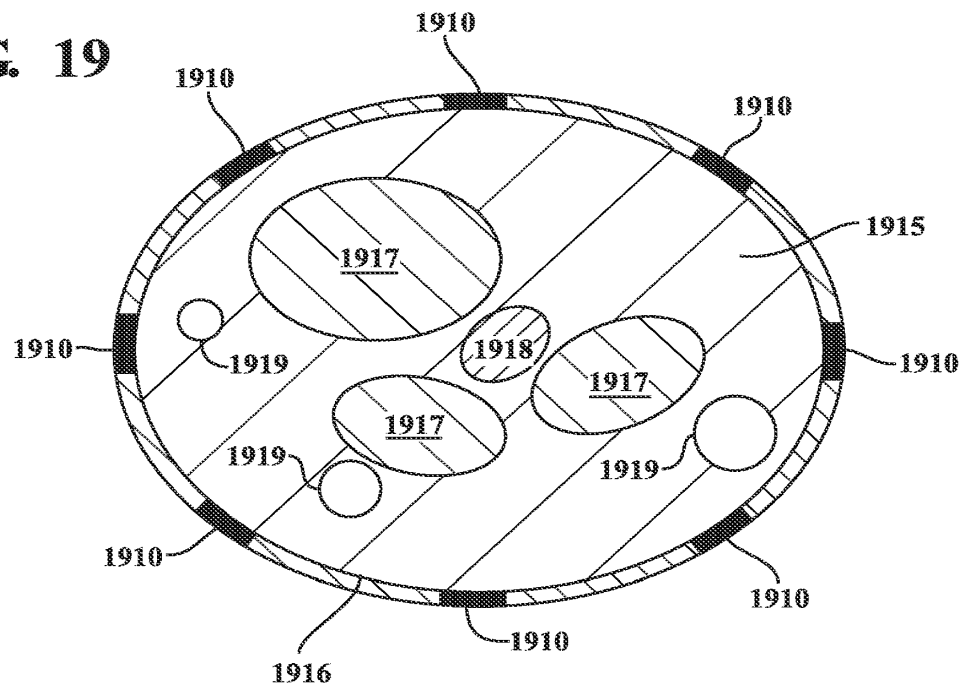


FIG. 19



EP 3 003 473 B1

REFERENCES CITED IN THE DESCRIPTION

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- WO 2011053607 A, Burnett [0002]

**CERTIFICATION AND REQUEST FOR PRIORITIZED EXAMINATION
UNDER 37 CFR 1.102(e) (Page 1 of 1)**

First Named Inventor:	MATTHEW ROBERT LEAPER	Nonprovisional Application Number (if known):	
Title of Invention:	COMMUNICATION DEVICES, METHODS, AND SYSTEMS		

APPLICANT HEREBY CERTIFIES THE FOLLOWING AND REQUESTS PRIORITIZED EXAMINATION FOR THE ABOVE-IDENTIFIED APPLICATION.

1. The processing fee set forth in 37 CFR 1.17(i)(1) and the prioritized examination fee set forth in 37 CFR 1.17(c) have been filed with the request. The publication fee requirement is met because that fee, set forth in 37 CFR 1.18(d), is currently \$0. The basic filing fee, search fee, and examination fee are filed with the request or have been already been paid. I understand that any required excess claims fees or application size fee must be paid for the application.
2. I understand that the application may not contain, or be amended to contain, more than four independent claims, more than thirty total claims, or any multiple dependent claims, and that any request for an extension of time will cause an outstanding Track I request to be dismissed.
3. The applicable box is checked below:

I. ☒ Original Application (Track One) - Prioritized Examination under § 1.102(e)(1)

- i. (a) The application is an original nonprovisional utility application filed under 35 U.S.C. 111(a). This certification and request is being filed with the utility application via Patent Center or EFS-Web.
---OR---
(b) The application is an original nonprovisional plant application filed under 35 U.S.C. 111(a). This certification and request is being filed with the plant application in paper.
- ii. An executed inventor's oath or declaration under 37 CFR 1.63 or 37 CFR 1.64 for each inventor, or the application data sheet meeting the conditions specified in 37 CFR 1.53(f)(3)(i) is filed with the application.

II. ☐ Request for Continued Examination - Prioritized Examination under § 1.102(e)(2)

- i. A request for continued examination has been filed with, or prior to, this form.
- ii. If the application is a utility application, this certification and request is being filed via Patent Center or EFS-Web.
- iii. The application is an original nonprovisional utility application filed under 35 U.S.C. 111(a), or is a national stage entry under 35 U.S.C. 371.
- iv. This certification and request is being filed prior to the mailing of a first Office action responsive to the request for continued examination.
- v. No prior request for continued examination has been granted prioritized examination status under 37 CFR 1.102(e)(2).

Signature /MATTHEW R. LEAPER/	Date DECEMBER 1, 2023
Name (Print/Typed) MATTHEW R. LEAPER	Practitioner Registration Number 73966
Note: This form must be signed in accordance with 37 CFR 1.33. See 37 CFR 1.4(d) for signature requirements and certifications. Submit multiple forms if more than one signature is required.*	
☐ *Total of _____ forms are submitted.	

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PTO/SB/08a (01-22)

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	First Named Inventor	Matthew Robert Leaper	
	Art Unit		
	Examiner Name		
	Attorney Docket Number	DF-P01-US08	

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Signature	/MATTHEW R. LEAPER/	Date (YYYY-MM-DD)	2023-12-01
Name/Print	Matthew R. Leaper	Registration Number	73,966
<p>This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 1 hour to complete, including gathering, preparing and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.</p>			

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re 1.53(b) Continuation Application of	)	Art Unit: Not Yet Assigned
U.S. Patent Application No. 18/388,489:	)	
	)	
MATTHEW R. LEAPER	)	Examiner: Not Yet Assigned
	)	
Application No.: Not Yet Assigned	)	
	)	Confirmation No.: Not Yet Assigned
Filed: December 1, 2023	)	
	)	
For: COMMUNICATION DEVICES,	)	VIA EFS WEB
METHODS, AND SYSTEMS	)	
	)	
	)	
	)	

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Commissioner:

**TRANSMITTAL OF NEW NON-PROVISIONAL PATENT APPLICATION WITH
A CERTIFICATION AND REQUEST FOR PRIORITIZED EXAMINATION**

Enclosed is a request for filing a continuation application under 37 CFR §1.53(b) of pending prior U.S. Patent Application No. 18/388,489, filed November 9, 2023, which is a continuation of pending U.S. Patent Application 18/143,142, filed May 4, 2023, which is a continuation of U.S. Patent Application 18/092,398, filed January 2, 2023, now U.S. Patent No. 11,684,313, which is a continuation of U.S. Patent Application No. 17/213,117, filed March 25, 2021, now U.S. Patent No. 11,589,816, which is a continuation of U.S. Patent Application No. 16/757,482, filed April 20, 2020, now U.S. Patent No. 10,959,674, which is a § 371 National Stage Entry of International Patent Application No. PCT/US18/56814, filed October 22, 2018, claiming the benefit of priority of U.S. Provisional Patent Application No. 62/676,949, filed May 26, 2018, and U.S. Provisional Patent Application No. 62/575,951, filed October 23, 2017, the entireties of which are incorporated by reference into the enclosed application.

The enclosed application also includes the following:

1. A specification (73 pages – including a cross-reference paragraph), claims (4 pages – including claims 1-20), an abstract (1 page), and drawings (14 sheets – including FIGs. 1A, 1B, 2A, 2B, 2C, 3A, 3B, 4A, 4B, 4C, 4D, 5, 6A, 6B, 6C, 6D, 7A, 7B, 7C, 7D, 8A, 8B, 9, 10, 11, 12, 13A, 13B, 14A, 14B).
2. An Application Data Sheet (ADS) in accordance with 37 CFR § 1.76 (8 pages).
3. An executed Assignment and Declaration for Inventor Leaper (2 pages).
4. An information disclosure statement.
5. A Certification and Request for Prioritized Examination under 37 CFR 1.102(e).
6. The total required small entity fees for a Track One application paid via EFS.

Please accord this application an application number and filing date.

If there is any fee due in connection with the filing of this application that is not otherwise provided with this filing, please charge the fee to Deposit Account No. **603446**. In addition, the Commissioner is hereby authorized to, now and throughout prosecution of this application, charge any additional required fees, including any fees due under 37 CFR §1.16 OR §1.17, charge any underpayments, or credit any overpayment to Deposit Account No. **603446**.

Please address all correspondence with respect to this application to: **DATAFEEL INC., Customer Number 158475**.

Respectfully submitted,

MATTHEW LEAPER
REGISTERED PATENT ATTORNEY
CEO, DATAFEEL INC.

Dated: **01DEC2023**

By: **/MATTHEW R. LEAPER/**
Matthew R. Leaper
Reg. No. 73,966
(626) 532-7371

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A61B 5/0478 (2006.01) *A61N 1/08* (2006.01)
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(71) Applicant: SOLACE LIFESCIENCES, INC. [US/US];
501 Silverside Road #7, Wilmington, Delaware 19809 (US).

(72) Inventors: HOLLOWAY, G. Blake; 1030 Bluebonnet
Drive, Kerrville, Texas 78028 (US). GROSS, Christopher;
219 Hockessin Circle, Hockessin, Delaware 19707 (US).

(74) Agent: HALPENNY, Genevieve et al.; FISH IP LAW,
LLC, 2603 Main Street, Ste 1000, Irvine, California 92614
(US).

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KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME,
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(54) Title: WEARABLE DEVICES, SYSTEMS, AND METHODS FOR BALANCING AND MAINTAINING AUTONOMIC NERVOUS SYSTEM HEALTH

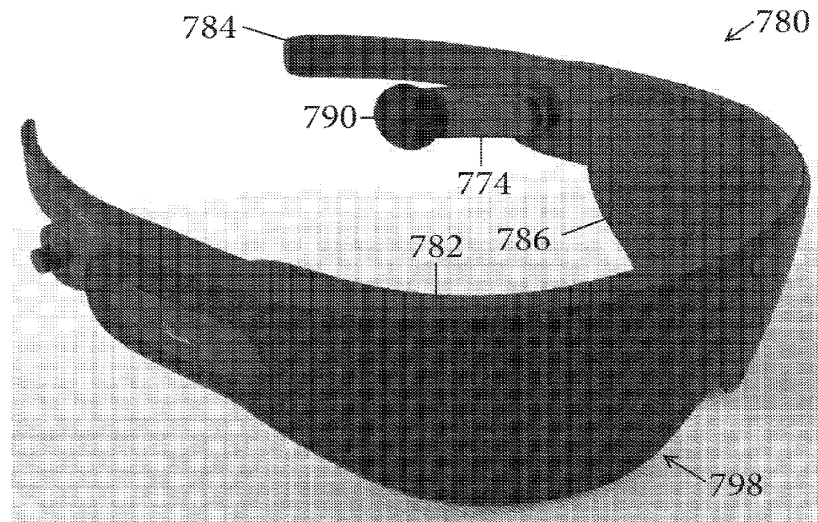


Fig. 7B

(57) Abstract: The inventive subject matter provides a wearable device for application of methods for balancing and maintaining the health of the human autonomic nervous system, including a wearable frame; cranio-electrical stimulation (CES) circuitry and electrodes positioned on the wearable frame; and optionally including audio entrainment with binaural beats circuitry and audio outputs, and an attachable visual mask containing light-blocking material and frequency-following response visual stimulation circuitry and lights. The device may also include sensors to monitor various physiologic indicators. The system communicates the physiologic data with other devices (such as smart phones or tablets) that have algorithms to interpret the data to determine whether additional therapy is required. Based on this feedback, the smart phone communicates with the therapy elements, e.g., CES, to continue or discontinue therapy.

[Continued on next page]

OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

- with international search report (Art. 21(3))
- with amended claims and statement (Art. 19(1))

Date of publication of the amended claims and statement:

01 March 2018 (01.03.2018)

AMENDED CLAIMS

received by the International Bureau on 26 JANUARY 2018 (26.01.2018)

What is claimed is:

1. An electrical stimulation device for modulating an autonomic nervous system of a user comprising:
 - a frame having at least one temple tip and at least one nose support that supports a weight of the device on a head of the user;
 - an electrode configured to deliver an electric stimulus to the skin of the user that entrains the user's brain waves with a binaural beat;
 - a power source mechanically coupled to the frame and electrically coupled to the electrode;
 - a sensor configured to detect an autonomic nervous system metric; and
 - a controller configured to control at least one of a power and a duration of the electric stimulus based on the autonomic nervous system metric.
2. The electrical stimulation device of claim 1, wherein the frame is configured to be worn across a human user's forehead and behind the human's ears.
3. The electrical stimulation device of claim 1 or 2, wherein the frame further comprises an eye mask coupled to the frame.
4. The electrical stimulation device of claim 3, wherein the eye mask is removably coupled to the frame via a coupler.
5. The electrical stimulation device of claim 4, wherein the coupler comprises a magnet.
6. The electrical stimulation device of claim 3, wherein at least one of the frame and the eye mask comprises a light-emitting diode (LED).
7. The electrical stimulation device of any of the preceding claims, wherein the sensor comprises an electroencephalogram (EEG) electrode, and the autonomic nervous system metric comprises an EEG of the user's brain activity.
8. The electrical stimulation device of any one of claims 1-6, wherein the sensor comprises a temperature sensor, and the autonomic nervous system metric comprises a temperature of the user.

9. The electrical stimulation device of any one of claims 1-6, wherein the sensor comprises a skin conductivity electrode, and the autonomic nervous system metric comprises a conductance of the user's skin.
10. The electrical stimulation device of any one of claims 1-6, wherein the sensor comprises a pulse sensor, and the autonomic nervous system metric comprises a heart rate of the user.
11. The electrical stimulation device of claim 9, wherein the pulse sensor comprises a blood volume pulse sensor.
12. The electrical stimulation device of any one of claims 1-6, wherein the sensor comprises a Laser Doppler Velocimeter (LDV), and the autonomic nervous system metric comprises at least one of a blood flow rate, a blood volume amplitude, and a pulse transit time of the user.
13. The electrical stimulation device of any one of claims 1-6, wherein the sensor comprises an electrocardiogram (ECG) electrode, and the autonomic nervous system metric comprises an electrocardiogram.
14. The electrical stimulation device of any one of claims 1-6, wherein the sensor comprises a respiration rate sensor, and the autonomic nervous system metric comprises a respiration rate.
15. A system for modulating the autonomic nervous system comprising:
an electrical stimulation device according to any one of claims 1-14; and
an audio system configured to entrain the user's brain waves with a binaural beat.
16. A method of modulating the autonomic nervous system comprising:
providing an electrical stimulation device according to any one of claims 1-14; and
providing software that when installed on a phone or tablet of the user is configured to play binaural audio that entrains the user's brain waves.
17. The method of claim 16, further comprising providing an anxiolytic agent to the user.
18. The method of claim 17, wherein the anxiolytic agent comprises a topical anxiolytic agent.
19. The method of claim 18, wherein the topical anxiolytic agent comprises a bio-frequency chip.

20. The method of claim 16, wherein the anxiolytic agent comprises an oral anxiolytic agent.

21. A system for balancing and maintaining the health of the human autonomic nervous system, the system comprising:

- a wearable frame having at least one temple tip and at least one nose support that supports a weight of the device on a head of the user;
- cranio-electrical stimulation (CES) circuitry and electrodes positioned on the wearable frame;
- audio entrainment with binaural beats circuitry and audio outputs that entrains the user's brain waves with a binaural beat selected as a function of signals detected by the CES circuitry; and
- a visual mask attachable to the wearable frame, the visual mask comprising light-blocking material and frequency-following response visual stimulation circuitry and lights.

REMARKS**D1: US 2012-0149973 A1 (Holloway, G. B.) 14 June 2012****D2: USE 2012-0271377 A1 (Hagedorn, D. W. et al.) 25 October 2012**

The Office considers claims 1-6 and 21 to lack novelty and an inventive step over Holloway Hagedorn. The amended claims clarify that the frame has a temple tip and an nose support so that the frame is supported by the ear and nose of the wearer, and that the electrodes or audio outputs provide binaural beats that entrain the user's brain waves.

All of the rejections have been overcome. Those features are not present in any of the cited references, and there is no teaching, suggestion or motivation in the cited art to include them.

Conclusion

Claims 1-21 are pending in this application. The Applicants request allowance of all pending claims.

Respectfully submitted,
Fish IP Law LLP

By: Andrew Mar *AM*
Andrew Mar
Reg. No. 59698

Fish IP Law LLP
2603 Main Street, Suite 1000
Irvine, CA 92614-4271
Telephone (949) 253-0944
Fax (949) 253-9069

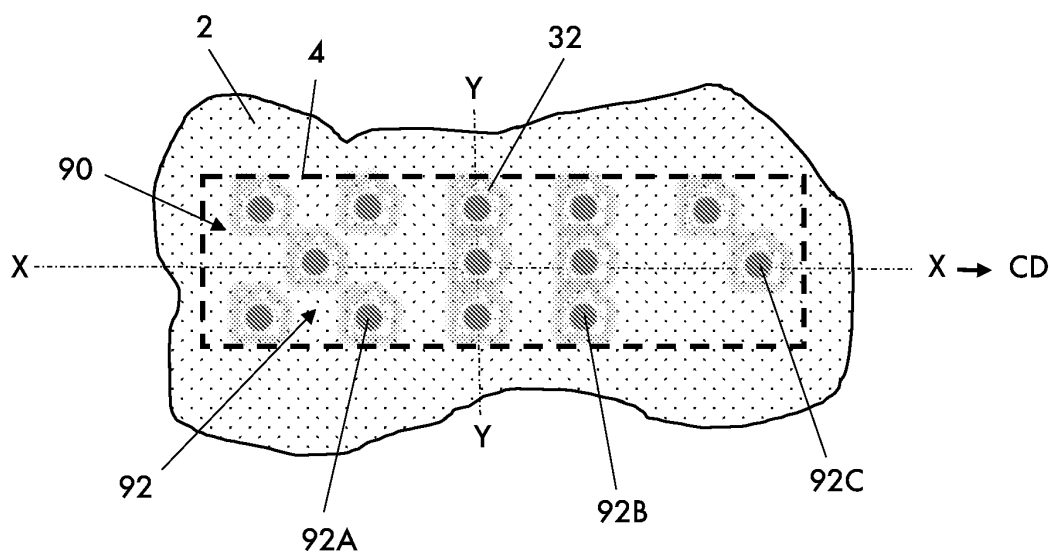


FIG. 1A

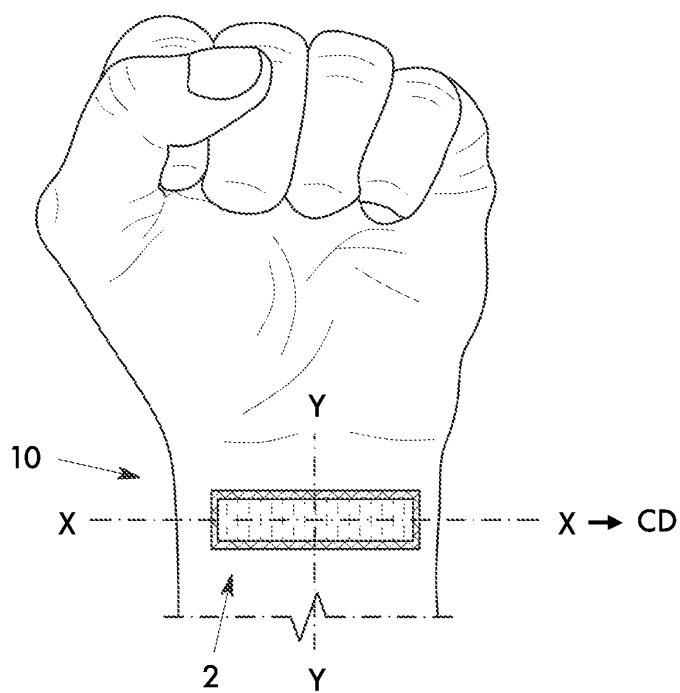


FIG. 1B

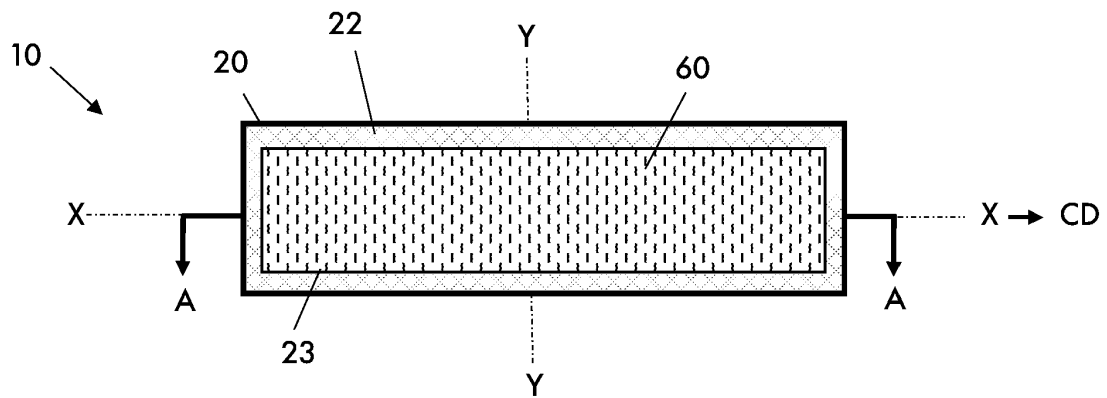


FIG. 2A

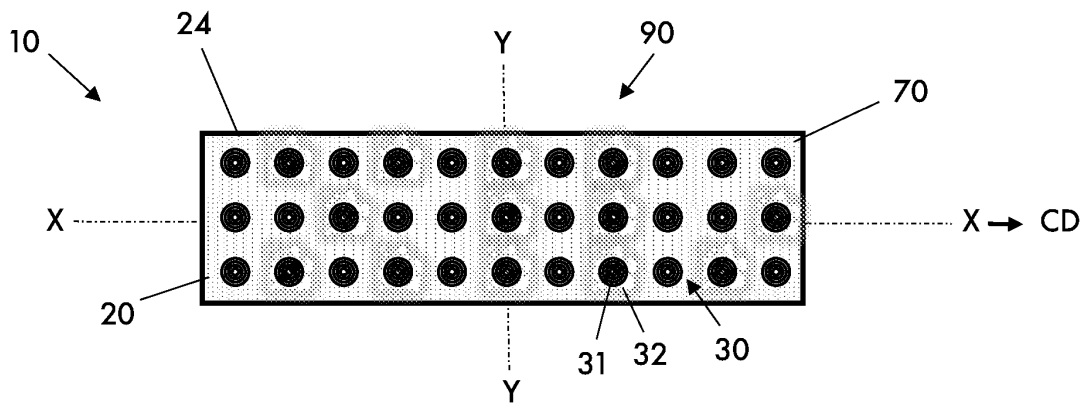


FIG. 2B

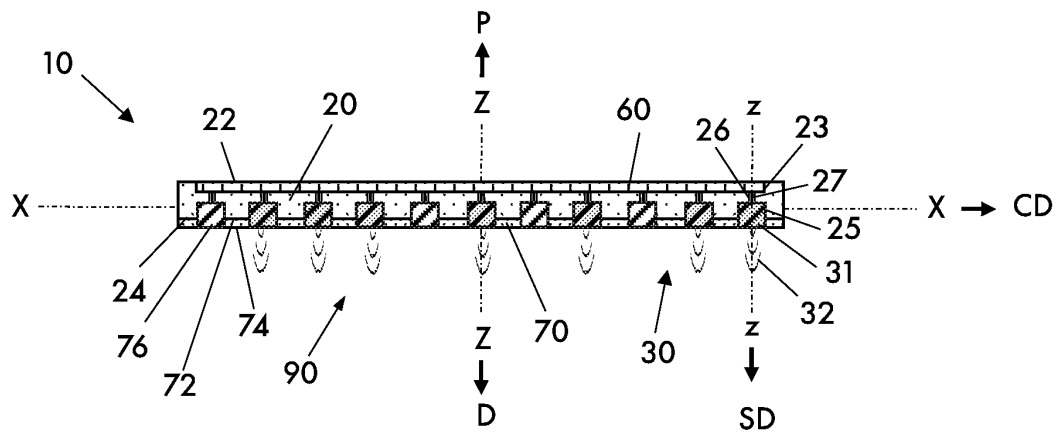


FIG. 2C

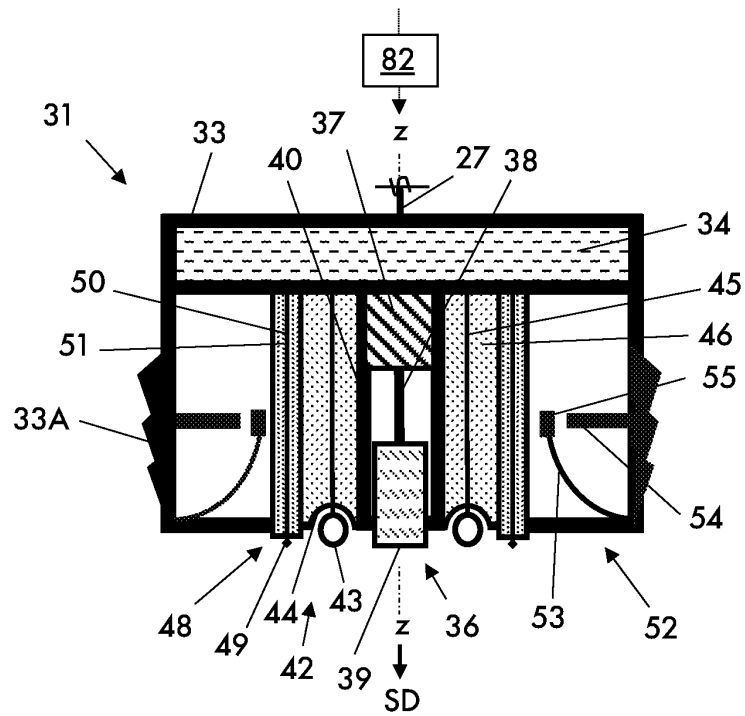


FIG. 3A

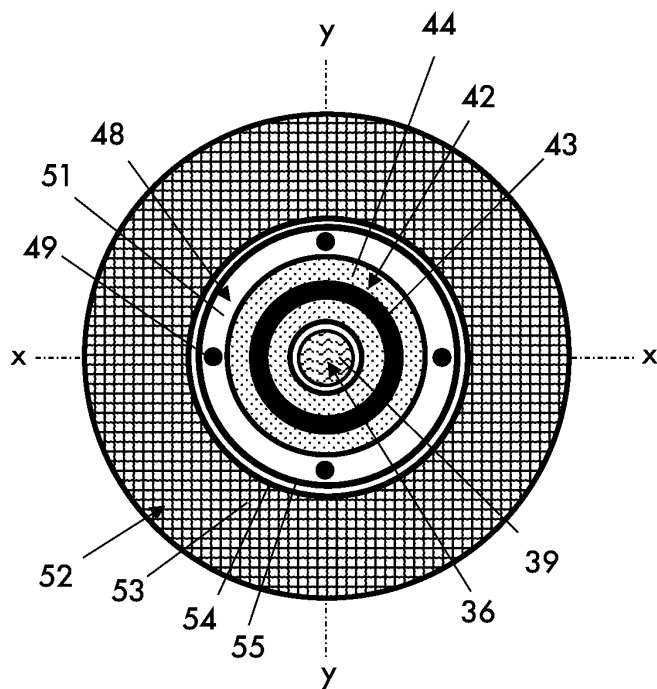


FIG. 3B

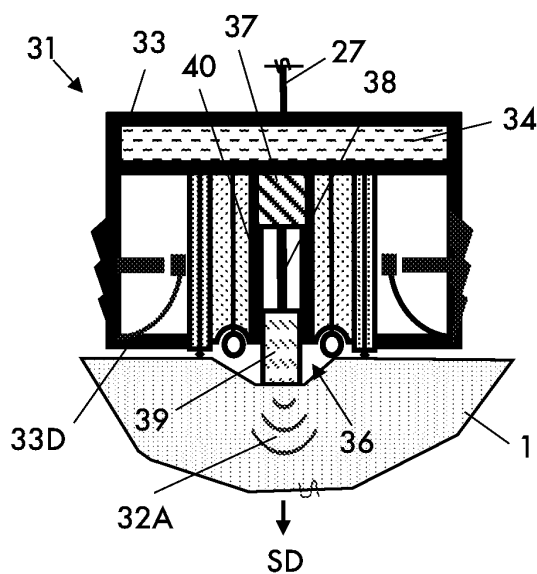


FIG. 4A

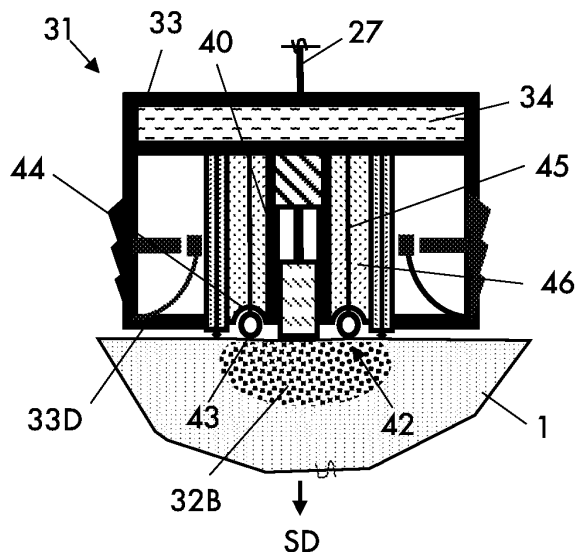


FIG. 4B

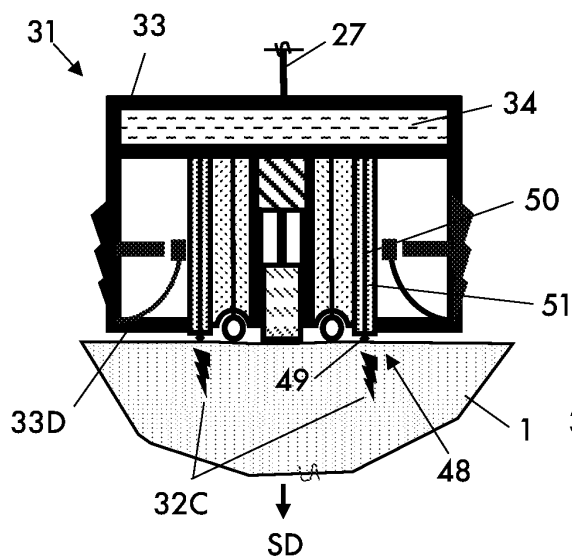


FIG. 4C

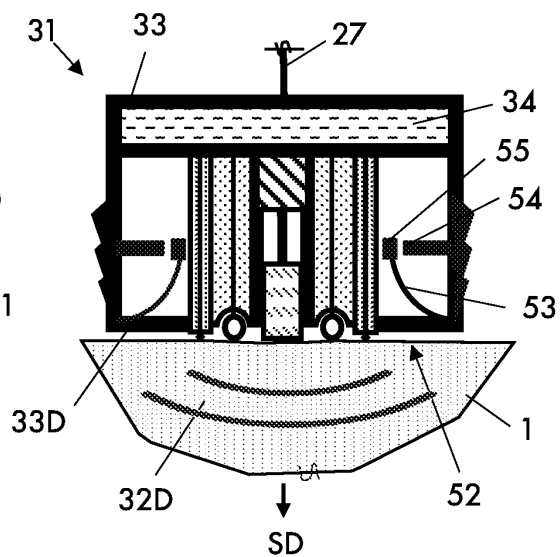


FIG. 4D

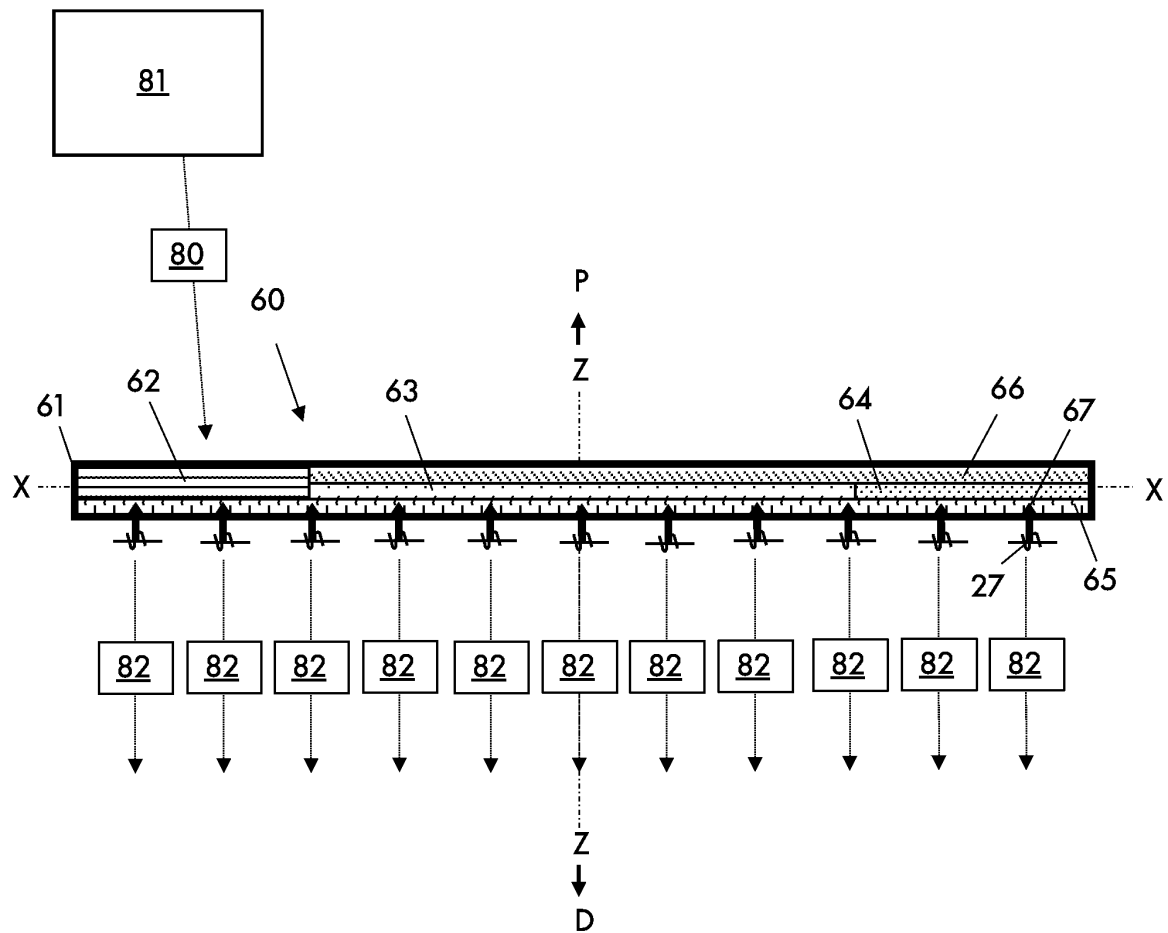


FIG. 5

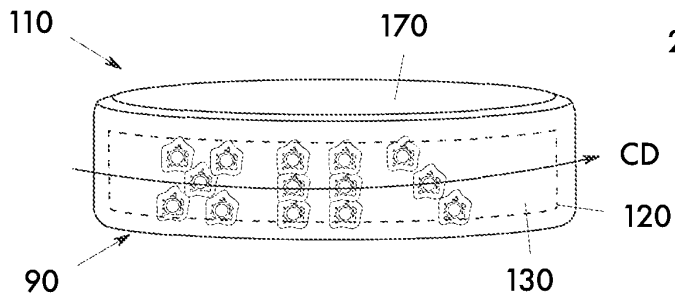


FIG. 6A

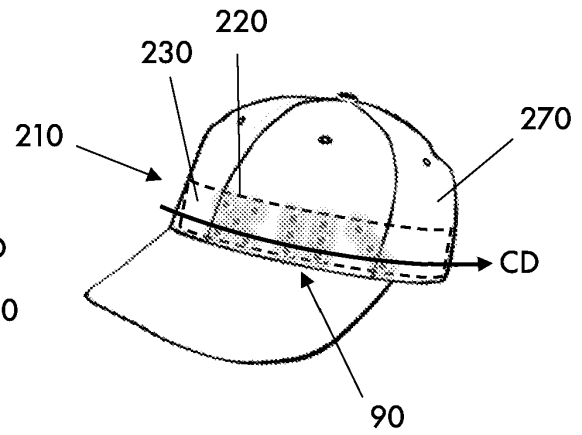


FIG. 6B

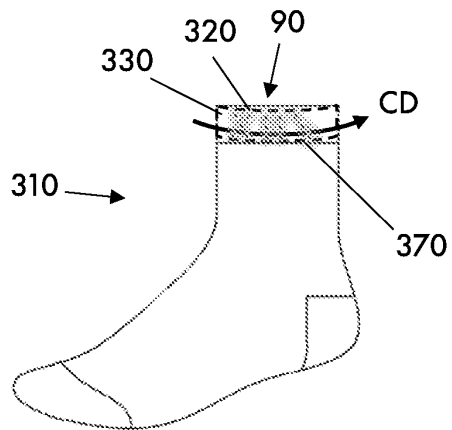


FIG. 6C

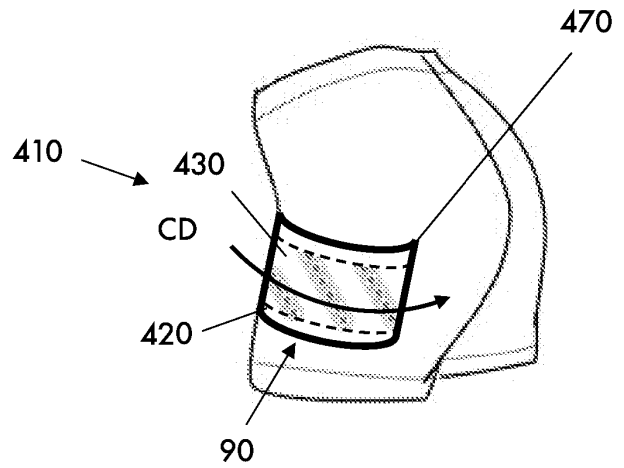


FIG. 6D

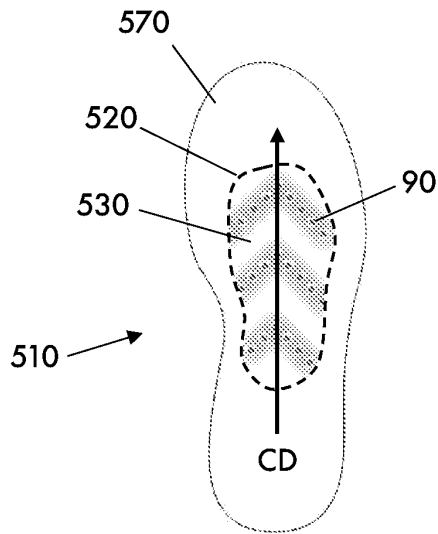


FIG. 7A

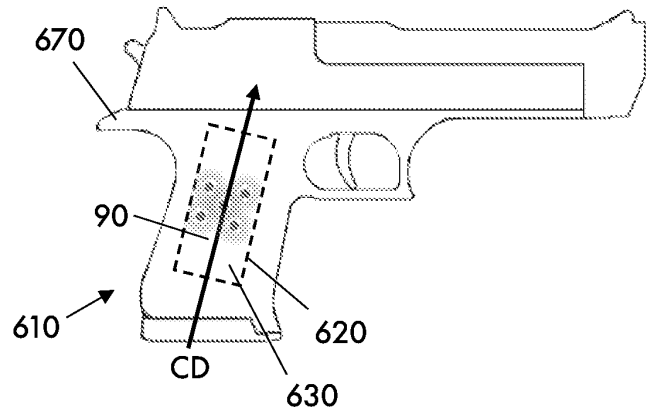


FIG. 7B

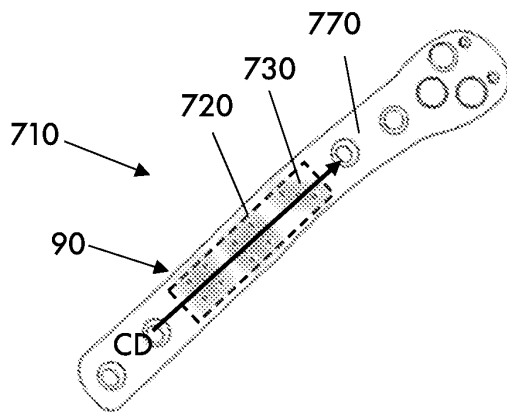


FIG. 7C

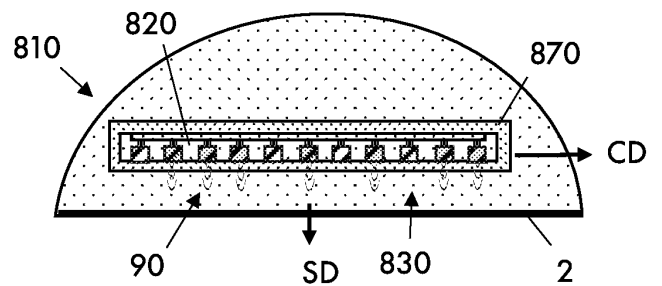


FIG. 7D

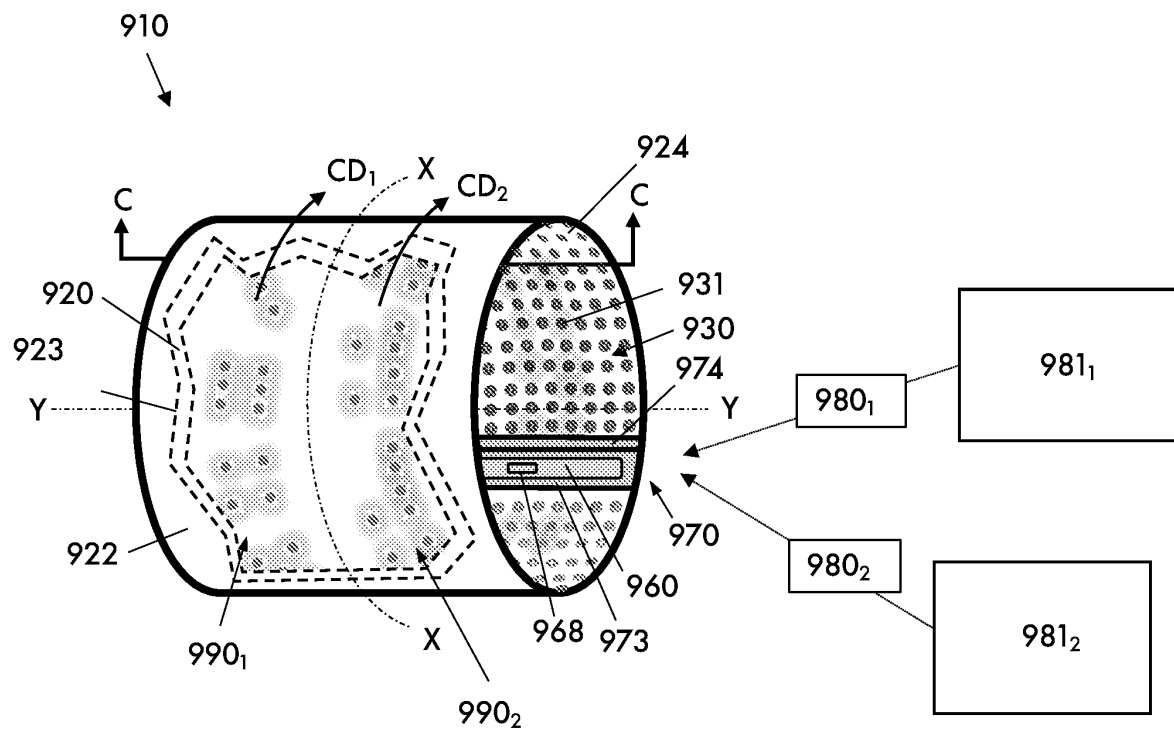


FIG. 8A

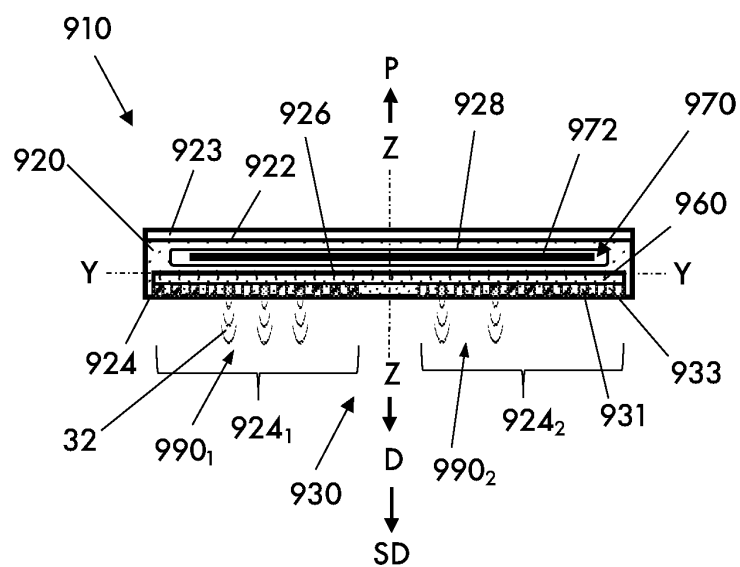


FIG. 8B

1000



1020: Receiving, with a processing unit, input data for a communication device including a tissue interface maintainable on or adjacent skin, the interface including a plurality of energy generators, each generator being operable to output a plurality of energies in a signal direction toward the skin.



1040: Operating, with the processing unit, the plurality of energy generators to communicate with nerves associated with the skin by outputting one or more energies of the plurality of energies in the signal direction based on the input data.

FIG. 9

1100



1120: Receiving, with a processing unit, input data for a communication device including a tissue interface maintainable on or adjacent skin, the interface including a plurality of energy generators arranged in bands or divided areas, each generator being operable to output a plurality of energies in a signal direction toward the skin.



1140: Operating, with the processing unit, the plurality of energy generators in each band or divided area to communicate with nerves associated with the skin by outputting one or more energies of the plurality of energies in response to the input data.

FIG. 10

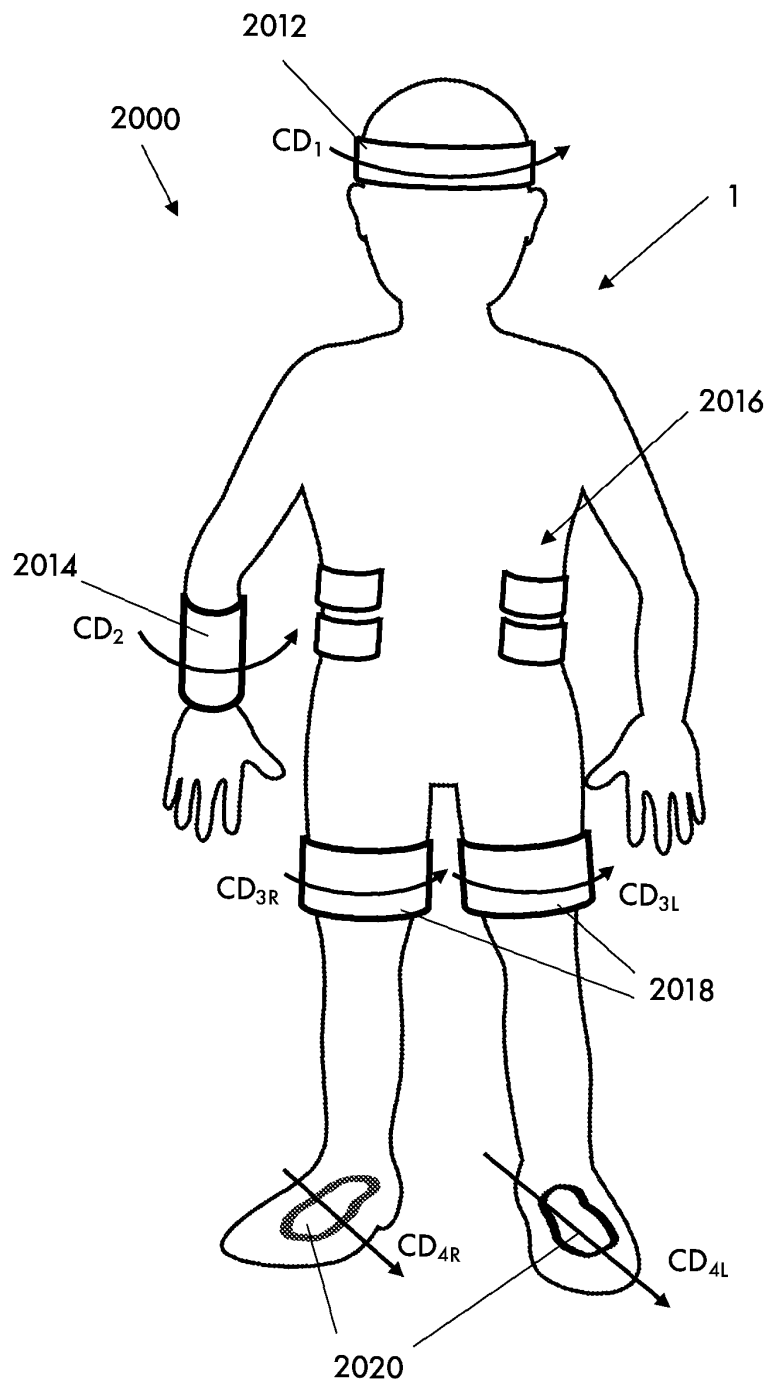


FIG. 11

2100



2120: Receiving, with one or more processors, position data for a plurality of communication devices mountable on or adjacent skin, each device including a tissue interface with a plurality of energy generators, each generator being operable to output a plurality of energies in a signal direction toward the skin.



2140: Receiving or generating, with the one or more processors, a corrective motion signal for the plurality of communication devices based on position data for each communication device.



2160: Operating, with the one or more processors, the plurality of energy generators of each communication device to output one or more energies of the plurality of energies in the signal direction based on the corrective motion signal.

FIG. 12

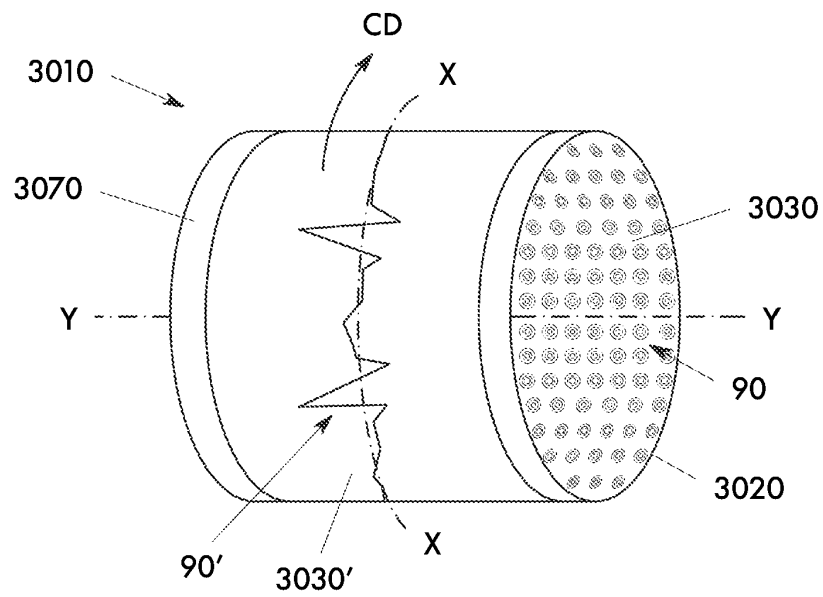


FIG. 13A

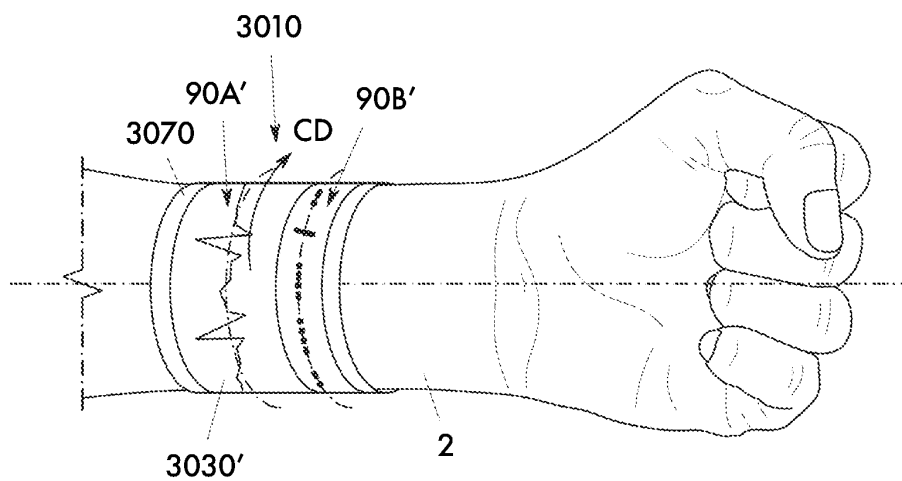


FIG. 13B

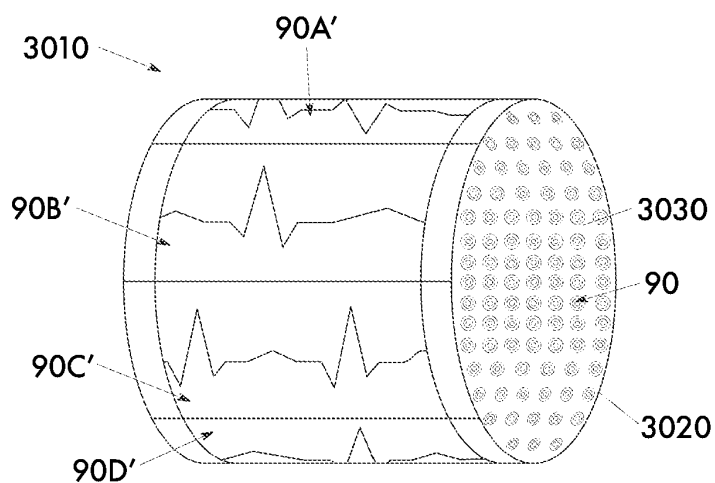


FIG. 14A

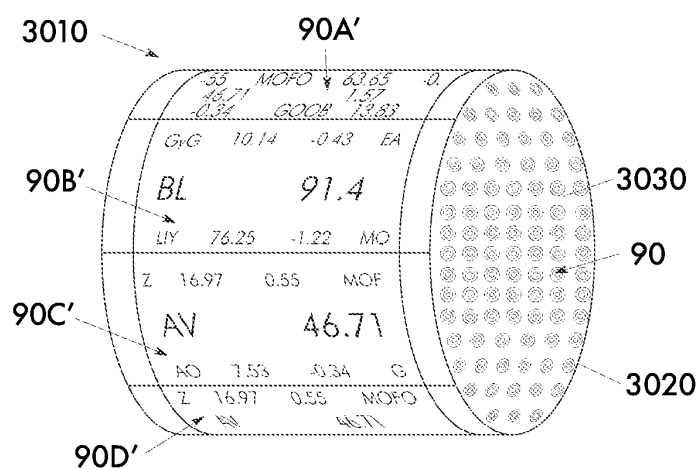


FIG. 14B



(12) **EUROPEAN PATENT APPLICATION**

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(71) Applicant : **NCR INTERNATIONAL INC.**
1700 South Patterson Boulevard
Dayton, Ohio 45479 (US)

(72) Inventor : **Hoevel, Lee Windsor**
718 Harman Avenue
Dayton, Ohio 45419 (US)

(74) Representative : **Robinson, Robert George**
International Patent Department NCR Limited
915 High Road North Finchley
London N12 8QJ (GB)

(54) **Data processing apparatus with user input feedback.**

(57) Data processing apparatus is provided which employs feedback to provide an indication when a data input instrument (52) touches or comes within a predetermined distance of a data capture surface (12). The data capture surface (12) may include a transparent digitizer over a liquid crystal display, over a hard surface bearing printed indicia or over a cathode ray tube (35), or it may include a digitizer (36) with an overlying form (39) bearing printed indicia. A feedback actuator (20) provides tactile, aural, or visual feedback.

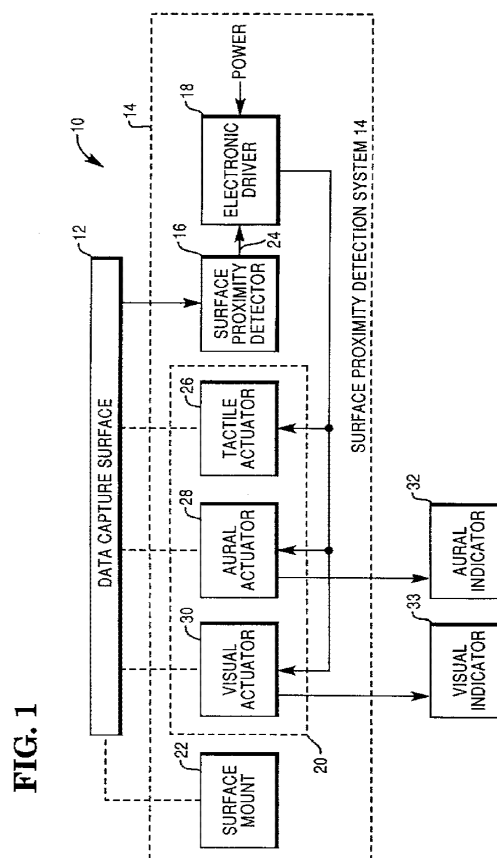


FIG. 1

The present invention relates to data processing apparatus.

When manually inputting data into a machine or system, the benefits of feedback to the user are well known. This feedback can serve to indicate to the user that he has accomplished his objective.

Data capture surfaces may include a digitizer or a combination of a display and an overlying transparent digitizer. The digitizer responds to pressure from a finger or writing instrument by generating a signal which is filtered, processed, and measured to determine the position of the pressure source on the digitizer.

When the data capture surface comprises a rigid surface, for example when an overlying transparent display forms the data capture surface, or when the surface is generally inflexible, a user is disadvantageously faced with the unfamiliar feel of a solid writing instrument such as a ballpoint pen or stylus against a hard and rigid surface.

It is an object of the present invention to provide data processing apparatus which does not have the above disadvantage.

In accordance with the present invention, there is provided data processing apparatus having a data input surface and data input means for touching said surface so as to input data into said apparatus, characterized by detection means for providing a signal when said input means comes within a predetermined distance from said surface, and feedback means connected to said detection means for providing feedback to a user in response to receiving said signal.

It should be understood that the term within a predetermined distance as used in the preceding paragraph includes a value of zero distance, such as when the data input means touches the surface.

It is an advantage of the present invention that a data capture system is provided with feedback in the form of displacement of the data capture surface when a data capture instrument touches the data capture surface so that the surface moves in response to use of the instrument.

The invention is described further hereinafter, by way of example only, with reference to the accompanying drawings in which:

Fig. 1 is a block diagram of apparatus embodying the present invention;

Fig. 2 shows a first type of data capture surface for use in the present invention;

Fig. 3 shows a second type of data capture surface for use in the present invention;

Fig. 4 shows a third type of data capture surface for use in the present invention;

Fig. 5 is a diagrammatic view of apparatus according to one embodiment of the present invention;

Fig. 6 is a diagrammatic view of apparatus ac-

cording to another embodiment of the present invention; and

Fig. 7 is a diagrammatic view of apparatus according to a further embodiment of the present invention.

Referring now to Figs. 1-7, data capture system 10 of the present invention includes a data capture surface 12 and a surface proximity detection system 14. Data capture surface 12 may include a liquid crystal display with a transparent digitizer or one or more touch sensitive elements across its top surface (Figs. 5-7). It could be a touch sensitive element within a video monitor (Fig. 2). Alternatively, data capture surface 12 may be a hard surface with printed captions in blocks and a transparent digitizer or touch sensitive overlay to enable the selection of a particular block (Fig. 3). Finally, data capture surface 12 may be a resistive or other type of digitizer underneath an overlay containing printed indicia thereon (Fig. 4).

Surface proximity detection system 14 includes a surface proximity detector 16, an electronic driver 18, a feedback actuator 20, and a data capture surface mount 22. Surface proximity detector 16 senses when a data input instrument touches or comes within a predetermined distance of data capture surface 12 and provides a signal 24 to electronic driver 18.

Electronic driver 18 amplifies and rectifies signal 24 to a level sufficient to activate feedback actuator 20.

Feedback actuator 20 provides feedback to the user when a data input instrument touches or comes within a predetermined distance of data capture surface 12. Feedback actuator 20 may include a tactile actuator 26, an aural actuator 28, and a visual actuator 30.

Tactile actuator 26 displaces data capture surface 12 when a touch is applied to data capture surface 12. Displacement may assist or oppose the touch force. Preferably, tactile actuator 26 includes an electromagnet, and a metal plate affixed to data capture surface 12. Tactile actuator 26 works in conjunction with data capture surface mount 22 to displace data capture surface 12. Surface mount 22 may include a hinge at one end of data capture surface 12.

Aural actuator 28 actuates aural indicator 32 when a data capture instrument touches or comes within a predetermined distance of data capture surface 12.

Visual actuator 30 actuates visual indicator 33 when a data capture instrument touches or comes within a predetermined distance of data capture surface 12.

Turning now to Fig. 2, a touch sensitive element 34 is shown on a video monitor 35.

Turning now to Fig. 3, a transparent digitizer 36 is shown over a hard surface 37 having printed captions in blocks.

Turning now to Fig. 4, a resistive digitizer 38 is

shown underneath an overlay 39 containing printed indicia thereon.

Turning now to Fig. 5, a first embodiment 40 of data capture system 10 is shown in which data capture surface 12 is a transparent digitizer 41 over a liquid crystal display 45. Data capture surface mount 22 includes a hinge 42 coupled to one end 44 of data capture surface 41, 45. Hinge 42 is normally biased by a spring 43 at the other end 48 of the surface 41, 45 so that data capture surface 12 is in an upward position. Data capture surface 12 moves in a downward direction during a touch when an electromagnet 50 attracts plate 46 mounted at end 48 of data capture surface 12.

In operation, when pressure is applied by writing instrument 52, data capture surface 12 rotates about hinge 42 in opposition to spring force from spring 43. End 48 deflects downward with the aid of the magnetic force from electromagnet 50. Thus, the user is provided with a sensation of having pushed data capture surface 12. Tactile feedback may be accompanied by an audible or visual indication from aural and visual indicators 32 and 33.

Preferably, downward travel of end 48 is limited to as small as about five thousandths of an inch (0.13mm) to minimize any adverse effects, if any, on the writing process. For data capture surfaces incorporating simple push-button motions, the limit of travel may be significantly greater to achieve an appropriate sensation.

Referring now to Fig. 6, a second embodiment 60 of data capture system 10 of the present invention is shown. Embodiment 60 is similar to embodiment 40, except that activated motion is in an upward direction, opposing the direction of the touch force. Embodiment 60 provides increased sensation to the user and tends to keep writing instrument 52 in contact with data capture surface 12.

Referring now to Fig. 7, a third embodiment 70 of data capture system 10 is shown. Instead of using hinge 42, embodiment 70 supports data capture surface 12 with a supporting frame 72. Springs 74 or some other type of resilient means bias the data capture surface 12 away from supporting frame 72 in an upward direction. Tactile actuator 26 includes a T-shaped armature 76, which moves upward to impact data capture surface 12 when electromagnet 50 is energized by contact from data capture instrument 52 with data capture surface 12. Magnitude and duration of tactile, aural, or visual sensations are established by the signal input to electromagnet 50, the weight and travel of armature 76, and the type of material from which the impacting surfaces are made. While embodiment 70 illustrates upward motion of armature 50, a downward direction of motion can be easily obtained by changes in the mechanical mounting of armature 76.

Claims

1. Data processing apparatus having a data input surface (12) and data input means (52) for touching said surface (12) so as to input data into said apparatus, characterized by detection means (16) for providing a signal when said input means (52) comes within a predetermined distance from said surface (12), and feedback means (20) connected to said detection means (16) for providing feedback to a user in response to receiving said signal.
2. Apparatus according to claim 1, characterized in that said feedback means (20) comprises displacement means (26) for displacing said surface (12) in response to said signal.
3. Apparatus according to claim 2, characterized in that said displacement means (26) includes a driver (18) for amplifying and rectifying said signal from said detecting means (16) and actuator means (26) coupled to said driver (18) for displacing said surface (12).
4. Apparatus according to claim 3, characterized by hinge means (42) at one end of said surface (12) and resilient means (43) at another end of said surface (12) for biasing said surface (12) in a predetermined direction.
5. Apparatus according to claim 3, characterized by a frame member (72) for displaceably supporting said surface (12) and resilient means (74) mounted between said surface (12) and said frame member (72) for outwardly biasing said surface (12).
6. Apparatus according to claim 3, 4 or 5, characterized in that said actuator means (26) comprises plate means (46) coupled to said data output surface (12) and electromagnetic means (50) for attracting said plate means and thereby displacing said surface.
7. Apparatus according to claim 3, 4 or 5, characterized in that said actuator means (26) comprises a plunger means (76) for displacing said surface (12) in a predetermined direction and electromagnetic means (50) for driving said plunger means (76).
8. Apparatus according to any one of the preceding claims, characterized in that said data input surface (12) comprises a digitizer layer (41) and a display layer (45).
9. Apparatus according to any one of the preceding

claims, characterized by audio means (32) for providing an aural indication when said data input means (52) is within a predetermined distance from said data input surface (12).

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10. Apparatus according to any one of the preceding claims, characterized by visual indication means (33) for providing a visual indication when said data input means (52) is within said predetermined distance from said data input surface (12).

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FIG. 1

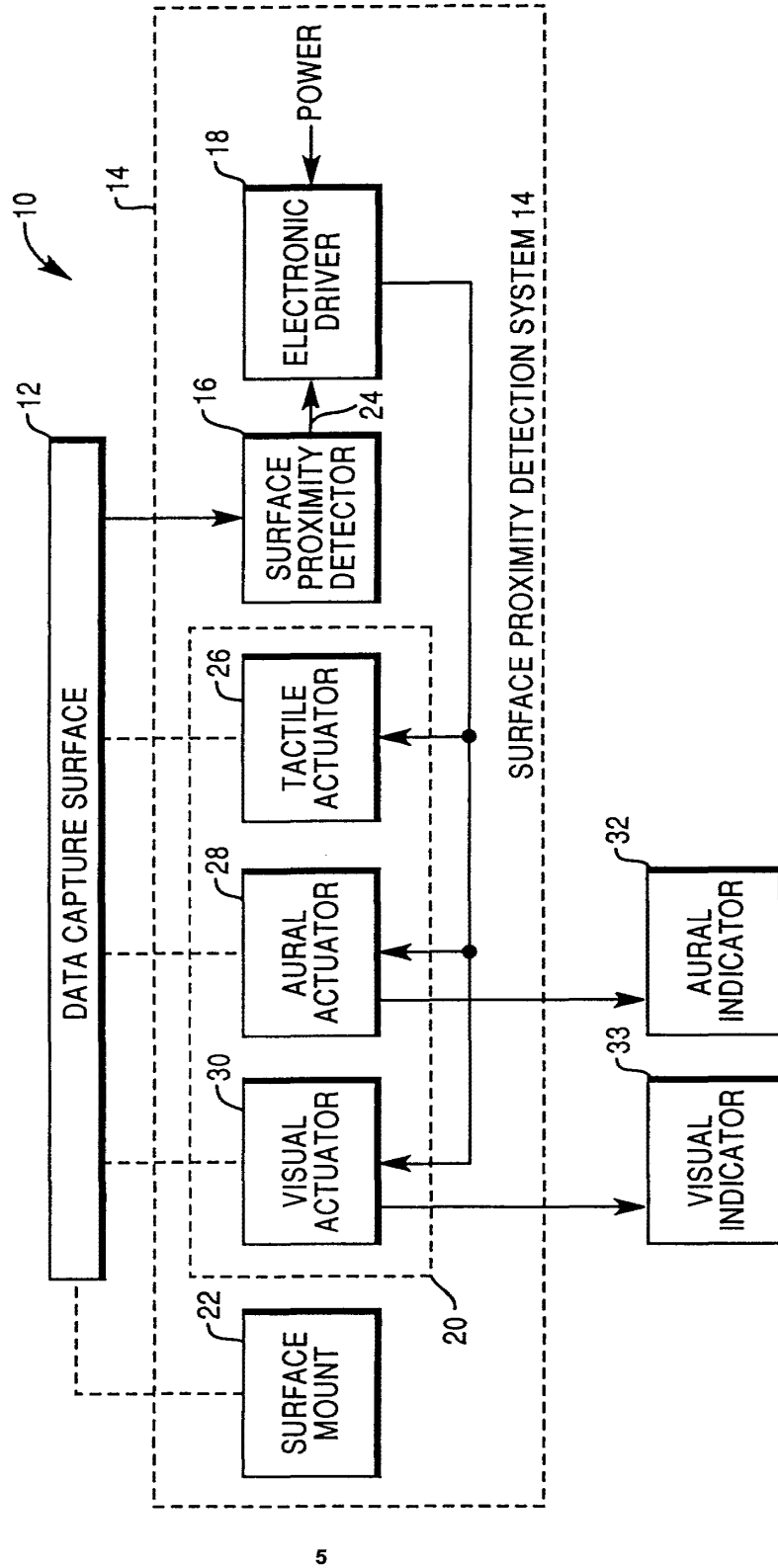


FIG. 2

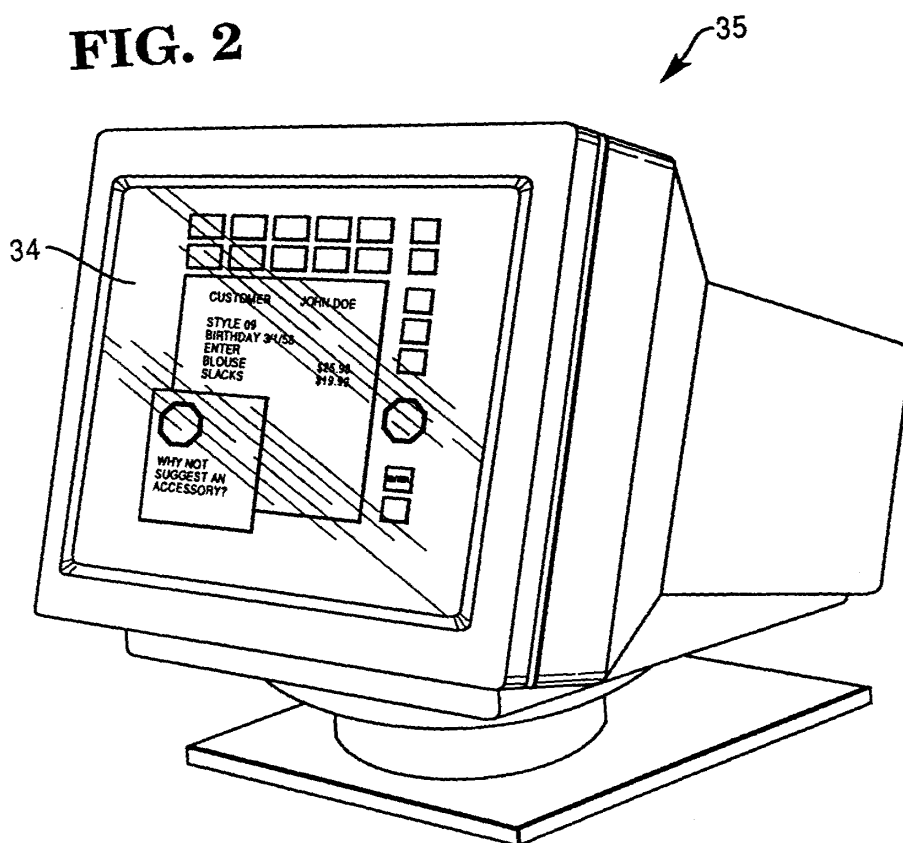


FIG. 3

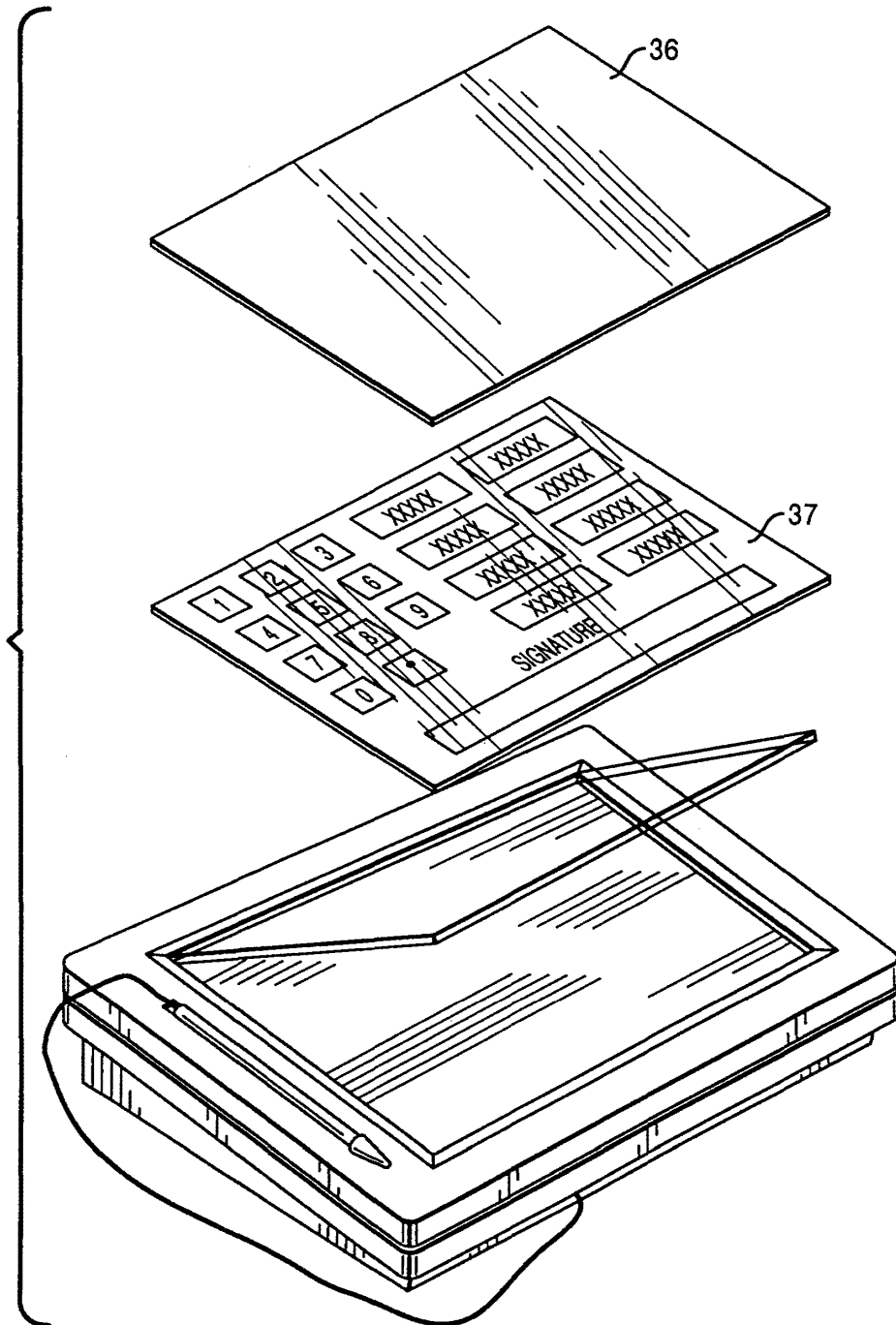
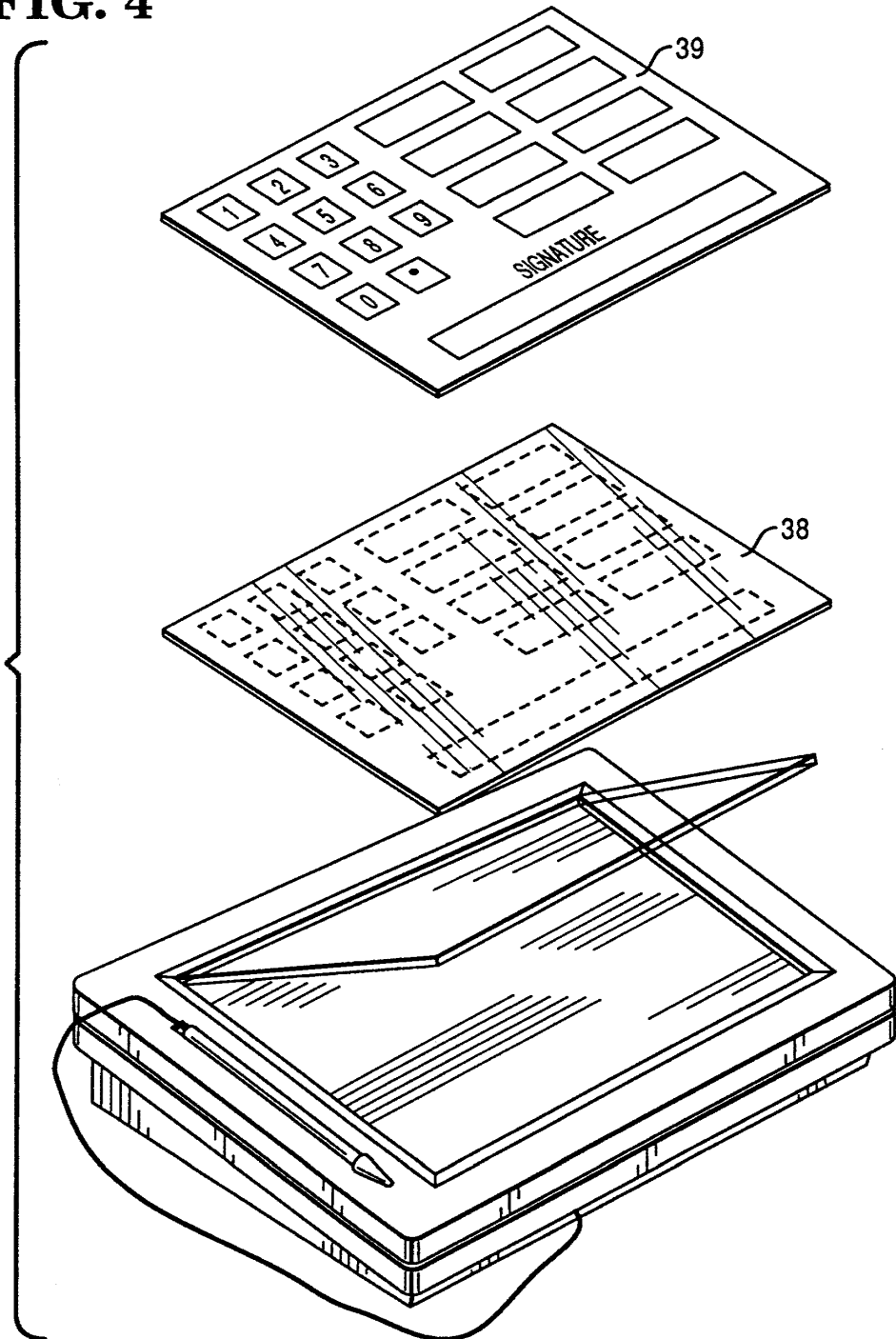
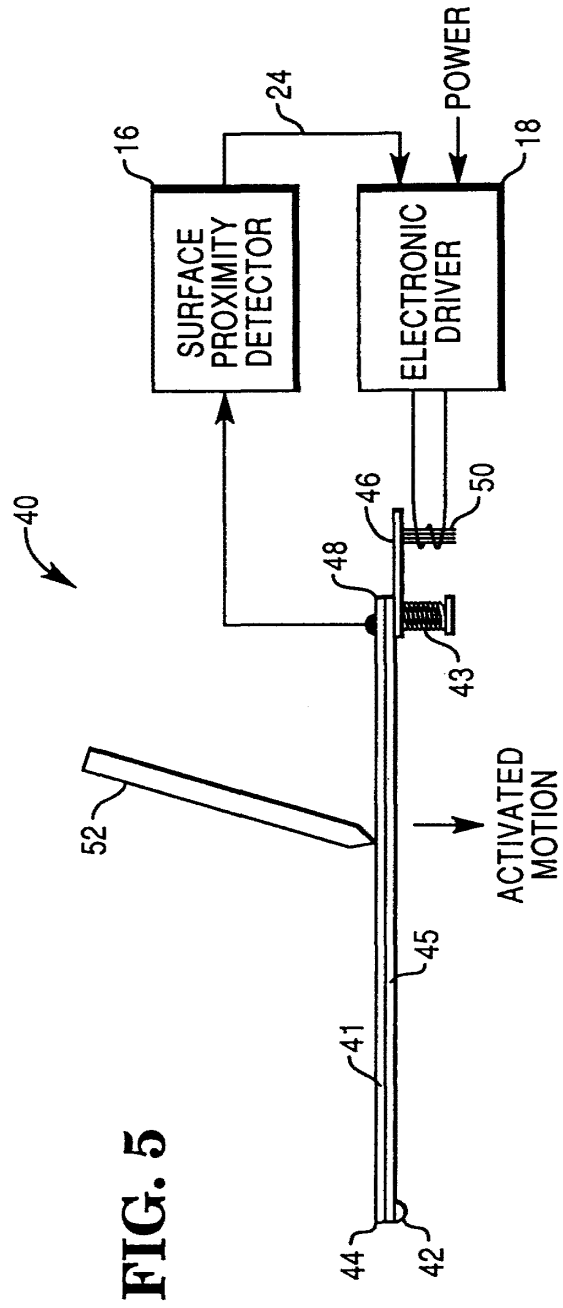
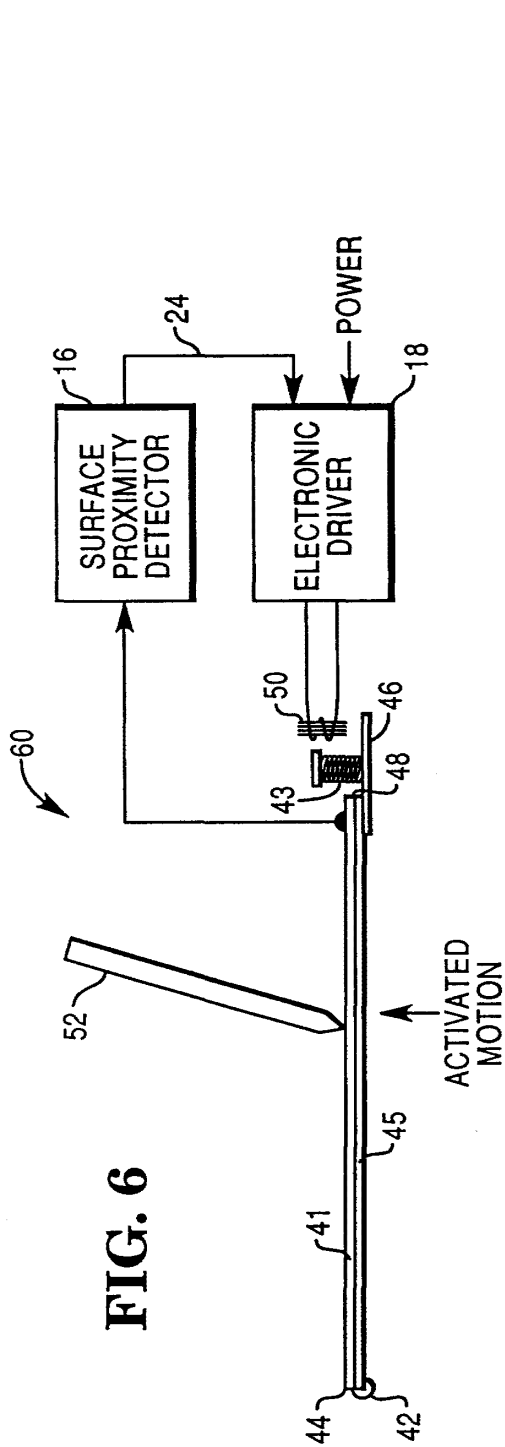
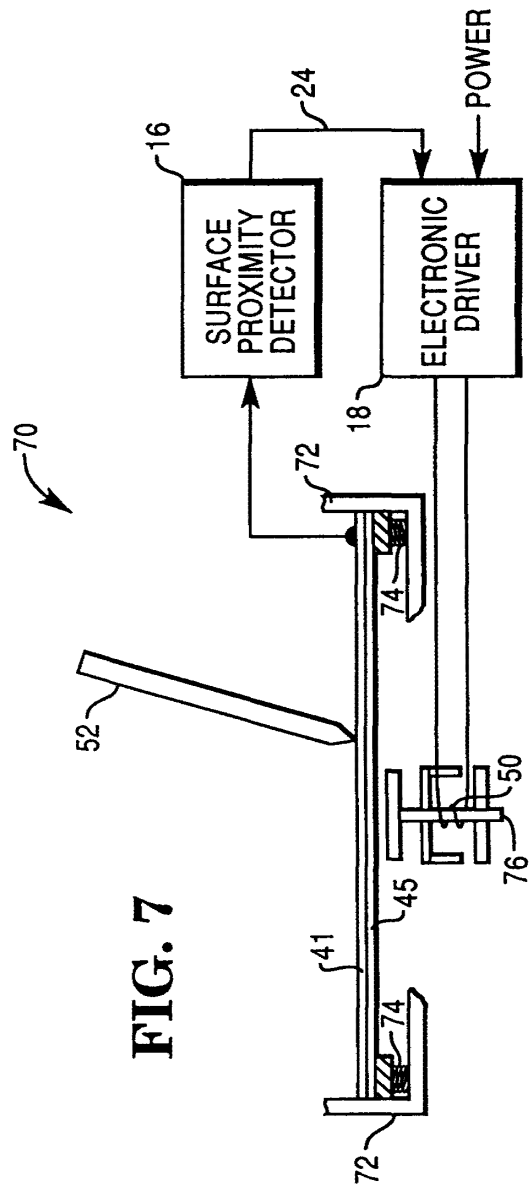


FIG. 4









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Application Number

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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	US-A-4 885 565 (EMBACH) * the whole document *	1-3, 5, 7-10	G06F3/033
X	WO-A-9 200 559 (HEWLETT-PACKARD CO.) * page 1, line 15 - line 19 * * page 3, line 1 - line 31 *	1, 8-10	
X	EP-A-0 445 906 (SONY CORP.) * abstract *	1, 8, 10	
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)
			G06F
The present search report has been drawn up for all claims			
Place of search BERLIN		Date of completion of the search 21 APRIL 1993	Examiner DURAND J.
<p>CATEGORY OF CITED DOCUMENTS</p> <p>X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document</p> <p>T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document</p>			

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(71) Applicant: BAYER MATERIALSCIENCE LLC
[DE/DE]; 51368 Leverkusen (DE).

(72) Inventors; and

(71) Applicants : BIGGS, Silmon, James [US/US]; 18410 Montevina Road, Los Gatos, CA 95033 (US). KRIDL, Thomas [US/US]; 1481 Ben Roe Drive, Los Altos, CA 94024 (US). SCHAPELER, Dirk [DE/US]; 3385 Tyrna Drive, Mountain View, CA 94040 (US). SWINDELLS, Colin, E. [CA/US]; 1228 Crescent Ter, Sunnyvale, CA 94087 (US).

(74) Agents: BROWN, N., Denise et al; Bayer Materialsce LLC, 100 Bayer Road, Pittsburgh, PA 15205-9741 (US).

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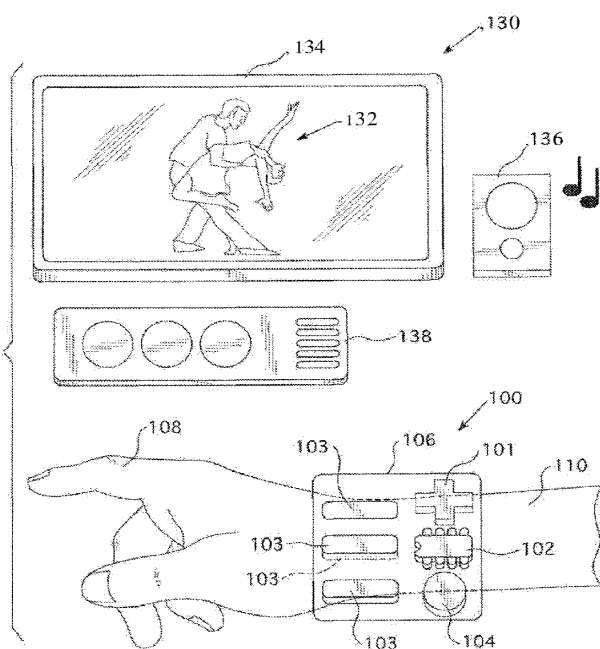


FIG. 4

(57) Abstract: Various apparatus and methods: are disclosed to: provide haptic feedback. A method and apparatus are disclosed: for biometric priming of closed-loop haptic feedback. Also disclosed are various mechanisms for vibrotactile feedback in a wearable system using electroactive polymers. Also disclosed, are a method and apparatus for adapting to resonant frequency shifts in a haptic device. Various aspects of wearable dielectric elastomer actuator(s) with compliant conductive shields and ground fault circuit interrupt circuit breaker therefor are also disclosed. An array of deformable surface actuators to provide force feedback upon touching a surface of a display/touch sensor to confirm action is also disclosed.

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**ELECTROACTIVE POLYMER ACTUATORS AND
FEEDBACK SYSTEM THEREFOR**

RELATED APPLICATIONS

[0001] This application claims the benefit, under 35 USC § 119(e), of U.S. Provisional Application Nos.: 61/757,312 filed January 28, 2013 entitled "HAPTIC BUTTON"; 61/776,942 FILED March 12, 2013 entitled "WEARABLE **DIELECTRIC** ELASTOMER ACTUATOR(S)"; 61/834,971 FILED June 14, 2013 entitled "METHOD AND **APPARATUS** FOR ADAPTING RESONANT FREQUENCY SHIFTS IN A HAPTIC DEVICE"; 61/834,976 FILED June 14, 2013 entitled "METHOD AND APPARATUS FOR BIOMETRIC PRIMING OF CLOSED-LOOP HAPTIC FEEDBACK"; and **61/878,151** filed September 16, 2013 entitled "MECHANISM FOR VIBROTACTILE FEEDBACK IN WEARABLE SYSTEMS USING ELECTROACTIVE POLYMERS"; the entirety of each of which is incorporated herein by reference.

FIELD OF THE INVENTION

[0002] The present invention is directed in general to wearable electroactive polymer devices and feedback systems therefor. In particular, the present invention is directed to electroactive polymer devices that provide a force feedback upon touching a surface of the electroactive polymer device for confirmation of action. More particularly, the present invention is directed to a wearable electroactive polymer device. Still, more particularly, the present invention is directed to adapting to resonant frequency shifts in an electroactive polymer device. Yet, more particularly, the present invention is directed to biometric priming of a closed-loop electroactive polymer device feedback. More particularly, the present invention is directed to vibrotactile feedback in a wearable electroactive polymer device.

BACKGROUND OF THE INVENTION

[0003] A tremendous variety of devices used today rely on actuators of one sort or another to convert electrical energy to mechanical energy. Conversely, many power generation applications operate by converting mechanical action into

electrical energy. Employed to harvest mechanical energy in this fashion, the same type of device may be referred to as a generator. Likewise, when the structure is employed to convert physical stimulus such as vibration or pressure into an electrical signal for measurement purposes, it may be characterized as a sensor. Yet, the term "transducer" may be used to generically refer to any electroactive devices described herein.

[0004] A number of design considerations favor the selection and use of advanced dielectric elastomer materials, also referred to as "electroactive polymers", for the fabrication of transducers. These considerations include potential force, power density, power conversion/consumption, size, weight, cost, response time, duty cycle, sendee requirements, environmental impact, etc. As such, in many applications, electroactive polymer technology offers an ideal replacement for piezoelectric, shape-memory alloy and electromagnetic devices such as motors and solenoids.

[0005] An electroactive polymer transducer comprises two electrodes having deformable characteristics and separated by a thin elastomeric dielectric material. When a voltage difference is applied to the electrodes, the oppositely charged electrodes attract each other thereby compressing the polymer dielectric layer therebetween. As the electrodes are pulled closer together, the dielectric polymer film becomes thinner (the Z-axis component contracts) as it expands in the planar directions (along the X- and Y-axes), i.e., the displacement of the film is in-plane. The electroactive polymer film may also be configured to produce movement in a direction orthogonal to the film structure (along the Z-axis), i.e., the displacement of the film is out-of-plane. U.S. Pat. No. 7,567,681 discloses electroactive polymer film constructs which provide such out-of-plane displacement - also referred to as surface deformation or as thickness mode deflection.

[0006] The material and physical properties of the electroactive polymer film may be varied and controlled to customize the deformation undergone by the transducer. More specifically, factors such as the relative elasticity between the polymer film and the electrode material, the relative thickness between the

polymer film and electrode material and/or the varying thickness of the polymer film and/or electrode material, the physical pattern of the polymer film and/or electrode material (to provide localized active and inactive areas), the tension or pre-strain placed on the electroactive polymer film as a whole, and the amount of voltage applied to or capacitance induced upon the film may be controlled and varied to customize the features of the film when in an active mode.

[0007] Numerous applications exist that benefit from the advantages provided by such electroactive polymer films whether using the film alone or using it in an electroactive polymer actuator. One of the many applications involves the use of electroactive polymer transducers as actuators to produce haptic feedback (the communication of information to a user through forces applied to the user's body) in user interface devices. There are many known user interface devices which employ haptic feedback, typically in response to a force initiated by the user. Examples of user interface devices that may employ haptic feedback include keyboards, keypads, game controller, remote control, touch screens, computer mice, trackballs, stylus sticks, joysticks, etc. The user interface surface can comprise any surface that a user manipulates, engages, and/or observes regarding feedback or information from the device. Examples of such interface surfaces include, but are not limited to, a key (e.g., keys on a keyboard), a game pad or buttons, a display screen, etc.

[0008] The haptic feedback provided by these types of interface devices is in the **form** of physical sensations, such as vibrations, pulses, spring forces, etc., which a user senses either directly (e.g., via touching of the screen), indirectly (e.g., via a vibrational effect such as when a cell phone vibrates in a purse or bag) or otherwise sensed (e.g., via an action of a moving body that creates a pressure disturbance sensed by the user). The proliferation of consumer electronic media devices such as smart phones, personal media players, portable computing devices, portable gaming systems, electronic readers, etc., can create a situation where a sub-segment of customers would benefit or desire an improved haptic effect in the electronic media device. However, increasing haptic capabilities in every model of an electronic media device may not be justified due to increased cost or

increased profile of the device. Moreover, customers of certain electronic media devices may desire to temporarily improve the haptic capabilities of the electronic media device for certain activities.

[0009] Use of electroactive polymer materials in consumer electronic media devices as well as the numerous other commercial and consumer applications highlights the need to increase production volume while maintaining precision and consistency of the films.

[0010] Most haptic actuators can generate greater maximum accelerations at some frequencies compared to others. It may be desirable to render haptic effects with spectrum intensities that are highest near the resonant frequency. Unfortunately, the resonant frequency of a typical vibrotactile system may shift by 10 Hz or more depending on application parameters such as an individual user's hand dynamics and grip strength while using the haptic device. This problem is typically ignored or approximated by designing haptic effects with wider than-optimal frequency distributions for a particular user, resulting in less compelling haptic effects. Additional drawbacks of prior art solutions include lower perceived haptic effect intensities and haptic effects that do not feel as compelling.

[0011] Effective high definition haptic feedback systems typically require update rates of 1000 Hz, or higher, and latencies of 5 ms, or lower. These performance requirements are challenging to meet with many contemporary computing systems. Conventional solutions for providing closed-loop haptic feedback typically involve measuring position, velocity, and acceleration motion, updating a model, and then rendering an updated haptic effect. A drawback of such conventional approach is a latency time that is often too long for compelling haptic feedback.

[0012] Furthermore, conventional wearable haptic feedback devices that can fit into a wearable device form factor, such as a wristband computing device, fail to create compelling vibrotactile feedback within a frequency range of 5 - 500 Hz. Conventional solutions typically place a vibrotactile actuator, such as an Eccentric Rotating Mass (ERM), Linear Resonant Actuator (LRA), or Piezoelectric actuator

-5-

(Piezo), within the wearable mechanical housing of the device. Such solutions require different mechanical assemblies to transfer vibrotactile feedback to the person and such assemblies typically have narrower operating frequency bandwidths and/or physical dimensions that are not desirable for a wearable device and/or reduced qualitative haptic "feel,"

[0013] Dielectric elastomer actuators integrated with wearable items need to be electrically shielded from the skin with a compliant electrical insulation to avoid injury to the user. The compliant insulation optionally should incorporate a conductive compliant layer to shunt any stray current away from the user and to provide a means of detecting fault current. Accordingly, it would be desirable to equip wearable haptic wrist bands or bracelets with size and stiffness sufficient to maintain contact of the actuated regions to the skin with a compliant electrical insulation layer.

[0014] Additionally, force feedback upon touching a surface with a digit is desired for confirmation of action. A glass display/touchscreen can make it difficult to type because of a lack of "press" feedback. It is also difficult to determine the location of the digit on the touchscreen because every point on the touchscreen feels the same. A standard keyboard has individual keys and ridges to make location determination easy. On a display/touch screen, this is not possible, so visual or audio feedback must be used instead. This is not as satisfying or accurate as touch feedback.

SUMMARY OF THE INVENTION

[0015] In one embodiment, the present invention provides an apparatus comprising an electroactive polymer actuator; at least one biometric sensor configured to measure a physiological characteristic of a user; and at least one motion sensor configured to measure motion of a body part, wherein the motion of the body part is associated with the physiological characteristic measured by the biometric sensor, wherein the response time of the biometric sensor is faster than the response time of the motion sensor; and a processor coupled to the electroactive polymer actuator, the biometric sensor, and the motion sensor, the

processor configured to receive and process a signal from the biometric sensor before a signal is received and processed from the motion sensor.

[0016] In another embodiment, the present invention provide a vibrolactile feedback apparatus comprising a housing having a first and second end, the housing configured to allows mechanical displacement in at least one direction; a mounting at each end of the housing; and one or more sheets of electroactive polymer arranged to form a an electroactive polymer stack actuator in a cross-sectional arrangement located within the housing, wherein the electroactive polymer stack actuator is configured for mechanical displacement upon the application of a corresponding electrical voltage potential to positive and negative electrical contacts located on opposite ends of the electroactive polymer stack actuator.

[0017] In yet another embodiment, the present invention provides a method for adapting a haptic effect rendered on a haptic device. The method comprises providing a haptic device, the haptic device including a sensor for detecting body motion, a processor for receiving body motion signals from the sensor, and an electroactive polymer actuator for producing a haptic effect, the sensor and the actuator are coupled to a mechanical accessory and are positioned relative to one another. In a computer system, the method further comprises sensing, by the computer system, a frequency response of the haptic effect while the haptic device is in use; determining, on the computer system, a frequency distribution of a rendered haptic effect; and mapping, on the computer system or in hardware, a function of the haptic effect to generate a new frequency response on the haptic device.

[0018] In yet another embodiment, the present invention provides a haptic device comprising a first sensor for capturing body motions of a person; a first actuator for rendering haptic effects to a person; and a processor for receiving the said body motion of the person and outputting haptic effects.

[0019] In yet another embodiment, the present invention provides an electroactive polymer actuator comprising a first electrical shield to provide a first shunt path

for stray current from a high voltage potential node to a low voltage potential node to shunt the stray current to the low potential node and isolate the stray current from the user; and a first ground fault circuit interrupt circuit breaker configured to detect the stray current in the first shunt path and shut down a high voltage power supply when the stray current is detected.

[0020] In yet another embodiment, the present invention provides an apparatus comprising a touch sensor; and an electroactive polymer layer disposed above the touch sensor, wherein the electroactive polymer layer comprises electrode areas configured to deform when touched to provide feedback.

[0021] These and other features and advantages of the embodiments of the present invention will become apparent to those persons skilled in the art upon reading the details of the invention as more fully described below. In addition, variations of the processes and devices described herein include combinations of the embodiments or of aspects of the embodiments where possible are within the scope of this disclosure even if those combinations are not explicitly shown or discussed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] The various embodiments of the invention are best understood from the following detailed description when read in conjunction with the accompanying drawings. To facilitate understanding, the same reference numerals have been used (where practical) to designate similar elements are common to the drawings. Included in the drawings are the following:

[0023] FIGS. 1A and 1B illustrate a top perspective view of an electroactive device before and after application of a voltage to electrodes in accordance with one embodiment of the present invention;

[0024] FIG. 2 illustrates a haptic feedback system comprising a configuration of sensors and actuators configured to provide biometric primed haptic feedback in accordance with one embodiment of the present invention;

[0025] FIG. 3 illustrates an information flow diagram depicting the relative response times of the biometric sensor(s) 104 and motion sensor(s) of the biometric primed haptic feedback system shown in FIG. 2 in accordance with one embodiment of the present invention;

[0026] FIG. 4 illustrates a gesture interaction system comprising a vibrotactile feedback wristband for use in an interactive dance game in accordance with one embodiment of the present invention;

[0027] FIG. 5 illustrates a timing diagram of a vibrotactile haptic effect having a faster response time rendered by a biometric feedback signal in accordance with one embodiment of the present invention;

[0028] FIG. 6 illustrates an architectural or component view of a computing system that may be employed with the haptic feedback systems described in connection with FIGS. 2-5 in accordance with one embodiment of the present invention;

[0029] FIG. 7 illustrates a vibrotactile feedback mechanism comprising multiple sheets of electroactive polymer material arranged in a stacked configuration in accordance with one embodiment of the present invention;

[0030] FIG. 8 illustrates a configuration of multiple electroactive polymer sheets arranged in a stack to provide a vibrotactile haptic wearable band with a stiff actuator holder in accordance with one embodiment of the present invention;

[0031] FIG. 9 illustrates an example of an electroactive polymer vibrotactile haptic wearable band with a rigid housing in accordance with one embodiment of the present invention;

[0032] FIG. 10 illustrates the vibrotactile haptic band being worn on the wrist of a user, where the vibrotactile haptic band includes an accelerometer and a processor for quantitatively measuring vibrotactile "feel" to be conveyed in a consumer device in accordance with one embodiment of the present invention;

[0033] FIG. 11 illustrates a retainer module situated in mechanical series with a wrist band in accordance with one embodiment of the present invention;

[0034] FIG. 12 is a graphical representation of a shift in frequency response of a vibrotactile haptic actuator in accordance with one embodiment of the present invention;

[0035] FIG. 13 illustrates an adaptive resonant frequency system that monitors the acceleration changes of the vibrotactile haptic device, adapts the frequency spectrum of a rendered haptic effect, and renders the adapted haptic effect to the user in accordance with one embodiment of the present invention;

[0036] FIG. 14 is a graphical representation of frequency responses of the same electroactive polymer based vibrotactile haptic actuator in the same game controller in accordance with one embodiment of the present invention;

[0037] FIG. 15 illustrates an exploded view of a compliant actuator module configuration for a touch interface in accordance with one embodiment of the present invention;

[0038] FIG. 16 illustrates an exploded view of the solid dielectric elastomer transducer roll module and various connection options in accordance with one embodiment of the present invention;

[0039] FIG. 17 is an exploded view of the compliant actuator module shown in FIG. 15 configured to electrically mount to a flex circuit in accordance with one embodiment of the present invention;

[0040] FIG. 18 illustrates a bottom perspective view of the electrical shield in accordance with one embodiment of the present invention;

[0041] FIG. 19 illustrates a schematic diagram of the compliant actuator module electrical isolation feature making it electrically safe for a user to touch the actuator module with the fingertip in accordance with one embodiment of the present invention in accordance with one embodiment of the present invention;

[0042] FIG. 20 is a graphical representation illustrating the dependency of thermal hazard of a fault upon resistance in accordance with one embodiment of the present invention;

[0043] FIG. 21 illustrates a schematic diagram of a ground fault circuit interrupter (GFCi) configured to detect current on a shield in accordance with one embodiment of the present invention;

[0044] FIG. 22A is a side sectional view of an array of deformable surface actuators in accordance with one embodiment of the present invention; and

[0045] FIG. 22B is a top view of the array of deformable surface actuators shown in FIG. 22A in accordance with one embodiment of the present invention.

[0046] Variation of the invention from that shown in the figures is contemplated.

DETAILED DESCRIPTION OF THE INVENTION

[0047] Examples of electroactive polymer devices and their applications are described, for example, in U.S. Pat. Nos. 7,394,282; 7,378,783; 7,368,862; 7,362,032; 7,320,457; 7,259,503; 7,233,097; 7,224,106; 7,211,937; **7,199,501**; 7,166,953; 7,064,472; 7,062,055; 7,052,594; **7,049,732**; **7,034,432**; 6,940,221; **6,911,764**; 6,891,317; 6,882,086; 6,876,135; 6,812,624; 6,809,462; **6,806,621**; **6,781,284**; 6,768,246; **6,707,236**; 6,664,718; 6,628,040; **6,586,859**; 6,583,533; 6,545,384; **6,543,110**; **6,376,971**; 6,343,129; 7,952,261; 7,911,761; **7,492,076**; 7,761,981; **7,521,847**; 7,608,989; 7,626,319; 7,915,789; 7,750,532; 7,436,099; **7,199,501**; **7,521,840**; 7,595,580; **7,567,681**; **7,595,580**; 7,608,989; 7,626,319; 7,750,532; 7,761,981; 7,911,761; 7,915,789; 7,952,261; **8,183,739**; 8,222,799; **8,248,750**, and in U.S. Patent Application **Publication** Nos. 2007/0200457; 2007/0230222; 2011/0128239; and 2012/0126959, the entireties of which are incorporated herein by reference.

[0048] It is noted that the figures discussed herein schematically illustrate exemplary configurations of devices and processes that employ electroactive polymer films or transducers having such electroactive polymer films. Many variations are within the scope of this disclosure, for example, in variations of the device, the electroactive polymer transducers can be implemented to control the size of apertures having varying geometries.

[0049] Embodiments of the present invention may be manufactured using various processes.

[0050] Various embodiments of electroactive polymer transducers are described in detail hereinbelow. Prior to describing such embodiments, however, the description turns briefly to FIGS. 1A-1B, which illustrate a top perspective view of an electroactive device before and after application of an electric voltage potential to electrodes in accordance with one embodiment of the present invention. A brief description of general electroactive polymer structures and processes for producing such structures are provided in connection with FIGS. 1A-1B.

[0051] Turning now to FIGS. 1A and 1B where an example of an electroactive polymer film or membrane 10 structure is illustrated. A thin elastomeric dielectric film or layer 12 is sandwiched between compliant or stretchable electrode plates or layers 14 and 16, thereby forming a capacitive structure or film. The length "l" and width "w" of the dielectric layer, as well as that of the composite structure, are much greater than its thickness "t". Preferably, the dielectric layer has a thickness in the range from about 10 μm to about 100 μm , with the total thickness of the structure in the range from about 15 μm to about 10 cm. Additionally, it is desirable to select the elastic modulus, thickness, and/or the geometry of electrodes 14, 16 such that the additional stiffness they contribute to the actuator is generally less than the stiffness of the dielectric layer 12, which has a relatively low modulus of elasticity, i.e., less than about 100 MPa and more preferably less than about 10 MPa, but is likely thicker than each of the electrodes. Electrodes suitable for use with these compliant capacitive structures are those capable of withstanding cyclic strains greater than about 1% without failure due to mechanical fatigue.

[0052] As seen in FIG. 1B, when a voltage is applied across the electrodes, the unlike charges in the two electrodes 14, 16 are attracted to each other and these electrostatic attractive forces compress the dielectric film 12 (along the Z-axis). The dielectric film 12 is thereby caused to deflect with a change in electric field.

As electrodes 14, 16 are compliant, they change shape with dielectric layer 12. In the context of the present disclosure, "deflection" refers to any displacement, expansion, contraction, torsion, linear or area strain, or any other deformation of a portion of dielectric film 12. Depending on the architecture, e.g., a frame, in which capacitive structure 10 is employed (collectively referred to as a "transducer"), this deflection may be used to produce mechanical work. Various different transducer architectures are disclosed and described in the above-identified patent references.

[0053] With a voltage applied, the transducer film 10 continues to deflect until mechanical forces balance the electrostatic forces driving the deflection. The mechanical forces include elastic restoring forces of the dielectric layer 12, the compliance or stretching of the electrodes 14, 16 and any external resistance provided by a device and/or load coupled to transducer 10. The resultant deflection of the transducer 10 as a result of the applied voltage may also depend on a number of other factors such as the dielectric constant of the elastomeric material and its size and stiffness. Removal of the voltage difference and the induced charge causes the reverse effects.

[0054] In some cases, the electrodes 14 and 16 may cover a limited portion of dielectric film 12 relative to the total area of the film. This may be done to prevent electrical breakdown around the edge of the dielectric or achieve customized deflections in certain portions thereof. Dielectric material outside an active area (the latter being a portion of the dielectric material having sufficient electrostatic force to enable deflection of that portion) may be caused to act as an external spring force on the active area during deflection. More specifically, material outside the active area may resist or enhance active area deflection by its contraction or expansion.

[0055] The dielectric film 12 may be pre-strained. The pre-strain improves conversion between electrical and mechanical energy, i.e., the pre-strain allows the dielectric film 12 to deflect more and provide greater mechanical work. Pre-strain of a film may be described as the change in dimension in a direction after

pre-straining relative to the dimension in that direction before pre-straining. The pre-strain may include elastic deformation of the dielectric film and be formed, for example, by stretching the film in tension and fixing one or more of the edges while stretched. The pre-strain may be imposed at the boundaries of the film or for only a portion of the film and may be implemented by using a rigid frame or by stiffening a portion of the film.

[0056] The transducer structure of FIGS. 1A and 1B and other similar compliant structures and the details of their constructs are more fully described in many of the referenced patents and publications disclosed herein. The following description now turns to various embodiments of electroactive devices for varying the size of or deforming an aperture defined within a pretensioned electroactive polymer film constrained on its perimeter edges by a rigid frame.

[0057] ***Method and Apparatus For Biometric Priming Of Closed-loop Haptic Feedback***

[0058] In various embodiments, the present invention provides haptic feedback systems. In one embodiment, the haptic feedback systems are vibrotactile feedback systems that are effective high definition haptic feedback systems with update rates of about 1000 Hz, or higher, and latencies of about 5 ms, or lower. In one embodiment, the present invention leverages the relatively faster response of biometric responses, such as electromyography (EMG), electroencephalography (EEG), and heart rate, which often occur before biological motor responses, such as movement of a body part.

[0059] Embodiments of the invention described hereinbelow in connection with FIGS. 2-6 provide faster and more accurate closed loop haptic feedback systems as compared to conventional haptic feedback systems. It will be appreciated that various embodiments of the present invention can be applied to all body sites, biometric sensing technologies, and haptic actuators. Audio, visual, and other sensory modalities, can be coupled into the closed loop feedback system.

[0060] FIG. 2 illustrates a haptic feedback system 100 comprising a configuration of sensors and actuators configured to provide biometric primed haptic feedback

in accordance with one embodiment of the present invention. The haptic feedback system 100 shown in FIG. 2 comprises an arrangement of sensor and actuator components that employ biometric priming. Biometric responses, such as EMG, EEG, and heart rate, often occur before a biological motor response, such as finger or arm movement. Therefore, incorporating biometric measurements, such as EMG, EEG, and heart rate, in the closed loop haptic feedback system 100 improves the speed and quality of the haptic feedback.

[0061] In the particular embodiment shown in FIG. 2, the haptic feedback system 100 comprises at least one motion sensor 101, a computing system 102, at least one biometric sensor 104, and at least one haptic actuator 103. The sensors and actuators are arranged on a wearable device such as a vibrotactile feedback wristband 106 or other wearable device suitable for transmitting vibrotactile sensations to the user. The haptic feedback system 100 is configured to monitor the physiologic characteristics of the user associated with corresponding musculoskeletal motion of the user's 108 body or body part including, without limitation, the user's 108 arm, hand, finger, leg, foot, toe, head, neck, torso, or any part of the user's 108 body, for example. In the illustrated embodiment, the haptic feedback system 100 is located on a vibrotactile feedback wristband 106 that is worn on the arm 110 of the user 108 making it particularly useful for detecting motion and biometric responses of the user's 108 arm, hand, and/or finger(s).

[0062] The at least one motion sensor 101 is coupled to the user and may comprise any suitable motion sensor such as an inertial sensor. An inertial sensor may comprise an accelerometer, a gyroscope, and/or a magnetometer, alone or in any combination thereof. In various embodiments, the accelerometer, gyroscope, and/or the magnetometer may be single, double, or triple axis. The at least one biometric sensor 104 is coupled to the user and may comprise any suitable biometric sensor for measuring the physiologic characteristics of the user 108, such as EMG, EEG, heart rate, among other physiologic parameters associated with the user 108. The at least one haptic actuator 103 may comprise any suitable haptic actuator comprising, for example, an electroactive polymer based actuator

described in connection with FIGS. 1A-1B and/or FIGS. 15-19 below, for example, among other suitable haptic actuators.

[0063] The motion sensor(s) 101, biometric sensor(s) 104, and/or haptic actuator(s) 103 are coupled to the computing system 102, which may contain a microcontroller or processor to control the sampling of the sensors 101, 104 and the actuation of the haptic actuator(s) 103. Data from the motion sensor(s) 101 may be used to sense muscle movements. For example, data from a triple axis accelerometer may be employed to monitor muscle motion. However, in accordance with the current embodiment, data from an accelerometer, gyroscope, and/or magnetometer may be fused and employed to track body motion. It will be appreciated that the motion sensor(s) 101 may comprise a plurality of inertial sensors where each inertial sensor comprises a subset of inertial sensors, e.g., accelerometer, gyroscope, magnetometer, among others, or may comprise additional inertial sensors. The response time of the biometric sensor 104 is faster than the response time of the motion sensor 101.

[0064] In one embodiment the processor of the computing system 102 may be implemented with an ATmega28RFA1 chip available from Atmel Corporation. The accelerometer may be implemented with an ADXL345 Digital Accelerometer board available from Analog Devices. The gyroscope may be implemented with an ITG3200 board available from InvenSense Inc. The magnetometer may be implemented with an HMC5883L 3-Axis Digital Compass IC available from Honeywell International Inc. It will be appreciated that such inertial sensor components may be replaced with any equivalent components without limiting the scope of the present invention. In one embodiment, the processor of the computing system 102 may be linked to the accelerometer, gyroscope, and/or magnetometer of the motion sensor 101 via an internal wired I2C bus interface. In one embodiment, the motion sensors 101 may be connected to each other and to a wireless device using a wired Serial Peripheral Interface (SPI), for example.

[0065] FIG. 3 illustrates an information flow diagram 120 depicting the relative response times of the biometric sensor(s) 104 and motion sensor(s) 101 of the

biometric primed haptic feedback system 100 shown in FIG. 2 in accordance with one embodiment of the present invention. The information flow diagram 120 illustrates a closed loop feedback path showing the speed advantage provided by biometric priming. According to the information flow diagram 120, a biometric sensor 104 monitors EMG activity in a person's arm corresponding to the user's muscle activity that con-elates to a leftward finger movement is identified first (t1) and is combined with spatial coordinates obtained from an accelerometer type of motion sensor 101 (t2). The response time (t1) of the biometric sensor 104 is faster than the response time (t2) of the motion sensor 101 such that response time (t1) of the biometric sensor 104 occurs before the response time (t2) of the motion sensor 101. Thus, before the data from the motion sensor 101 has been fully processed by the computing system 102, a predictive haptic effect model may be updated with the current data from the biometric sensor(s) 104 and previous data from the motion sensor(s) 101 as appropriate for a leftward finger movement, for example. The haptic effect is then rendered on the haptic actuator(s) 103 to provide feedback to the user. Accordingly, the biometric priming of the haptic feedback loop 100 shown in FIG. 2 reduces the perceived system lag in the haptic feedback system 100 and provides effective high definition haptic feedback at update rates of about 1000 Hz, or higher, and latencies of about 5 ms, or lower.

[0066] The haptic feedback system 100 shown in FIG. 2 and the relative response times illustrated in FIG. 3, leverage the fact that biometric responses, such as EMG, EEG, and heart rate, often occur before a corresponding biological motor response, such as movement of a finger, hand, or arm. For example, the signal produced by a biometric sensor 104 monitoring EMG activity in a person's arm is generated before the signal produced by the motion sensor 101 triggered by the actual muscle activity that correlates to a leftward finger movement, for example. The comparative speed of biometric response times relative to motion response times are described in A. C. Guimaraes et al, "The EMG-Force Relationship Of The Cat Soleus Muscle And Its Association With Contractile Conditions During Locomotion," *The Journal of Experimental Biology* 198, Great Britain, 1995, pp. 975-987, which is incorporated herein by reference. The reference describes that

an EMG signal is fired 3-5 ms faster than a resulting force. Examples of different firing rates for EMG signals may be found at the following link:

<http://www.aanem.org/getmedia/46bbb93d-d326-41bb-827a-38d511490e25/Tech-Rgnl-2-Basic-EMG-AANEM-Koontz.pdf.aspx>, p. 23, which is incorporated herein by reference. In addition, an example of an EMG in a jogging application is described in Mamix G. J. Gazendam, "Averaged EMG Profiles In Jogging And Running At Different Speeds," *Gate and Posture* 25, The Netherlands, 2007, pp. 604-614, which is also incorporated herein by reference.

[0067] FIG. 4 illustrates a gesture interaction system 130 comprising a vibrotactile feedback wristband 106 for use in an interactive dance game in accordance with one embodiment of the present invention. This example describes a typical use of biometric priming for closed-loop haptic feedback using the haptic feedback system 100 described in connection with FIG. 2. FIG. 4 illustrates a typical gaming context that benefits from vibrotactile haptic feedback provided by the haptic feedback system 100. The user 108 wears a haptic wristband 106 to control the characters 132 displayed on the video game display 134 and audio speakers 136. The haptic wristband 106 provides game control with vibrotactile haptic feedback to the user 108. The wristband 106 controller is connected to a video game system 138. As the user 108 performs a gesture with his/her arm 110, the biometric sensor(s) 104 and the motion sensor(s) 101 track the motion of the arm 110. Haptic feedback is provided to the user 108 via electroactive polymer stack actuator(s) 103 within the wristband 106. Haptic feedback aids positioning of the dancers 132 or beat matching of music in the game. A microcontroller 102 within the wristband 106 rapidly and continuously senses muscle activity data from the EMC sensor 103 and motion data from the accelerometer 101. The wristband 106 is a specialized game controller that is linked to the video game system 138. Typical update rates for the haptic feedback system 100 range between 1000 Hz to 10,000+ Hz (1 ms to 0.1 ms),

[0068] FIG. 5 illustrates a timing diagram 140 of a vibrotactile haptic effect having a faster response time rendered by a biometric feedback signal in accordance with one embodiment of the present invention. The response time is

faster because, as previously discussed, bionietric data such as EMG waveforms of arm muscle activity 142 is sensed before any corresponding physical movement of the arm of the user is sensed by an accelerometer 144. As shown in FIG. 5, biometric priming results in faster, higher quality haptic feedback.

[0069] The EMG muscle activity is indicated by the EMG waveform 142 and is sensed before the accelerometer activity 144. As shown by the biometric timeline 146, sensed bionietric data relating to the user's arm gesture for the game is acquired over period t_{EMG} is processed by the microcontroller's 150 haptic effect functions 148 before the acceleration data 144 acquired over period $t_{a,c}$ is presented to the microcontroller 150 as shown by the motion timeline 154. Consequently, an appropriate haptic effect update can be actuated on the electroactive polymer actuators 152 faster and with better quality than only using spatial data, such as acceleration 144 updates.

[0070] FIG. 6 illustrates an architectural or component view of a computing system 160 that may be employed with the haptic feedback systems described in connection with FIGS. 2-5 in accordance with various embodiments of the present invention. In various embodiments, as illustrated, the computing system 160 comprises one or more processors 162 (e.g., microprocessor, microcontroller) coupled to various sensors 174 (e.g., motion sensors, biometric sensors) and at least one haptic actuator 172 (e.g., electroactive polymer stack actuator) via a suitable driver 170 circuit. In addition, to the processor(s) 162, a storage 164 (having operating logic 166) and communication interface 168, are coupled to each other as shown.

[0071] As described earlier, the sensors 174 may be configured to detect and collect biometric data associated with position, posture, and/or movement of any part of the user's body, such as, for example, the user's arms(s), hand(s), finger(s), leg(s), foot/feet, toe(s), head, neck, torso, among other body parts. The processor 162 processes the biometric and motion sensor data received from the sensors(s) 174 to provide haptic feedback to the user by actuating the haptic actuator 172 via the driver 170 circuit.

[0072] The processor 162 may be configured to execute the operating logic 166. The processor 162 may be any one of a number of single or multi-core processors known in the art. The storage 164 may comprise volatile and non-volatile storage media configured to store persistent and temporal (working) copy of the operating logic 166.

[0073] In various embodiments, the operating logic 166 may be configured to process the collected biometric associated with motion data of the user, as described above. In various embodiments, the operating logic 166 may be configured to perform the initial processing, and transmit the data to the computer hosting the application to determine and generate instructions on the visual and/or tactile feedback to be provided. For these embodiments, the operating logic 166 may be further configured to receive the biometric and motion data associated with the user and provide tactile feedback to a hosting computer. In alternate embodiments, the operating logic 166 may be configured to assume a larger role in receiving the biometric and motion data and determining the tactile feedback, e.g., but not limited to, the generation of vibratory sensations by driving 170 the haptic actuator 172. In either case, whether determined on its own or responsive to instructions from a hosting computer, the operating logic 166 may be further configured to control the haptic actuator 172 to provide or tactile feedback to the user.

[0074] In various embodiments, the operating logic 166 may be implemented in instructions supported by the instruction set architecture (ISA) of the processor 162, or in higher level languages and compiled into the supported ISA. The operating logic 166 may comprise one or more logic units or modules. The operating logic 166 may be implemented in an object oriented manner. The operating logic 166 may be configured to be executed in a multi-tasking and/or multi-thread manner. In other embodiments, the operating logic 166 may be implemented in hardware such as a gate array.

[0075] In various embodiments, the communication interface 168 may be configured to facilitate communication between a peripheral device and the

computing system 160. The communication may include transmission of the collected biometric data associated with position, posture, and/or movement data of the user's body part(s) to a hosting computer, and transmission of data associated with the tactile feedback from the host computer to the peripheral device. In various embodiments, the communication interface 168 may be a wired or a wireless communication interface. An example of a wired communication interface may include, but is not limited to, a Universal Serial Bus (USB) interface. An example of a wireless communication interface may include, but is not limited to, a Bluetooth interface.

[0076] For various embodiments, the processor 162 may be packaged together with the operating logic 166. In various embodiments, the processor 162 may be packaged together with the operating logic 166 to form a System in Package (SiP). In various embodiments, the processor 162 may be integrated on the same die with the operating logic 166. In various embodiments, the processor 162 may be packaged together with the operating logic 166 to form a System on Chip (SoC).

[0077] ***Mechanism For Vihrotactile Feedback In A Wearable System Using Electroactive Polymers***

[0078] In various other embodiments, the present invention provides haptic feedback devices configured to fit into a wearable device form factor, such as a wristband. In one embodiment, the wearable haptic feedback device according to the present invention may comprise a computing device. In one embodiment, the wearable haptic feedback device provides compelling vihrotactile feedback within a frequency range of 5 to 500 Hz. In one embodiment, the wearable haptic feedback device according to the present invention comprises stacked layers or sheets of electroactive polymer materials and in some embodiments, the electroactive polymer stack may be located within a retainer module and can be either pre-stressed or unstressed.

[0079] Embodiments of the invention described below in connection with FIGS. 7-11 provide a mechanical assembly that can leverage electroactive polymer to provide vihrotactile haptic feedback over a wider frequency range and in a more

convenient form factor than conventional realizations. Form factor improvements include mechanical compliance suitable for wearable computing devices and a tension sheath that provides tension over the electroactive polymer stacks to improve overall acceleration intensity and frequency response consistency as well as mechanical support for the wearable device. Other possible uses of these embodiments include industrial and consumer applications where vibration on an object is desired without applying adhesives or fasteners directly to the object(s) to receive the vibration.

[0080] FIG. 7 illustrates a vibrotactile feedback mechanism 200 comprising multiple sheets of electroactive polymer material arranged in a stacked configuration 208 in accordance with one embodiment of the present invention. In the illustrated embodiment, the vibrotactile feedback mechanism 200 is coupled to a tension sheath 204 to provide a vibrotactile haptic wearable band 202. In various embodiments, the invention is typically incorporated in a wearable device 202 to provide touch feedback (vibrotactile haptic feedback) on a person's body, such as the wrist 206 or arm. Multiple electroactive polymer sheets are arranged to form a stack 208 of electroactive polymer sheets or materials in a cross-sectional arrangement and are attached to a rigid base 210 that is firmly mounted to the wearable device 202. An electrical contact mechanism 212 attaches to positive and negative electrical contacts to the opposing ends or edges of the electroactive polymer stack 208. A tension sheath 204 provides continuous forces 214 to keep the electroactive polymer stack 208 tightly connected to the main device assembly 202 while providing suitable compliance and flexibility to generate effective vibrotactile haptic feedback forces 214. The electroactive polymer stack 208 predominantly creates vibrotactile displacements perpendicular to the electroactive polymer surface axis 216; however, some parallel displacements also may occur.

[0081] FIG. 8 illustrates a configuration 250 of multiple electroactive polymer sheets arranged in a stack 258 to provide a vibrotactile haptic wearable band 252 with a stiff actuator holder in accordance with one embodiment of the present invention. As shown in FIG. 8, the electroactive polymer stack 258 are housed

within a rigid assembly 262, 263 where a section 261 is able to move back and forth along an axis 256 because the right edge of the electroactive polymer stack 258 housing 263 has compliance along the axis 256. Similar to the embodiment described in connection with FIG. 7, vibrotactile haptic feedback forces 264 occur as voltage is applied across the surface of each electroactive polymer sheet within the stack 258. The electroactive polymer stack 258 predominantly creates vibrotactile displacements perpendicular to the electroactive polymer surface axis 256; however, some parallel displacements also may occur.

[0082] An electrical contact mechanism 266 attaches to positive and negative electrical contacts to the opposing edges of the electroactive polymer stack 258. An electrical grounding sheath 253 protects the user from electrical shock and protects the electroactive polymers from environmental hazards such as moisture. The vibrotactile assembly is contained within a wearable device 252 that is placed in contact with a user's body, such as the wrist 256. In one embodiment, the electroactive polymer stack 258 may be held in the stiff assembly 262, 263 in a pre-compressed state whereas in other embodiments, the electroactive polymer stack 258 is held in the rigid assembly 262, 263 in a non-compressed state.

[0083] FIG. 9 illustrates an example of an electroactive polymer vibrotactile haptic wearable band 270 with a rigid housing in accordance with one embodiment of the present invention. The embodiment shown in FIG. 9 is a prototype of the electroactive polymer vibrotactile haptic wearable band 270 incorporated in a watch strap 272 form factor.

[0084] FIG. 10 illustrates the vibrotactile haptic band 270 being worn on the wrist 274 of a user, where the vibrotactile haptic band includes an accelerometer 276 and a processor 278 for quantitatively measuring vibrotactile "feel" to be conveyed in a consumer device in accordance with one embodiment of the present invention. The embodiment shown FIG. 10 is an example of the electroactive polymer vibrotactile haptic wearable band 270 incorporated in a watch band 272 and worn on a person's wrist 274. In the illustrated embodiment, 40 electroactive polymer stacks 5 mm wide by 18 mm long were driven with a voltage difference

of 1800 V. As a result, vibrotactile "feels" between 0 - 3 Gs of acceleration and 30-250 Hz were conveyed to the person's wrist 274.

[0085] FIG. 11 illustrates a retainer module 300 situated in mechanical series with a wrist band in accordance with one embodiment of the present invention. As shown in FIG. 11, the retainer module 300 may be situated in mechanical series with a wrist band. A central gap is defined by a re-curved face 302 of a flexure 304. The central gap is slightly shorter than the thickness of a electroactive polymer stack actuator module 306 to hold it in a pre-compressed state. Electrical terminals 308 located on the stack actuator module 306 electrically mate with corresponding terminals in the retainer module 300. The retainer module 300 has a face 310 that is optionally integral with the body of a watch or other personal electronic device to be worn by the user. In various embodiments, the stack actuator module 306 is similar to the elastomer transducer roll module 504 shown in connection with FIGS. 15-17 and 19.

[0086] With reference again to FIGS. 7-11, in various embodiments, a vibrotactile feedback apparatus includes a housing having a first and second end that allows mechanical displacement in at least one direction, a mounting at each end of the housing, and one or more sheets of electroactive polymer stacked in a cross-sectional arrangement located within the housing. In one embodiment, the mechanical displacement provides movement perpendicular to the sheets of electroactive polymer and the mechanical displacement is rigid to prevent movement in both axes parallel to the sheets of electroactive polymer. In another embodiment, the mechanical displacement provides movement perpendicular to the sheets of electroactive polymer and the mechanical displacement also provides movement in one or two axes parallel to the sheets of electroactive polymer. In yet another embodiment, the housing is a semi-rigid plastic body and in one such embodiment the housing comprises two or more semi-rigid bodies that are connected by an elastic sheath material. In yet another embodiment, the housing is a wearable computing accessory such as, but not limited to, a wristband, hand band, arm band, torso band, ankle band, headband, or ear attachment sheets of electroactive polymer. Yet in another embodiment, the elastic sheath material

provides tensions between 0 - 5 N of force. In another embodiment, the vibrotactile feedback is operated at frequencies between 0 to 500 Hz when electric voltage potentials between 0 to 2000 V are applied across the sheets of electroactive polymer.

[0087] *Method And Apparatus For Adapting To Resonant Frequency Shifts In A Haptic Device*

[0088] In various other embodiments, the present invention provides haptic actuators configured to generate greater maximum accelerations near the resonant frequency. In one embodiment, the haptic feedback effects are rendered within a spectrum of intensities that are highest near the resonant frequency. In one embodiment, the haptic actuators according to the present invention compensate for any shifts in the resonant frequency depending on hand dynamics and grip strength of an individual user while using the haptic device. Accordingly, in one embodiment, the haptic actuators according to the present invention are configured to provide haptic effects within an optimal frequency distribution for a particular user, resulting in more compelling haptic effects.

[0089] In various embodiments, the present invention provides a method and apparatus that adapts to resonant frequency shifts in a handheld vibrotactile haptic device. It would be desirable to render haptic effects with a spectrum of intensities that are highest near or at the resonant frequency. Unfortunately, the resonant frequency of a typical vibrotactile system may shift by up to 10 Hz or more depending on an individual user's hand dynamics and grip strength while using the haptic device.

[0090] Embodiments of the invention described below in connection with FIGS. 12-14 provide haptic effects that are more intense and compelling and/or maintain similar intensity and perceived haptic quality levels while increasing lifespan, lowering operating voltages, and lowering production costs for implementations using actuators such as electroactive polymers. Other possible uses of these various embodiments of the present invention include adapting a vibrotactile

effect to maximize resonant frequencies in applications other than haptics, such as electroactive polymer valve operations, for example,

[0091] FIG. 12 is a graphical representation 400 of a shift in frequency response of a vibrotactile haptic actuator in accordance with one embodiment of the present invention. Acceleration (g) is shown along the vertical axis and frequency (Hz) is shown along the horizontal axis. A first curve 402 represents the frequency response F_d (default frequency response) centered at first resonant frequency R_d for a vibrotactile haptic actuator. A second curve 404 represents the shifted frequency response F_s (shifted frequency response) centered at a second resonant-frequency R_s because of a user's hand dynamics and grip strength. This results in a resonant frequency shift from R_d to R_s .

[0092] FIG. 13 illustrates an adaptive resonant frequency system 410 that monitors the acceleration changes of the vibrotactile haptic device, adapts the frequency spectrum of a rendered haptic effect, and renders the adapted haptic effect to the user in accordance with one embodiment of the present invention. The adapted haptic effect provides improved "feel" attributes such as greater intensity and wider perceived frequency range. The system 410 adapts the haptic effect frequency distribution in response to a user's body dynamics such that the user feels effects at or near a resonant frequency. Haptic effects at or near resonant frequency are typically perceived as more intense and are desirable in many haptic applications including gaming, medical, automotive, and home appliance domains.

[0093] Still with reference to FIG. 13 the system 410 is configured to implement the steps for vibrotactile haptic effect frequency adaptation in accordance with one embodiment of the present invention. As shown in FIG. 13, at Step 1, an accelerometer 412 system monitors the frequency response 418 of the haptic system. At Step 2, a haptic effect model 414 is updated in response to the frequency experienced by a particular user. At Step 3, the frequency spectrum adapted haptic effect is rendered to the haptic actuator 416. As shown in FIG. 13, the system 410 monitors the acceleration changes of the vibrotactile haptic

actuator 416 using an accelerometer 412, then adapts the frequency spectrum of a rendered haptic effect in a haptic effect model 414, and finally renders the adapted haptic effect to the user via the haptic actuator 416. The adapted haptic effect provides improved "feel" attributes such as greater intensity and wider perceived frequency range.

[0094] Haptic effects can be adapted using purely software, purely hardware, or a combination of software and hardware approaches. Software approaches would typically involve filtering the haptic model 414 using band pass filters, gain adjustments, and other techniques to create a new waveform with dominant frequencies near the system resonant frequency and less dominant frequencies elsewhere. Hardware approaches include physical assemblies that alter the dynamic properties, such as stiffness and damping, of the haptic system while monitoring the system's resonant frequency. Adaptation to haptic effects should consider perceptual sensitivities of users to frequency changes. For example, users may not notice a frequency shift of 5 to 10 Hz, but may notice a shift in 20 Hz. Consequently, the adaptive resonant frequency system 410 needs to consider both the physical characteristics of the haptic device and human sensitivities and preferences. User preferences can be satisfied with a user controllable switch, an automated recommendation system, or other embodiments.

[0095] FIG. 14 is a graphical representation 450 of frequency responses of the same electroactive polymer based vibrotactile haptic actuator in the same game controller in accordance with one embodiment of the present invention.

Acceleration (g) is shown along the vertical axis and Frequency (Hz) is shown along the horizontal axis and various frequency responses are depicted by the graphical representation 450. The dashed lines 452, 454 show two frequency responses for a particular user while holding the game controller with a light grip. The dark solid lines 456, 458 show two frequency responses for the same user holding the controller, but with a different grip. The light solid line 460 shows a user holding the same game controller with a light grip. The various curves 452, 454, 456, 458, 460 suggest that a pulsing haptic effect might best span a frequency band similar to Target Frequency Band A while users hold the controller with a

light grip and a frequency band similar to Target Frequency Band B while users hold the controller with a tight grip.

[0096] Additional considerations are the perceived intensity of the target body site, such as an index finger or palm of hand, for a particular acceleration at a particular frequency. If the dominant frequency of the haptic effect is at 65 Hz during a tight grip, for example, FIG. 14 shows that high accelerations between 2.0 to 2.3 g can be expected; however, with a tight grip, the same 65 Hz frequency would result in accelerations less than 1.0 g. Conversely, if a haptic effect is updated to have a dominant frequency of 90 Hz, accelerations of 1.5 g can be expected. Haptic effects can be adapted using well known techniques such as band pass filtering and gain adjustments with decision trees, or more sophisticated machine learning approaches. The haptic effects should typically span a relatively wide frequency band, with varying high intensity components near certain desirable frequencies, such as the resonant frequency for the system. This wide frequency range enables acceleration measurements to continuously monitor the dynamic frequency response of the system while user interacts with the haptic device. Although stability may present an issue in these and all haptic systems, closed-loop control is designed to maximize acceleration or perceived intensity of a vibrotactile haptic effect using actuators such as electroactive polymers or piezoelectric devices.

[0097] Accordingly, in one embodiment, the present invention described in connection with FIGS. 12-14 provides a method for adapting a haptic effect rendered on a haptic device. The method comprises providing a haptic device, the haptic device including a sensor for capturing body motion, a processor for receiving the body motion, and an actuator for providing haptic feedback to the person. The sensor and the actuator are coupled to a mechanical accessory and positioned relative to one another. In a computer system, the method further comprises sensing the frequency response of the haptic effect while a person uses the haptic device, performing, on the computer system, a calculation to determine the frequency distribution of a rendered haptic effect, performing, on the computer or in hardware, a mapping function of a haptic effect to generate a new frequency

response on the haptic device. Filtering or other modifications of a haptic effect may be influenced by the haptic device user.

[0098] In another embodiment, the mapping function involves filtering frequencies between 5 to 500 Hz. In yet another embodiment, the calculation updates at rates between 500 to 50,000 Hz. In another embodiment, the calculation includes a calculation to define a peak frequency.

[0099] Yet in another embodiment, the body motion is a hand motion of the person. In various other embodiments, the sensor is an accelerometer, a position sensor, or a combination thereof. In various other embodiments, the actuator is an electroactive polymer, a piezoelectric material, or a combination thereof.

[0100] In another embodiment, the present invention provides a haptic device comprising: a first sensor for capturing body motions of a person, a first actuator for rendering haptic effects to a person, and a processor for receiving the body motion of the person and outputting haptic effects. Each of the haptic effects based on a calculation where the calculation adapts to changes in the frequency distribution as a dynamic physical system changes. The dynamic physical system comprises the haptic device.

[0101] *Wearable Dielectric Elastomer Actuator(s) With Compliant Conductive Shield And Ground Fault Circuit interrupt Circuit Breaker Therefor*

[0102] In various other embodiments, the present invention provides dielectric elastomer actuators integrated with wearable items that are electrically shielded from the user's skin with a compliant electrical insulation to avoid injury to the user. In one embodiment, the compliant insulation optionally incorporates a conductive compliant layer or shield to shunt any stray current away from the user and to provide a means of detecting fault current. In one embodiment, the haptic wrist bands or bracelets are equipped with a size and stiffness sufficient to maintain contact of the actuated regions to the skin with a compliant electrical insulation layer. In other embodiments, the present invention provides electrical circuits configured with ground fault circuit interrupters (GFCI) to detect any

current on the conductive compliant layer or shield and cut off the current flow when it is detected.

[0103] Dielectric elastomer actuators are integrated with a wearable item. They are electrically shielded from the skin with a compliant insulation. The compliant insulation optionally incorporates a conductive compliant layer that shunts any stray current away from the user and provides a means of detecting fault current. One embodiment of the invention is a wrist band or bracelet with size and stiffness sufficient to maintain contact of the actuated regions to the skin.

[0104] FIG. 15 illustrates an exploded view of a compliant actuator module 500 configuration for a touch interface in accordance with one embodiment of the present invention. The compliant actuator module 500 is packaged in a manner that is safe to touch. In the embodiment shown in FIG. 15, the compliant actuator module 500 is integrated with a case or housing 512 defining an aperture 514 to provide touch access to a portion of the compliant actuator module 500. In one embodiment, the compliant actuator module 500 comprises a compliant electrically conductive housing 502 and a solid dielectric elastomer transducer roll module 504 attached to a module support 508, which is specific to the case or housing in which the compliant actuator module 500 is integrated with. The module support 508 is configured to fixedly attach the substrate 506 to the housing 512. Optionally, the compliant actuator module 500 may comprise mounting fasteners 510. A portion of the compliant conductive housing 502 protrudes through an opening 514 defined in the housing 512 or housing of a device. The compliant conductive housing 502 is made of an electrically conductive material and is electrically connected to case ground (shield ground) at terminal 518 by an electrically conductive adhesive 520. In one embodiment, a flex connector 522 electrically couples the solid dielectric elastomer transducer roll module 504 to an electronic system through electrical contacts and/or traces 524.

[0105] FIG. 16 illustrates an exploded view of the solid dielectric elastomer transducer roll module 504 and various connection options in accordance with one

embodiment of the present invention. The solid dielectric elastomer transducer roll module 504 comprises a substrate 506 which includes holes 526a, 526b for injection molding and for wire termination. The substrate also includes electrically conductive terminals 528 that are suitable for soldering wires or for soldering surface mount technology (SMT) components thereto. The conductive terminals 528a, 528b are accessible above and below the substrate as discussed hereinbelow. SMT terminal points 530 are soldered to the conductive terminals 528a, 528b. A solid dielectric elastomer transducer roll 531 is then attached to the substrate 506 and conductive silicone 534 is applied at the ends of the solid dielectric elastomer transducer roll 531, by insert molding or other techniques, to electrically couple the transducer roll 534 to the terminal points 530 and the conductive terminals 528a, 528b. An electrically insulative silicone coating 516 is applied to the exterior surface of the transducer roll 534, by insert molding, or other techniques. The electrically insulative silicone coating 516 is interposed between the transducer roll 534 and the compliant electrically conductive housing 502.

[0106] There are various options for providing electrical connections to the solid dielectric elastomer transducer roll module 504. One option includes attaching the flex circuit 522 to the transducer module 504 via SMT conductive terminals 536a, 536b provided underneath the substrate 506. The conductive terminals of the flex circuit 522 are coupled to a high voltage driver circuit. The SMT conductive terminals 536a, 536b on the bottom layer of the substrate 506 are electrically coupled to the SMT conductive terminals 528a, 528b on the top layer of the substrate 506. The bottom SMT conductive terminals 536a, 536b may be used to attach the transducer roll module 504 to other substrates and / or external devices. Alternatively, the transducer roll module 504 may be electrically coupled by electrical wires 538a, 538b attached through conductive via through-holes 526a, 526b through the substrate 506. The high voltage positive (HV+) lead wire 538a is connected to the positive terminal of a high voltage drive circuit and the high voltage ground (HV GND) lead wire 538b is connected to the ground terminal of the high voltage drive circuit. Housing ground (SHIELD GND) is connected to

terminal 518. Alternatively, the transducer roll module 504 may be electrically connected to other systems and / or substrates by way of quick-connect interconnects such as those described in commonly owned PCT International Patent Application PCT/US 13/55304, which is hereby incorporated by reference in its entirety.

[0107] FIG. 17 is an exploded view of the compliant actuator module 500 shown in FIG. 15 configured to electrically mount to a flex circuit 522 in accordance with one embodiment of the present invention. The compliant actuator module 500 comprises a solid dielectric elastomer transducer roll module 504, an electrical shield 532, and a flex circuit 522. The electrical shield 532 provides electrical isolation and makes it electrically safe for a user to touch the actuator module 500 with the fingertip.

[0108] FIG. 18 illustrates a bottom perspective view of the electrical shield 532 in accordance with one embodiment of the present invention. With reference to FIG. 18, the illustrated embodiment of the electrical shield 532 is fabricated by laminating thermoplastic urethane to an electrically conductive fabric and vacuum forming it to make a stretchable conductive shield. The electrical shield 532 is soft to the touch with a durometer (Shore A 50-80) and can be configured as an active button for handsets, game controllers, and the like. In one embodiment, an electrically insulating film allows the actuator the most freedom to move. In other embodiments, the electrically conductive fabric can be sandwiched between two thinner layers of thermoplastic polyurethane, for example, 5/1000" (5 mil),

[0109] FIG. 19 illustrates a schematic diagram of the compliant actuator module 500 electrical isolation feature making it electrically safe for a user to touch the actuator module 500 with the fingertip in accordance with one embodiment of the present invention. As shown the HV÷ terminal on the flex circuit 522 is electrically coupled to the positive terminal (528a as shown in FIG. 16) of the solid dielectric elastomer transducer roll module 504. The SHIELD GND terminal of the flex circuit 522 is electrically coupled to the electrical shield 532 through the terminal 518. To connect the shield 532 to the terminal 518, a small

portion of the conductive textile is exposed and soldered to the terminal 518. In the event a fault occurs, such as short circuit between the solid dielectric elastomer transducer roll module 504 and the shield 532 through the electrically insulative silicone coating 516, the shield provides a shunt path ($\sim 3 \Omega$) from a high voltage potential node to a low voltage potential node such as the SHIELD GND relative to a high impedance user resistance path ($\sim 2000 \Omega$) to ground. Accordingly, any stray current is shunted to ground and the shunt current is isolated from the user with a layer of compliant insulation, such as for example, electrically insulative silicone coating 516. When the shunt current is detected, a signal is provided to a ground fault circuit interrupter (GFCI) circuit breaker that shuts down the high voltage power supply to prevent the user from being shocked. A robust chain of electrical and mechanical connections are employed to couple the compliant actuator module 500 to rigid electronics.

[0110] FIG. 20 is a graphical representation 600 illustrating the dependency of thermal hazard of a fault upon resistance in accordance with one embodiment of the present invention. Thermal power into a fault (Watt) is shown along the vertical axis and resistance of carbonized hole in potting (Ohm) is shown along the horizontal axis. A partial cross-sectional view of a compliant actuator module 602 is shown inset within the graph 600. From the most inner layer to the most outer layer, the compliant actuator module 602 includes a conductive silicone layer covered by a potting compound. The potting compound is covered by the conductive case ground and the thermoplastic polyurethane layer covers the conductive case ground. A carbon coated tunnel is formed through the potting compound between the conductive case ground and the conductive silicone to simulate a fault.

[0111] FIG. 21 illustrates a schematic diagram 650 of a GFCI circuit breaker configured to detect current on a shield in accordance with one embodiment. The schematic diagram 650 shown in FIG. 21 includes two separate GFCI circuit breakers suitable to detect shunt current on two separate shields. Current from a first shield ("shield 1") is received by a first conductor 658 through a connector 656 and is routed to a first GFCI circuit breaker network 652. Current from a

second shield ("shield 2") is received by a second conductor 660 through the connector 656 and is routed to a second GFCI circuit breaker network 654. Each GFCI circuit breaker network 652, 654 includes a bleed charge resistor R2, R1 to receive the stray current from the current shunt path and a capacitor C1, C14 to accumulate charge based on the stray current. Diode D1, D3 shunts current spikes to prevent false triggers. A comparator U2, U4 receives a voltage reference on its negative terminal and the capacitor voltage representing the accumulated charge on the capacitor C1, C14 on its positive terminal. When the voltage on the positive terminal exceeds the reference voltage on the negative terminal, the first comparator U2 triggers a first flip-flop 662 to generate a first signal to shut down a first high voltage power supply. When the voltage on the positive terminal exceeds the reference voltage on the negative terminal, the second comparator U4 triggers a second flip-flop 664 to generate a first signal to shut down a first high voltage power supply. Thus, the GFCI circuit breaker networks 652, 654 detect the shunt current on the shield and interrupt the current by shutting down the high voltage power supply when it exceeds a predetermined threshold set by each one of the voltage references.

[0112] *Array Of Deformable Surface Actuators To Provide Force Feedback Upon Touching A Surface Of A Display/Touch Sensor To Confirm Action*

[0113] In various other embodiments, the present invention provides deformable surface actuators configured to provide force feedback upon sensing a touch on the surface of an electroactive polymer layer positioned above a display/touch sensor to provide feedback of the action. In accordance with one embodiment, the present invention provides a glass display/touch sensor configured to provide haptic feedback to a force simulating the "pressing" of a virtual key displayed on the touch sensor. In one embodiment, the deformable surface actuators provide haptic feedback to assist a user to determine the location of a virtual key on the touch sensor without resorting to visual or audio feedback alone.

[0114] The embodiment of the invention described in connection with FIGS. 22A-22B provide localization or feedback that is lacking on conventional touch

sensors, which are limited by moving the entire screen or handset. With this embodiment, tactile feedback is localized to the spot or "key" that is touched by the user to provide a sensation similar to a standard keyboard and therefore it is easier and more accurate to type.

[0115] FIG. 22A is a side sectional view of an array of deformable surface actuators 700 in accordance with one embodiment of the present invention. FIG. 22B is a top view of the array of deformable surface actuators 700 shown in FIG. 22A in accordance with one embodiment of the present invention. With reference to FIGS. 22A-22B, although only two deformable surface actuators 702, 704 are shown, it will be appreciated that the array 700 may comprises a plurality of actuators arranged in any predetermined pattern. In one embodiment, the surface of a display/touchscreen 706 is covered by a deformable electroactive polymer surface layer 712. The electroactive polymer layer 712 comprises sensitive areas 708, 710 that deform into the actuators 702, 704 when touched to provide feedback to the user. The electroactive polymer surface layer 712 is incorporated into the surface above the display/touchscreen 706. The actuators 702, 704 are activated by high voltage when the appropriate sensitive area 708, 710 senses a touch. When the touch is detected or sensed in the defined area 708, 710 the electroactive polymer surface layer 712 expands/contracts in defined areas 708, 710 and is deformed in such a manner as to generate the actuator 702, 704 bumps that are detectable by the person touching the display/touchscreen. The actuators 702, 704 can also be a part of the surface of the display/touchscreen 706 that deforms to the shape of keys. This can be either a permanent feature or a temporary feature that appears on demand. The flexible electroactive polymer dielectric film layer 712 would be the deformable surface. The electroactive polymer surface layer 712 should needs to be very flexible to be an effective electroactive polymer actuator. Printed on the electroactive polymer surface layer 712 film would be an electrode pattern 708, 710 that when activated would produce a movement/vibration to provide the haptic feedback to the finger by the actuator bumps 702, 704 to indicate that a press was sensed and confirmed. A simple actuator design of just a circle that expands and contracts could be used.

The expansion/contraction vibration would provide the forced feedback to the finger. Other suitable patterns beside a circle may be employed for the actuator pattern 708, 710. Such patterns include ellipses, triangles, rectangles, squares, rhombus, any suitable polygon, as well as irregular or randomly formed patterns.

[0116J As for other details of the present invention, materials and alternate related configurations may be employed as within the level of those with skill in the relevant art. The same may hold true with respect to process-based aspects of the invention in terms of additional acts as commonly or logically employed. In addition, though the invention has been described in reference to several examples, optionally incorporating various features, the invention is not to be limited to that which is described or indicated as contemplated with respect to each variation of the invention. Various changes may be made to the invention described and equivalents (whether recited herein or not included for the sake of some brevity) may be substituted without departing from the true spirit and scope of the invention. Any number of the Individual parts or subassemblies shown may be integrated in their design. Such changes or others may be undertaken or guided by the principles of design for assembly.

[0117] Also, it is contemplated that any optional feature of the inventive variations described may be set forth and claimed independently, or in combination with any one or more of the features described herein. Reference to a singular item, includes the possibility that there are plural of the same items present. More specifically, as used herein and in the appended claims, the singular forms "a," "an," "said," and "the" include plural referents unless the specifically stated otherwise. In other words, use of the articles allow for "at least one" of the subject item in the description above as well as the claims below. It is further noted that the claims may be drafted to exclude any optional element. As such, this statement is intended to serve as antecedent basis for use of such exclusive terminology as "solely," "only" and the like in connection with the recitation of claim elements, or use of a "negative" limitation. Without the use of such exclusive terminology, the term "comprising" in the claims shall allow for the inclusion of any additional element - irrespective of whether a given number

of elements are enumerated in the claim, or the addition of a feature could be regarded as transforming the nature of an element set forth in the claims. Stated otherwise, unless specifically defined herein, all technical and scientific terms used herein are to be given as broad a commonly understood meaning as possible while maintaining claim validity.

[0118] Various aspects of the subject matter described herein are set out in the following numbered clauses:

[0119] 1. An apparatus comprising: a first sensor for measuring one or more body motions of a person; a first actuator for rendering one or more haptic effects to a person; and a processor for receiving the one or more body motions of the person and outputting one or more haptic effects.

[0120] 2. The apparatus according to clause 1 further comprising at least one biometric sensor configured to measure a physiological characteristic of a user, wherein response time of the biometric sensor is faster than response time of the first sensor for measuring one or more body motions of a person.

[0121] 3. The apparatus according to one of clause 1 and 2, wherein the first actuator comprises an electroactive polymer transducer.

[0122] 4. The apparatus according to clause 3, wherein the electroactive polymer transducer is a surface deformation transducer configured to provide programmable surface features.

[0123] 5. The apparatus according to clause 3, wherein the electroactive polymer transducer comprises two or more stacked layers of electroactive polymer film.

[0124] 6. The apparatus according to clause 3, wherein the electroactive polymer transducer is configured to provide both haptic effects and sensing responses.

[0125] 7. The apparatus according to clause 3, wherein the electroactive polymer transducer is electrically shielded and connected to a ground fault circuit interrupt circuit.

[0126] 8. The apparatus according to clause 3, wherein the electroactive polymer transducer is mounted in a housing comprising a structural element, the element

providing a compressive prestrain on the transducer and transmitting a force generated by activation of the electroactive polymer transducer to a separate portion of the apparatus.

[0127] 9. The apparatus according to any one of clauses 1 to 8, wherein one or more selected from the group consisting essentially of the electroactive polymer actuator, the biometric sensor, the processor and the motion sensor are located on a wearable device.

[0128] 10. The apparatus according to clause 9, wherein the wearable device is selected from the group consisting essentially of a wristband, a hand band, an arm band, a torso band, an ankle band, a headband, and an ear attachment, and any combination thereof.

[0129] 11. The apparatus according to clause 1, wherein the first sensor comprises any one of an accelerometer, a gyroscope, a magnetometer, a touch sensor, and any combination thereof and wherein the first sensor is configured to measure musculoskeletal motion.

[0130] 12. The apparatus according to clause 2, wherein the least one biometric sensor is configured to measure one or more physiological characteristics selected from the group consisting essentially of electromyography (EMG), electroencephalography (EEG), and heart rate, and any combination thereof.

[0131] 13. The apparatus according to clause 2, wherein the processor is configured to drive the electroactive actuator in accordance with electrical signals received from the biometric and first sensors.

[0132] 14. The apparatus according to clause 2, wherein the processor is configured to receive and process an electrical signal from the biometric sensor before a signal is received and processed from the first sensor.

[0133] 15. A method for adapting a haptic effect rendered on a haptic device, the method comprising: providing the apparatus according to any of clauses 1 to 14; sensing, by the computer system, a frequency response of the haptic effect while the haptic device is in use; determining, on the computer system, a frequency

distribution of a rendered haptic effect; and mapping, on the computer system or in hardware, a function of the haptic effect to generate a new frequency response on the haptic device.

WHAT IS CLAIMED IS:

1. An apparatus comprising:
a first sensor capable of measuring one or more body motions of a person;
a first actuator capable of rendering one or more haptic effects to a person;
and
a processor capable of receiving the one or more body motions of the person and outputting one or more haptic effects.
2. The apparatus according to Claim 1 further comprising at least one biometric sensor configured to measure a physiological characteristic of a user, wherein response time of the biometric sensor is faster than response time of the first sensor for measuring one or more body motions of a person.
3. The apparatus according to one of Claims 1 and 2, wherein the first actuator comprises an electroactive polymer transducer.
4. The apparatus according to Claim 3, wherein the electroactive polymer transducer comprises a surface deformation transducer configured to provide programmable surface features.
5. The apparatus according to Claim 3, wherein the electroactive polymer transducer comprises two or more stacked layers of electroactive polymer film.
6. The apparatus according to Claim 3, wherein the electroactive polymer transducer is configured to provide both haptic effects and sensing responses.
7. The apparatus according to Claim 3, wherein the electroactive polymer transducer is electrically shielded and connected to a ground fault circuit interrupt circuit.

8. The apparatus according to Claim 3, wherein the electroactive polymer transducer is mounted in a housing comprising a structural element, the element providing a compressive prestrain on the transducer and transmitting a force generated by activation of the electroactive polymer transducer to a separate portion of the apparatus.
9. The apparatus according to any one of Claims 1 to 8, wherein one or more selected from the group consisting essentially of the electroactive polymer actuator, the biomeixic sensor, the processor and the motion sensor are located on a wearable device.
10. The apparatus according to Claim 9, wherein the wearable device is selected from the group consisting essentially of a wristband, a hand band, an arm band, a torso band, an ankle band, a headband, and an ear attachment, and any combination thereof.
11. The apparatus according to Claim 1, wherein the first sensor comprises any one of an accelerometer, a gyroscope, a magnetometer, a touch sensor, and any combination thereof and wherein the first sensor is configured to measure musculoskeletal motion.
12. The apparatus according to Claim 2, wherein the least one biometric sensor is configured to measure one or more physiological characteristics selected from the group consisting essentially of electromyography (EMG), electroencephalography (EEG), and heart rate, and any combination thereof.
13. The apparatus according to Claim 2, wherein the processor is configured to drive the electroactive actuator in accordance with electrical signals received from the biometric and first sensors.

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14. The apparatus according to Claim 2, wherein the processor is configured to receive and process an electrical signal from the second sensor before a signal is received and processed from the first sensor.

15. A method for adapting a haptic effect rendered on a haptic device, the method comprising:

providing the apparatus according to any of Claims 1 to 14;

sensing, by the computer system, a frequency response of the haptic effect while the haptic device is in use;

determining, on the computer system, a frequency distribution of a rendered haptic effect; and

mapping, on the computer system or in hardware, a function of the haptic effect to generate a new frequency response on the haptic device,

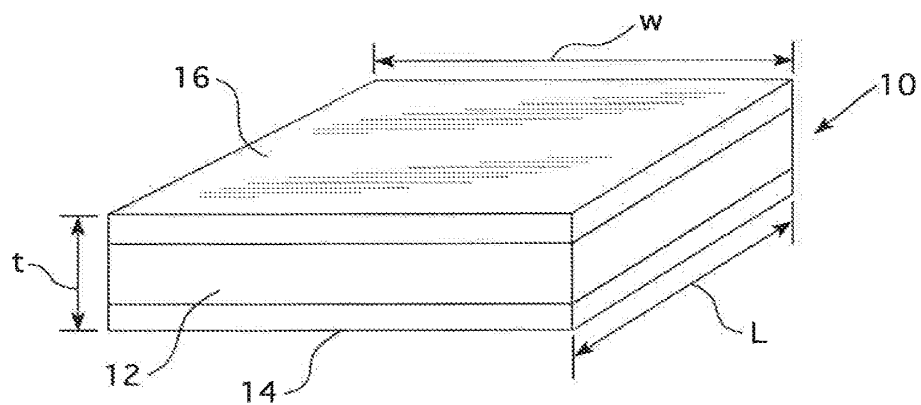


FIG. 1A

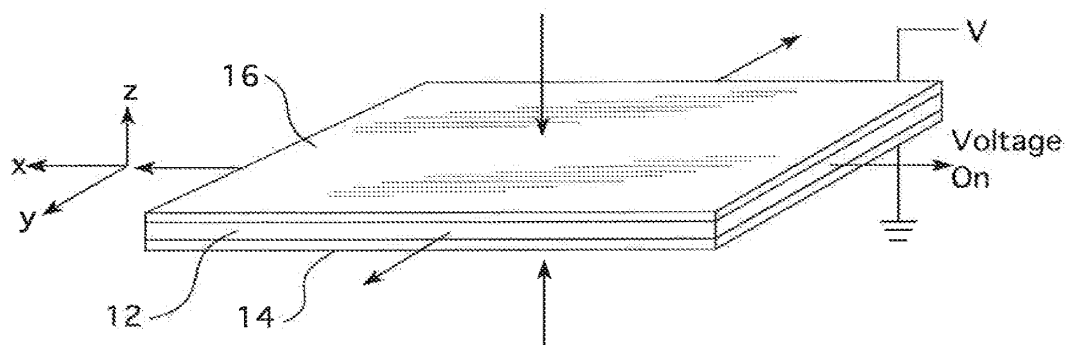


FIG. 1B

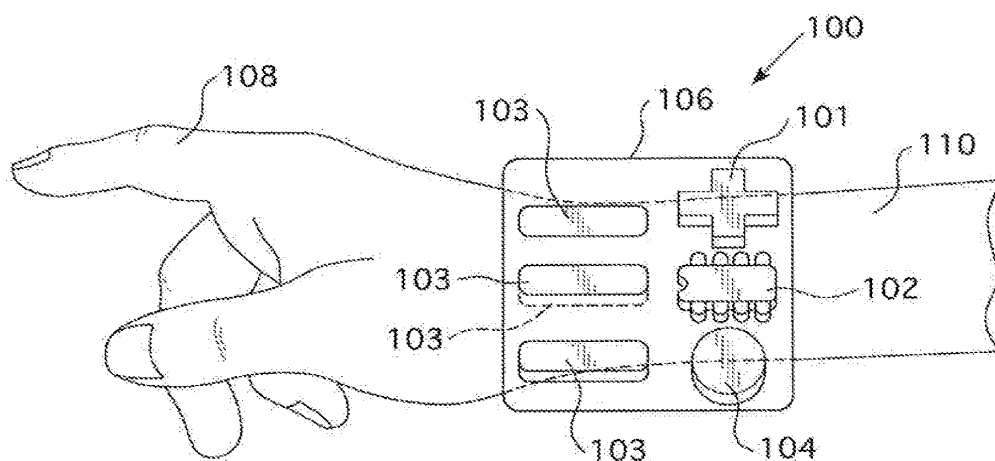


FIG. 2

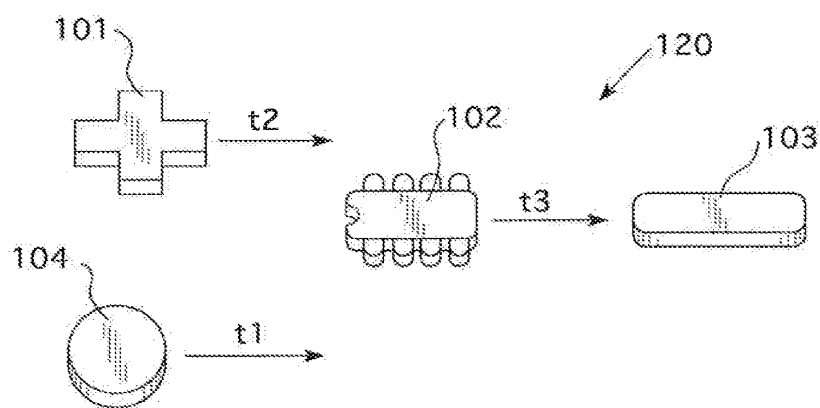


FIG. 3

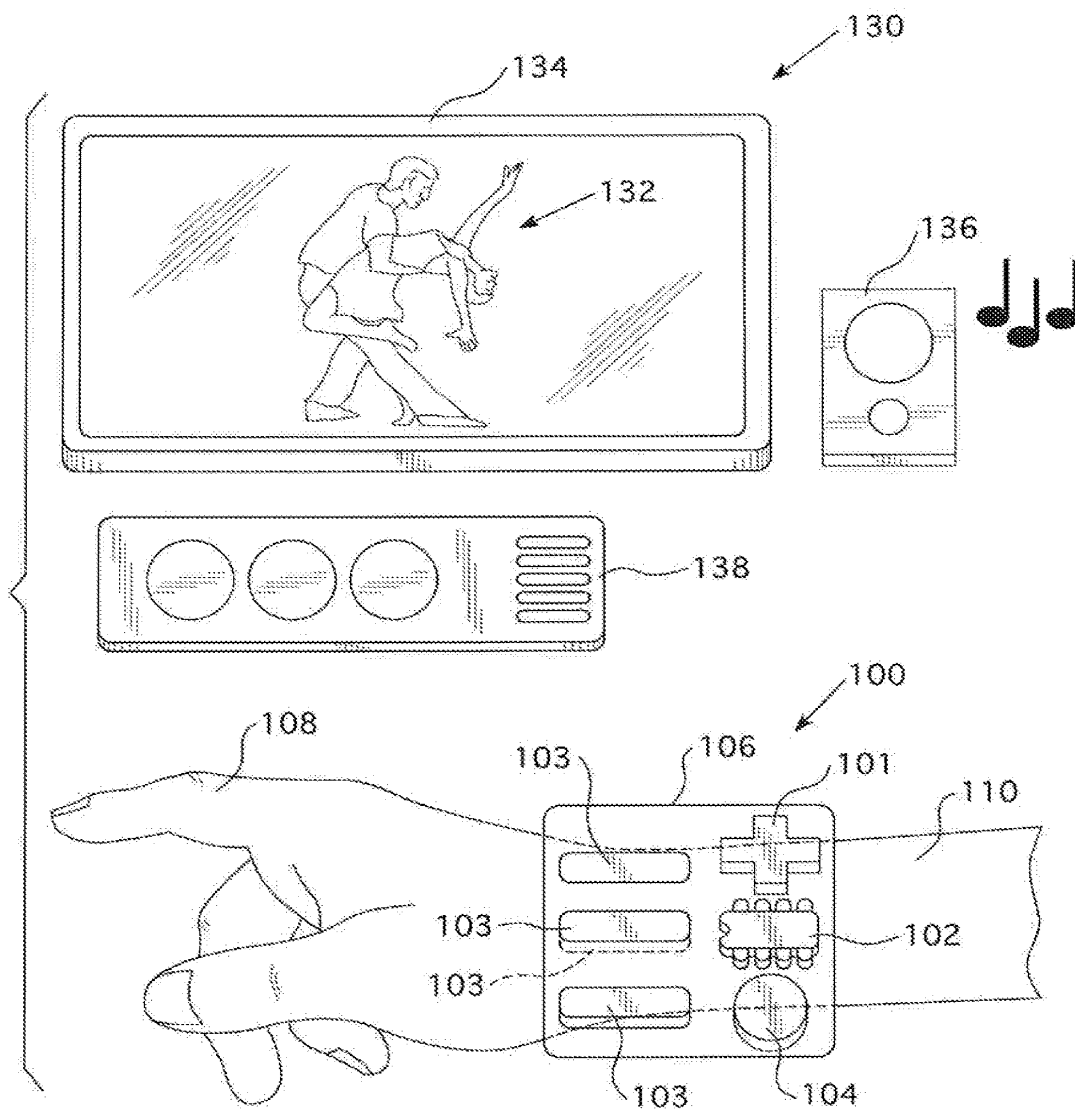


FIG. 4

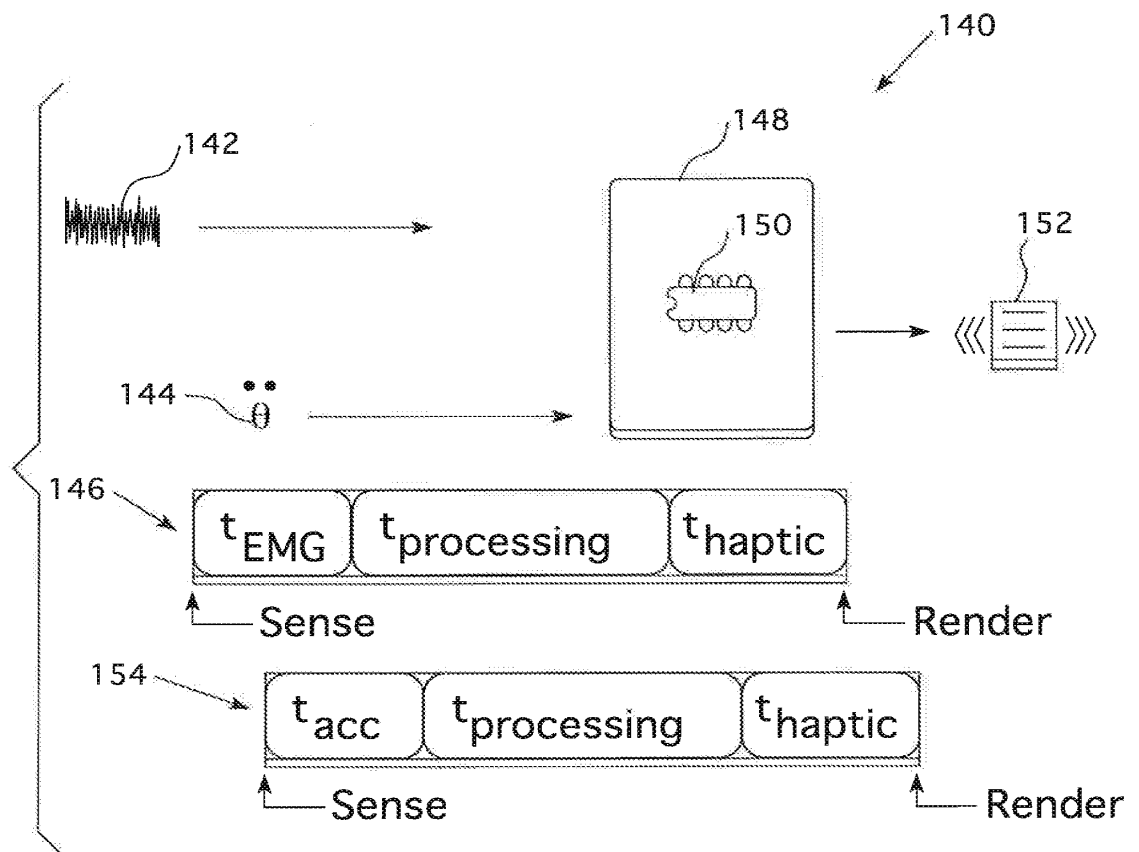


FIG. 5

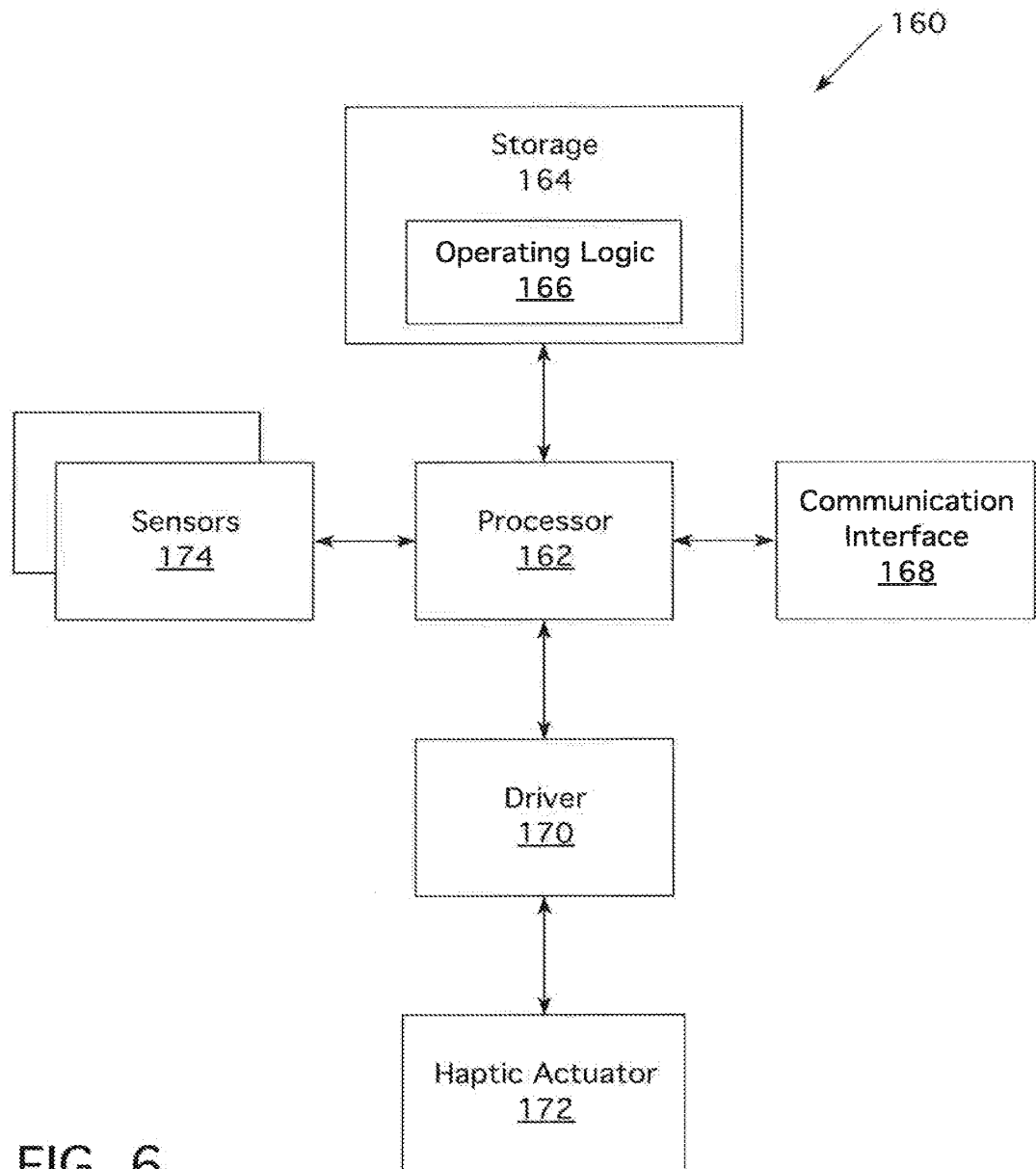


FIG. 6

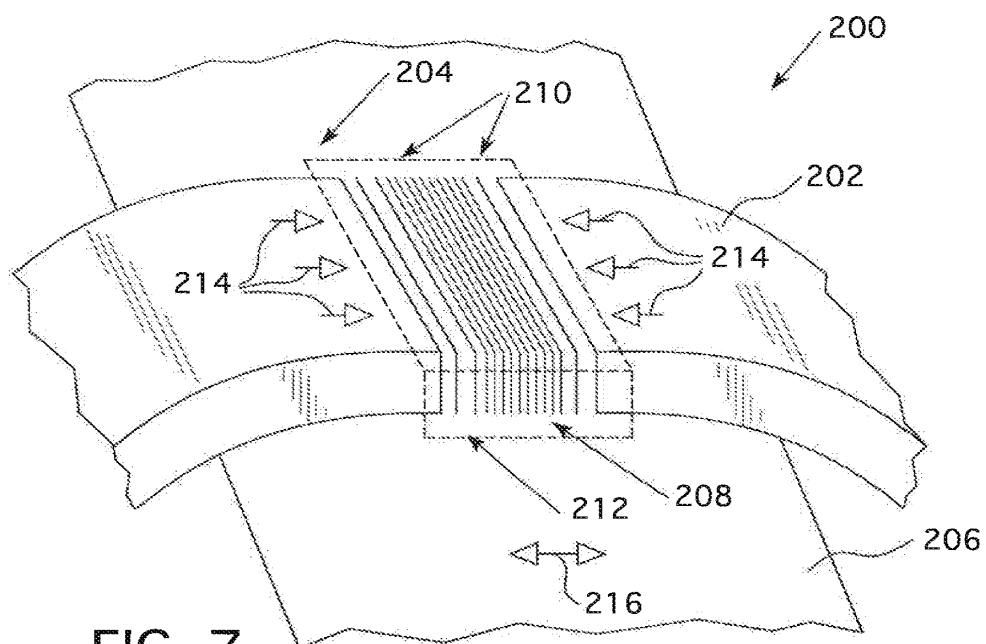


FIG. 7

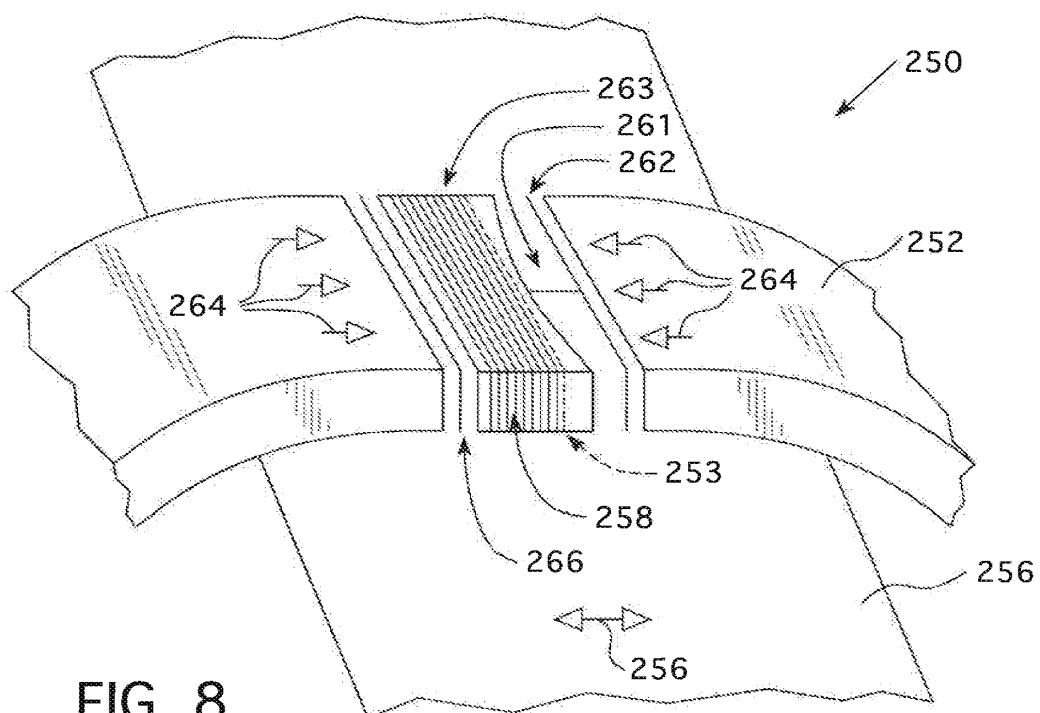


FIG. 8

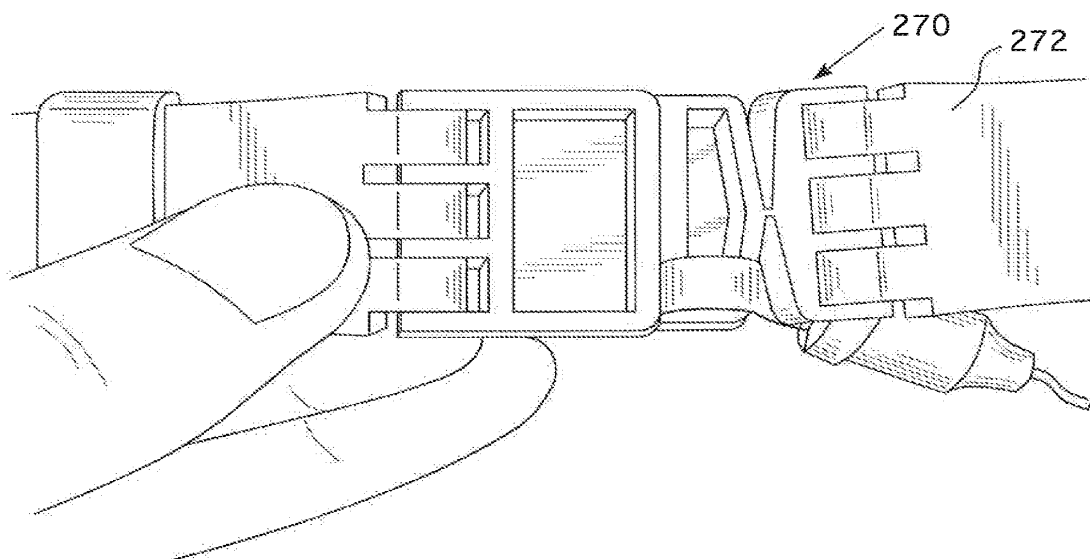


FIG. 9

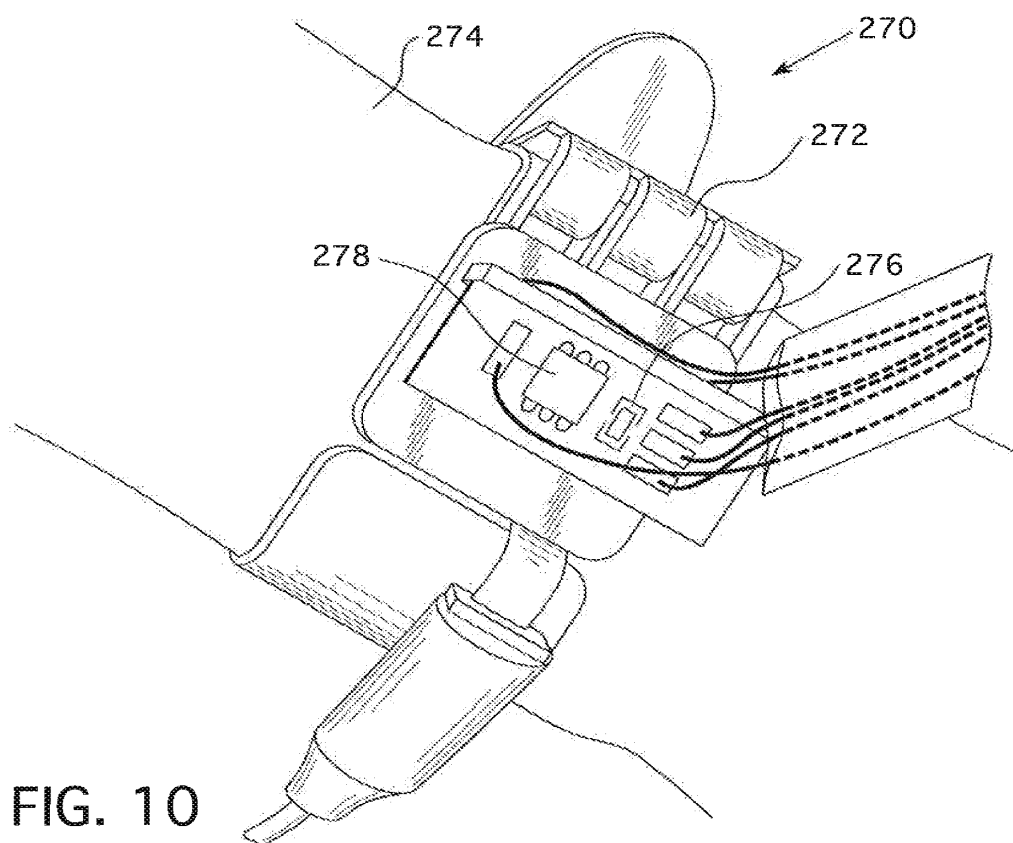


FIG. 10

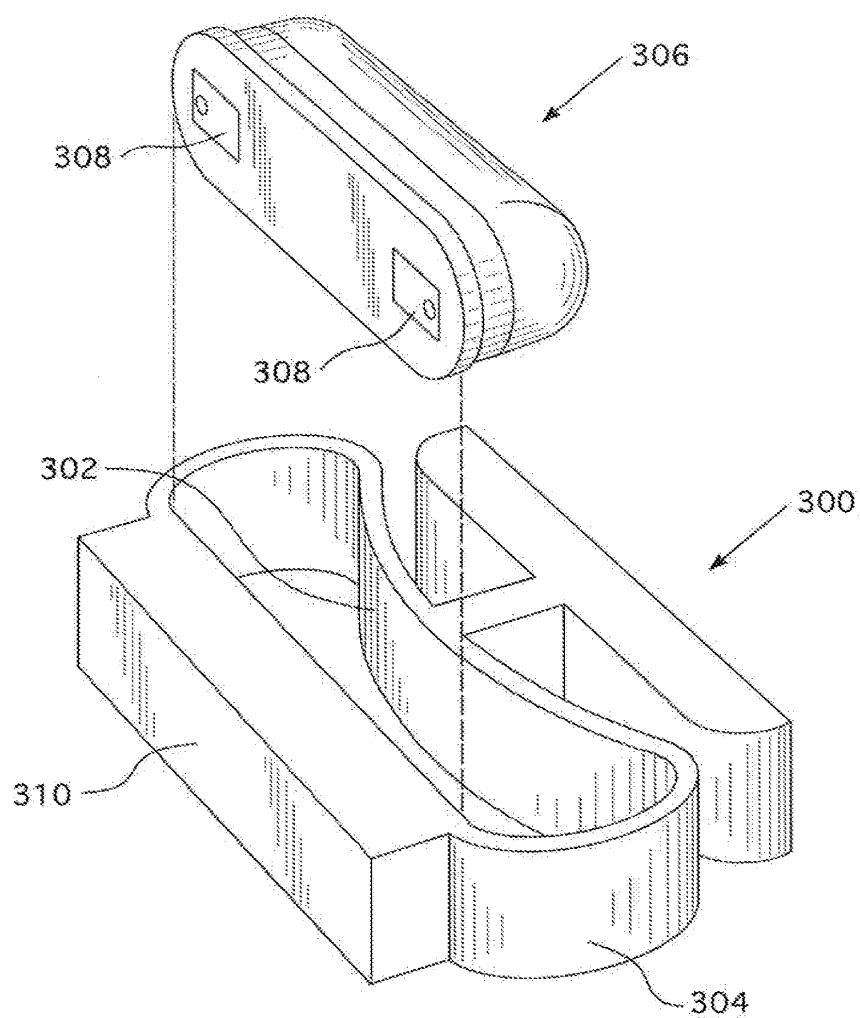


FIG. 11

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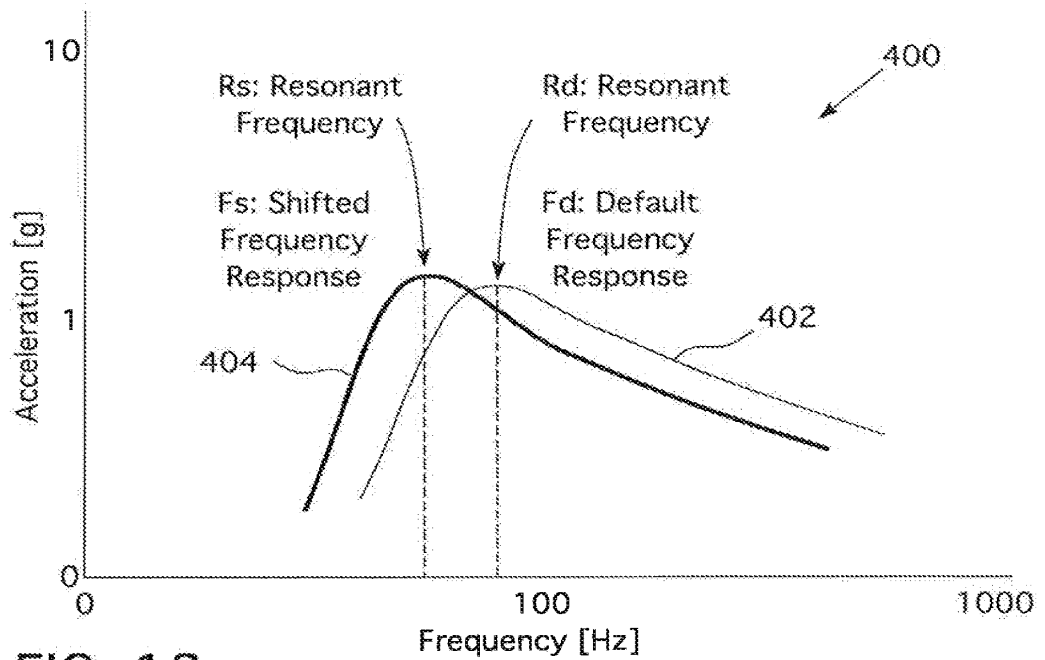


FIG. 12

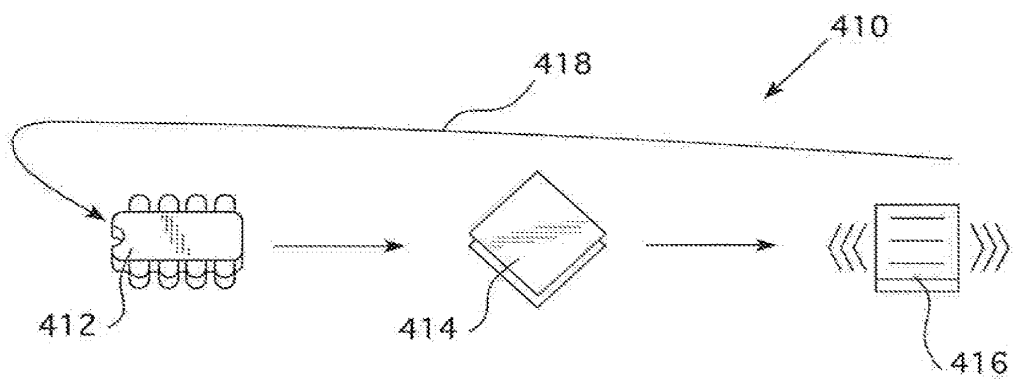


FIG. 13

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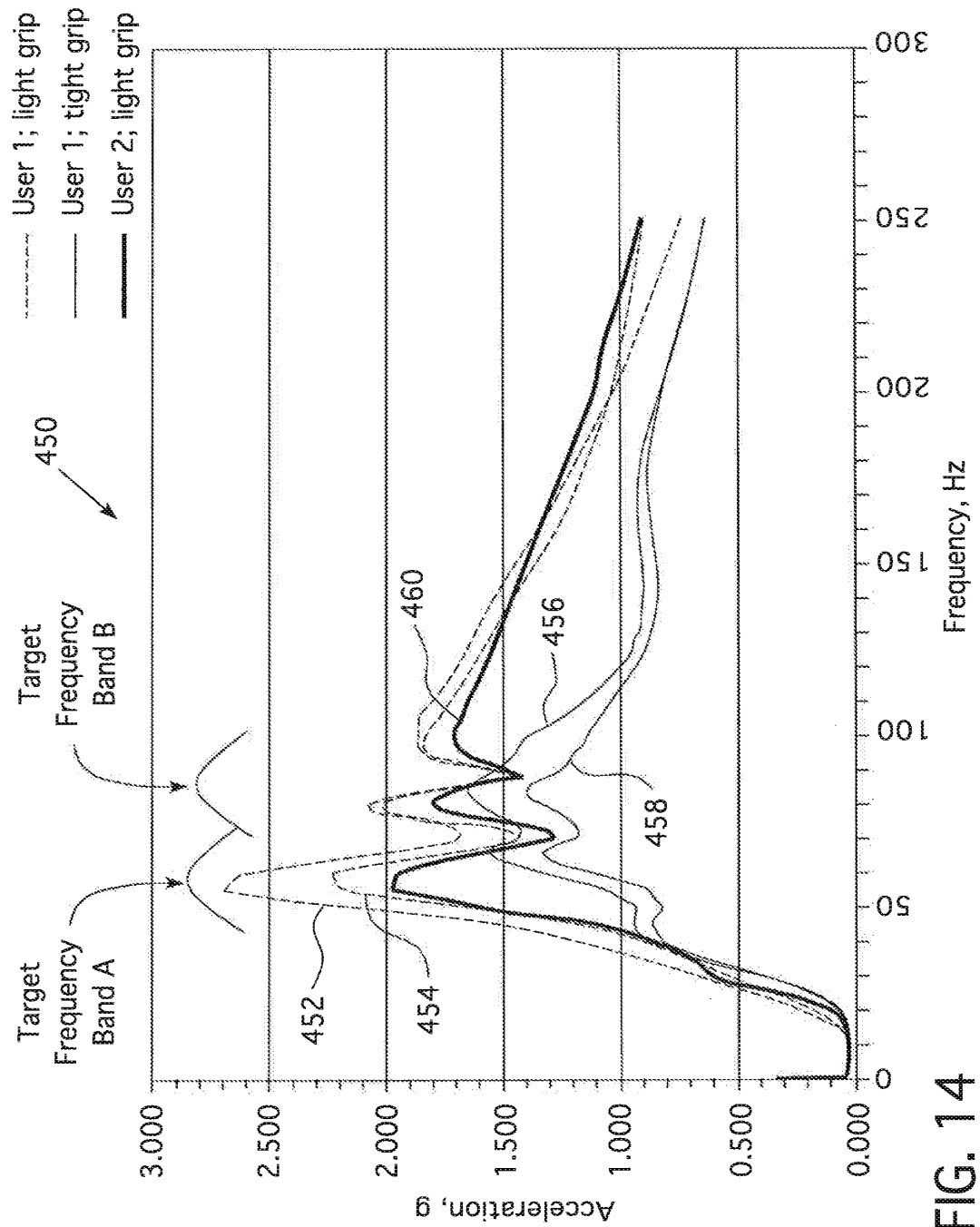
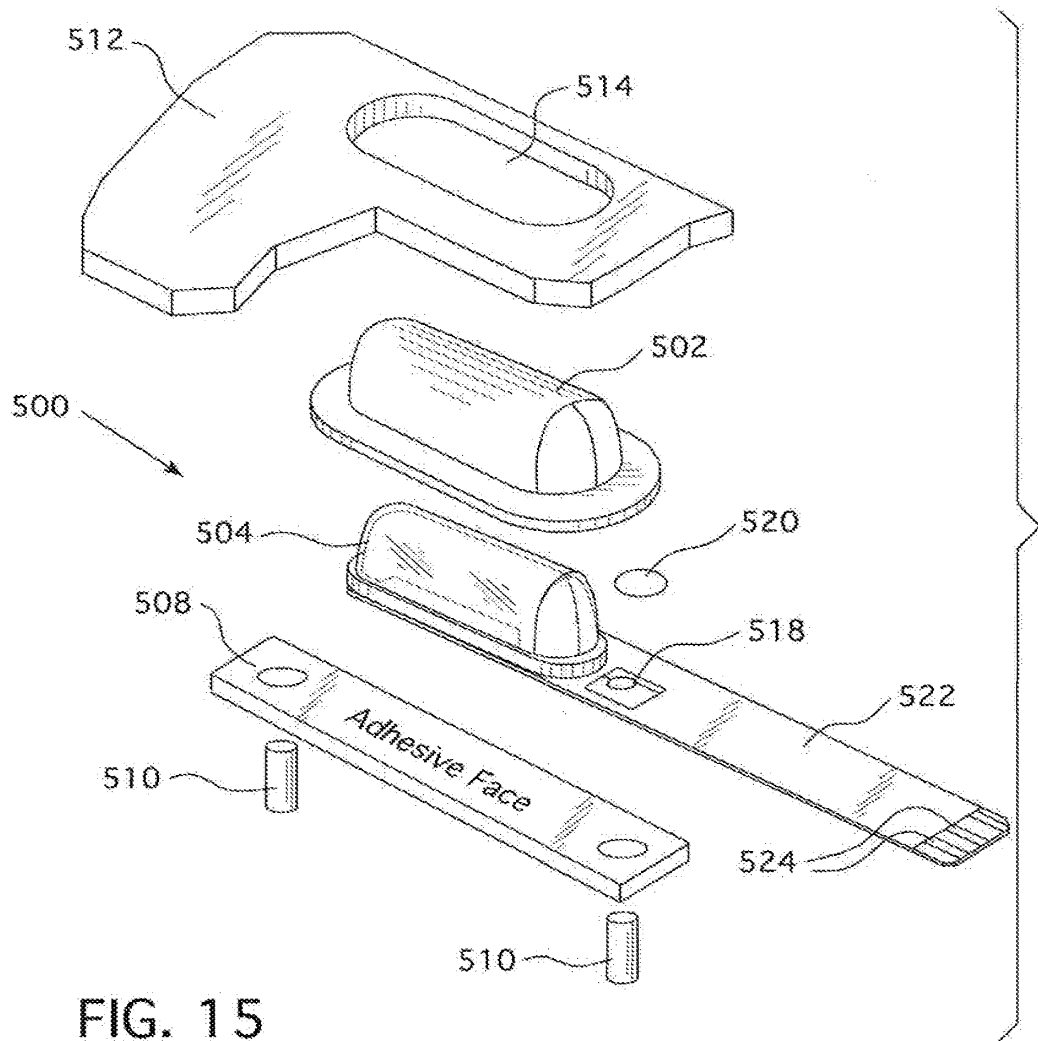


FIG. 14



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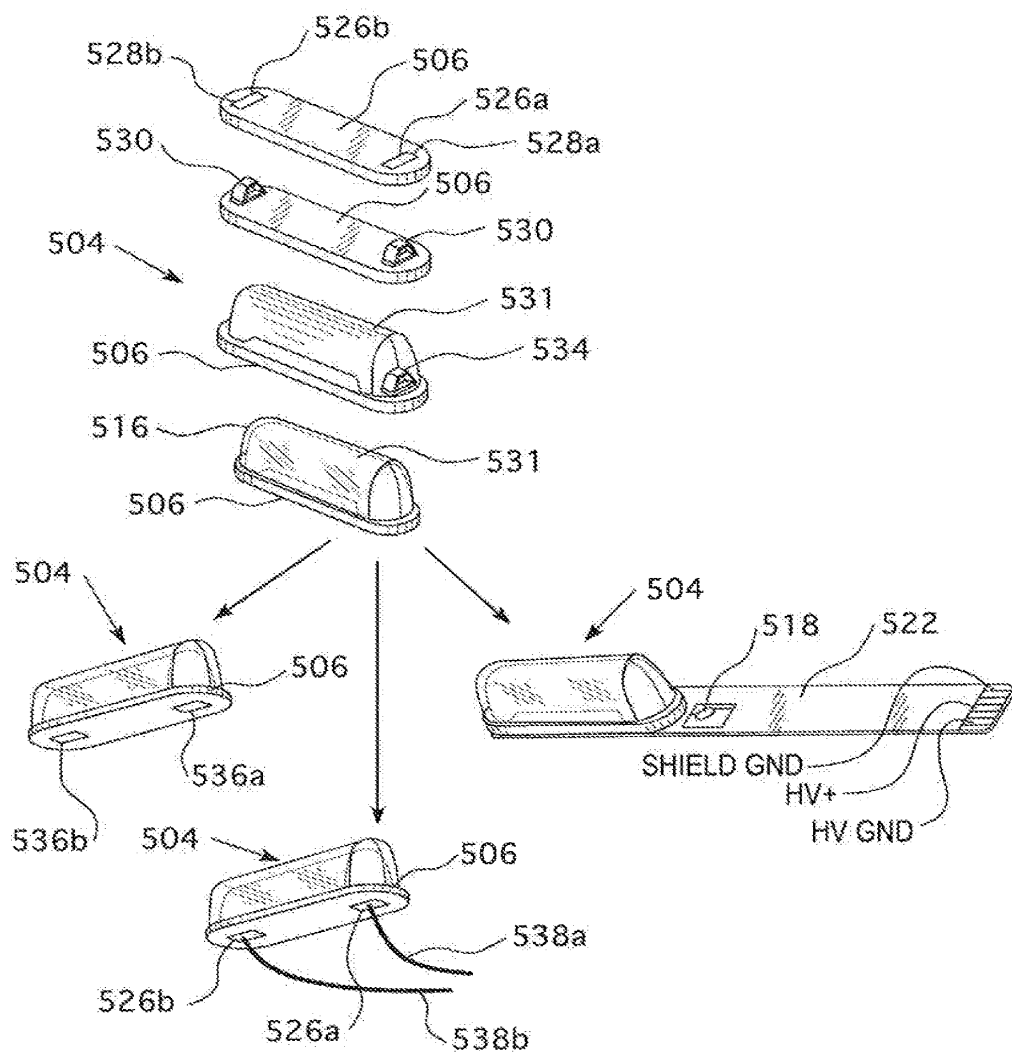


FIG. 16

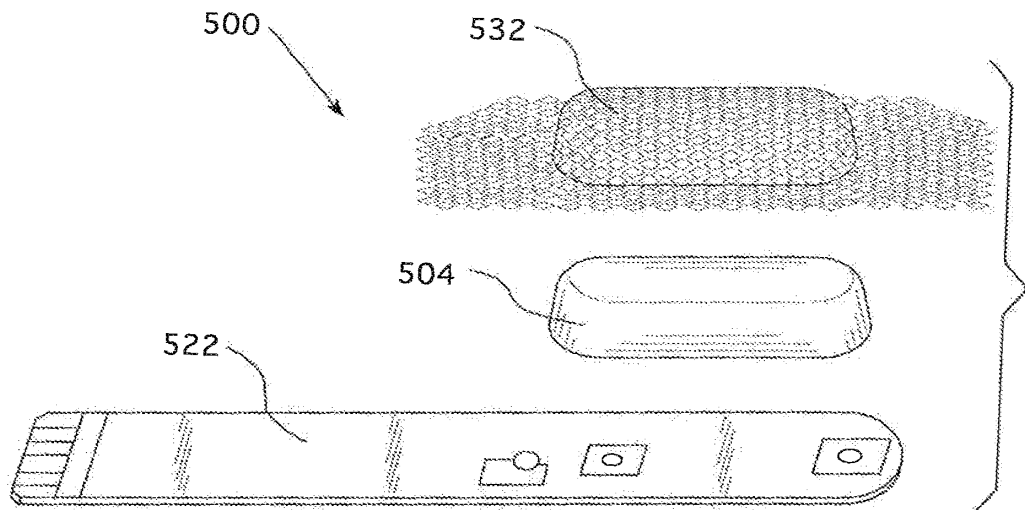


FIG. 17

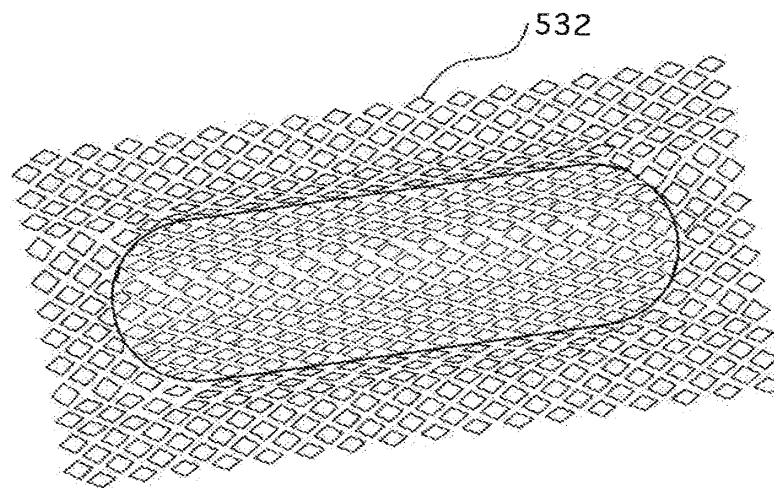


FIG. 18

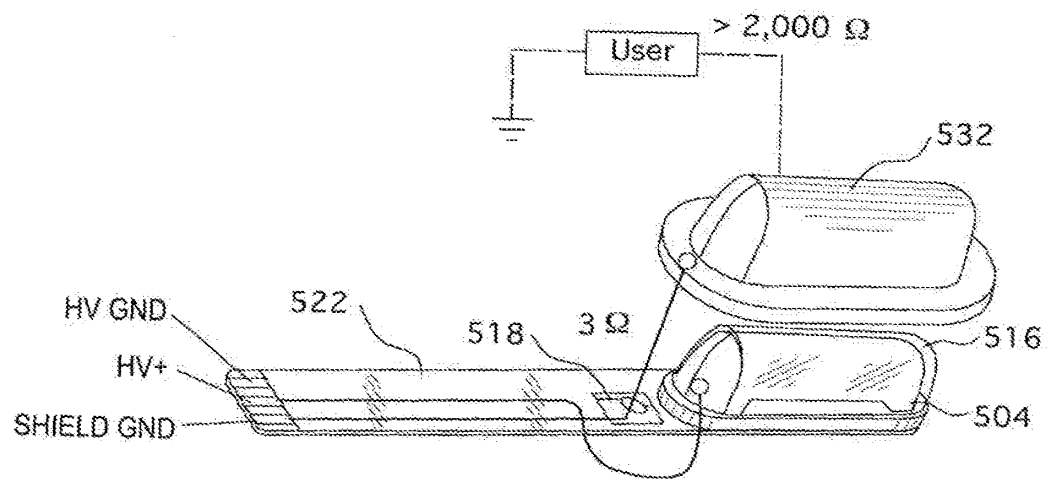


FIG. 19

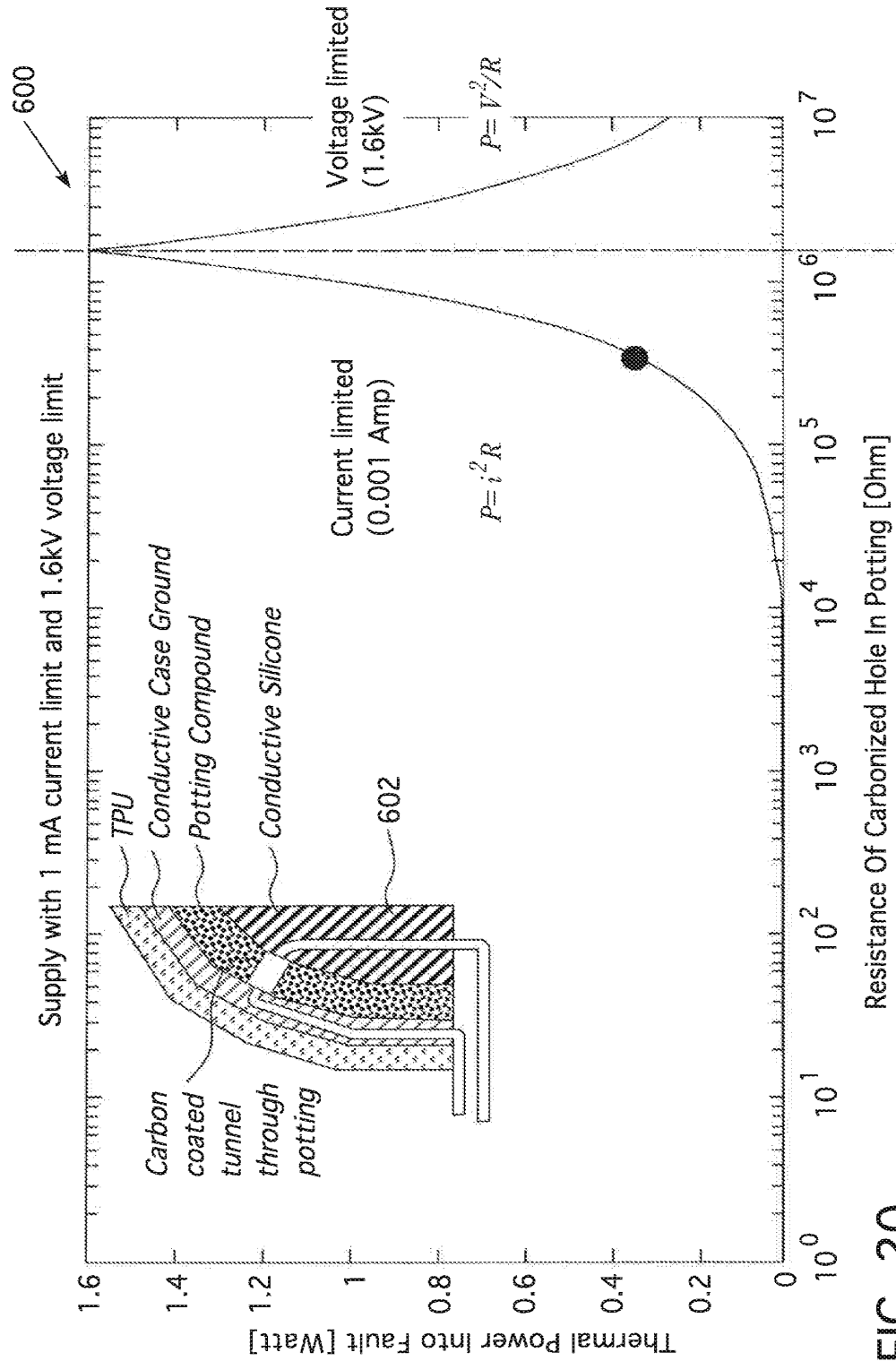


FIG. 20

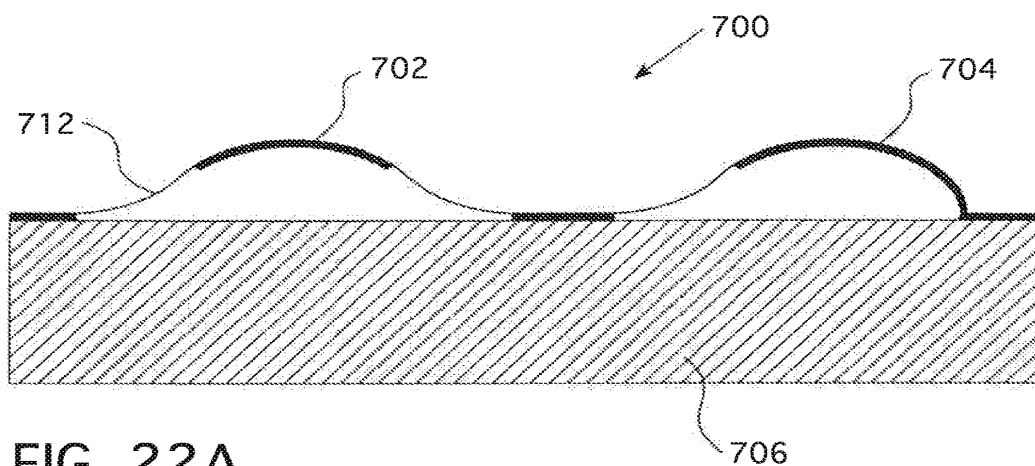


FIG. 22A

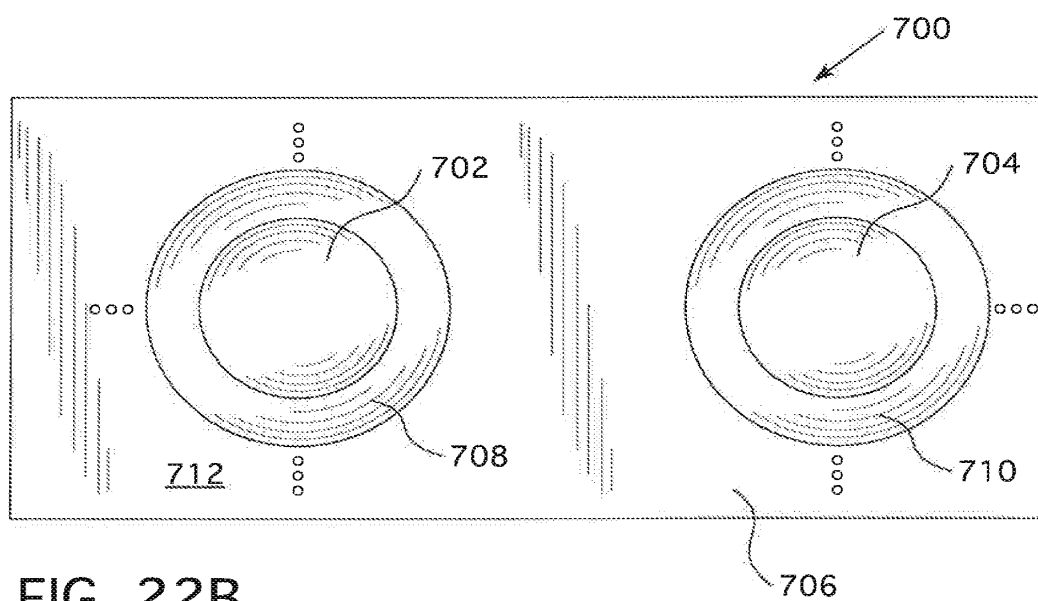


FIG. 22B

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2014/013303

A. CLASSIFICATION OF SUBJECT MATTER
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According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G06F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal , WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2011/244963 AI (GRANT DANNY A [CA] ET AL) 6 October 2011 (2011-10-06)	1-14
Y	paragraph [0009] - paragraph [0044] figures 1-2	15
X	----- Wo 2010/085575 AI (ARTI FICIAL MUSCLE INC [US] ; WEABER CHRIS A [US] ; ZARRABI ALI REZA [US] ;) 29 July 2010 (2010-07-29)	1-14
A	paragraph [0077] - paragraph [0109] figures 1a-12c	15
X	----- US 2012/229401 AI (BI RNBAUM DAVID [US] ET AL) 13 September 2012 (2012-09-13)	1
Y	paragraph [0022] - paragraph [0069]	15
A	figures 1-12	2-14
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☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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Date of the actual completion of the international search

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NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Bal dan , Marco

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2014/013303

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	<p>US 2010/141407 A1 (HEUBEL ROBERT W [US] ET AL) 10 June 2010 (2010-06-10) paragraph [0080] - paragraph [0095] figures 10-11</p> <p>-----</p>	1-15

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2014/013303

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(54) **METHOD AND APPARATUS FOR SENSORY STIMULATION**

VERFAHREN UND VORRICHTUNG ZUR SENSORISCHEN STIMULATION

PROCÉDÉ ET APPAREIL DE STIMULATION SENSORIELLE

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(73) Proprietor: **Senseg OY**
02600 Espoo (FI)

(72) Inventors:
• **MÄKINEN, Ville**
FI-02720 Espoo (FI)
• **SUVANTO, Petro**
FI-01280 Vantaa (FI)
• **LINJAMA, Jukka**
FI-02200 Espoo (FI)

(74) Representative: **Kolster Oy Ab**
Iso Roobertinkatu 23
PO Box 148
00121 Helsinki (FI)

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- **YAMAMOTO, A. ET AL.: 'Electrostatic tactile display with thin film slider and its application to tactile telepresence systems' IEEE TRANSACTIONS ON VISUALIZATION AND COMPUTER GRAPHICS vol. 12, no. 2, March 2006, pages 168 - 177, XP003026562**
- **'2nd Annual International IEEE-EMB Special Topic Conference on Microtechnologies in Medicine & Biology', 02 May 2002 article AGARWAL, A.K. ET AL.: 'A hybrid natural/artificial electrostatic actuator for tactile stimulation', pages 341 - 345, XP003026563**
- **'IEEE 17th Annual Conference', vol. 2, 20 September 1995 article BEEBE, D.J. ET AL.: 'A polyimide-on-silicon electrostatic fingertip tactile display; Engineering in Medicine and Biology Society', pages 1545 - 1546, XP010214849**
- **KACZMAREK, K.A. ET AL.: 'Electrotactile and vibrotactile displays for sensory substitution systems' IEEE TRANSACTIONS ON BIOMEDICAL ENGINEERING vol. 38, no. 1, January 1991, pages 1 - 16, XP003026564**

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Description

Background of the invention

[0001] The present invention relates to an apparatus and method for sensory stimulation. The invention is particularly applicable for stimulating the sense of touch.

[0002] Manual input devices, such as joysticks and mice, are frequently complemented by means for providing tactile sensations such that the manual input devices provide tactile feedback to their users. There are hundreds of US patents for tactile feedback devices. In most or all of the prior art devices the tactile stimulation is generated by means of moving or vibrating mechanical members. A problem shared by most such devices is that such moving mechanical members tend to be bulky, unreliable and/or difficult to control. Examples of tactile stimulation devices are disclosed in the following documents:

KACZMAREK, K.A., et al., "Polarity Effect in Electrovibration for Tactile Display"; IEEE Transactions on Biomedical Engineering, Volume 53, Issue 10, Oct. 2006 Page(s): 2047-2054, <DOI: 10.1109/TBME.2006.881804> YAMAMOTO, A., et al., "Electrostatic tactile display with thin film slider and its application to tactile telepresentation systems"; IEEE Transactions on Visualization and Computer Graphics, Volume 12, Issue 2, March-April 2006 Page(s): 168-177 <DOI: 10.1109/TVCG.2006.28>

AGARWAL, A.K., et al., "A hybrid natural/artificial electrostatic actuator for tactile stimulation"; 2nd Annual International IEEE-EMB Special Topic Conference on Microtechnologies in Medicine & Biology, 2-4 May 2002 Page(s): 341-345 <DOI: 10.1109/MMB.2002.1002343>

BEEBE, D.J., et al., "A polyimide-on-silicon electrostatic fingertip tactile display"; Engineering in Medicine and Biology Society, 1995., IEEE 17th Annual Conference Volume 2, 20-23 Sept. 1995 Page(s): 1545-1546 vol.2 <DOI: 10.1109/IEMBS.1995.579819>

Brief description of the invention

[0003] An object of the present invention is to provide a method and apparatus for alleviating at least one of the problems identified above.

[0004] The object of the invention is achieved by features which are disclosed in the attached independent claims. The dependent claims and the present patent specification disclosed additional specific embodiments and non-essential features of the invention.

[0005] The invention is based on the surprising discovery that subcutaneous Pacinian corpuscles can be stimulated by means of a capacitive electrical coupling and an appropriately dimensioned control voltage, either without any mechanical stimulation of the Pacinian cor-

puscles or as an additional stimulation separate from such mechanical stimulation. An appropriately dimensioned high voltage is used as the control voltage. In the present context a high voltage means such a voltage that direct galvanic contact must be prevented for reasons of safety and/or user comfort. This results in a capacitive coupling between the Pacinian corpuscles and the apparatus causing the stimulation, wherein one side of the capacitive coupling is formed by at least one galvanically isolated electrode connected to the stimulating apparatus, while the other side, in close proximity to the electrode, is formed by the body member, preferably a finger, of the stimulation target, such as the user of the apparatus, and more specifically the subcutaneous Pacinian corpuscles.

[0006] Without committing themselves to any particular theory, the inventors find it likely that the invention is based on a controlled formation of an electric field between an active surface of the apparatus and the body member, such as a finger, approaching or touching it. The electric field tends to give rise to an opposite charge on the proximate finger. A local electric field and a capacitive coupling can be formed between the charges. The electric field directs a force on the charge of the finger tissue. By appropriately altering the electric field a force capable of moving the tissue may arise, whereby the sensory receptors sense such movement as vibration.

[0007] A benefit of the invention is independence from mechanical vibration and its associated problems in the prior art.

[0008] An aspect of the invention is an apparatus for generating an electro-sensory stimulus to at least one body member. The apparatus comprises one or more conducting electrodes each of which is provided with an insulator. When the body member is proximate to the conducting electrode, the insulator prevents flow of direct current from the conducting electrode to the body member. A capacitive coupling over the insulator is formed between the conducting electrode and the body member. The apparatus also comprises a high-voltage source for applying an electrical input to the one or more conducting electrodes, wherein the electrical input comprises a low-frequency component in a frequency range between 10 Hz and 1000 Hz. The capacitive coupling and electrical input are dimensioned to produce an electro-sensory sensation which is produced independently of any mechanical vibration of the one or more conducting electrodes or insulators.

[0009] Another aspect of the invention is a method for causing an electrosensory sensation to a body member. The method comprises providing one or more conducting electrodes. Each conducting electrode is provided with an insulator wherein, when the body member is proximate to the conducting electrode, the insulator prevents flow of direct current from the conducting electrode to the body member. A capacitive coupling over the insulator is formed between the conducting electrode and the body member. A high-voltage source is provided for applying

an electrical input to the one or more conducting electrodes. The electrical input comprises a low-frequency component in a frequency range between 10 Hz and 1000 Hz, while the capacitive coupling and electrical input are dimensioned to produce an electrosensory sensation. The electrosensory sensation is produced independently of any mechanical vibration of the one or more conducting electrode(s) or insulator(s).

[0010] It is beneficial to vary the capacitive coupling such that the variation comprises one or more frequency components in a range wherein the Pacinian corpuscles exhibit their maximal sensitivity. This frequency range is roughly 10 to 1000 Hz and in most humans 100 to 500 Hz. The capacitive coupling can be varied by varying the control voltage and/or parameters of the capacitive coupling.

[0011] By way of example, the high-voltage charge applied to the electrode can have a voltage of at least 750, 1000, 1500 or 2000 V and at most 20, 50 or 100 kV (no-load measurements). In the present context, voltage values may refer to voltage in direct current or effective (RMS) voltages in alternating current. The high-voltage current applied may be direct current or alternating current. When alternating current is being used, the frequency of the current may be high, such as at least 1 kHz, 10 kHz, 20 kHz or 30 kHz and at most 100 kHz, 500 kHz or 1 MHz, provided that the signal also exhibits a low-frequency component, for example such that high-frequency signal has an envelope whose frequency stimulates the desired sensory cells. The high-frequency alternating current can be modulated by means of a control signal having a low-frequency component, for example.

[0012] When high-voltage direct current is being used, the electrode may be embodied as a MEMS component (micro electromechanical system), which comprises a set of rotating, preferably individually controllable tiny electrodes. The strength of the capacitive coupling formed by the electrode can be adjusted by adjusting these tiny electrodes. In this case the strongest coupling is achieved when the tiny electrodes are oriented such that they collectively form a plane. In the inventive technique, by measuring the characteristics of the capacitive coupling, for example the capacitance of its variation, it may be possible to measure the distance of the body member from the surface of the apparatus, for example. Additionally, it may be possible to detect separately the touching of the surface by the body member. The inventive technique may be further enhanced by power control functionality of the electric field being formed, for example. Utilization of some embodiments of the invention in the implementation of a proximity sensor may require a weaker electric field than what is required by causing the inventive sensory stimulus. Accordingly it may be beneficial to be able to vary the strength of the electric field depending on the currently needed functionality. Such variation may, for instance, involve strengthening the electric field such that a sense of touch or vibration is caused in the body member when it is brought sufficiently

close to the electrode or insulator.

[0013] By way of example, the low-frequency component of the control signal being used in the inventive technique may be generated by modulating a high-frequency alternating current. The modulation signal may be continuous or pulsed, for example. The duration of individual pulses may be 0.01, 0.5 or 4 ms and the pause between pulses can be at least 1, 10 or 100 ms.

[0014] The low-frequency component of the control signal may have a frequency of at least 10, 50 or 100 Hz and at most 300, 500 or 1000 Hz. In one specific embodiment the control signal has an exemplary frequency of 120 Hz. In the inventive technique the alternating electric field, which causes the stimulus to be provided, may exhibit an intensity peak of at least 100 V/mm, 200 V/mm or 500 V/mm and at most 10 kV/mm, 30 kV/mm or 100 kV/mm. The field strength may be measured, for example, by means of a grounded electrode with a surface area of eg 1 cm² positioned 0.05 to 5 mm, preferably about 1 mm from the surface of the insulated electrode.

[0015] By way of example, the electric field generated by the electrode can be controlled according to a processing logic being executed in a computer or other electronic data processing apparatus. For example, the control logic can be used to control the variation frequency and/or intensity of the electric field generated by an individual electrode. Furthermore, the control logic can be used to pulse the varying electric field, for example. The control logic can also receive control information via a data network from another apparatus, such as another computer or data processing apparatus.

[0016] An inventive apparatus for sensory stimulation comprises at least one insulated electrode, wherein the apparatus is operable to apply a charge to the electrode such that the charge causes a stimulation of the Pacinian corpuscles. For humans this normally requires a voltage of at least 750 V. The apparatus further comprises means for varying the intensity of the charge-generated, capacitively-coupled electric field by utilizing a signal having a component with a frequency of at least 10 Hz and at most 1000 Hz.

[0017] Some embodiments of the inventive apparatus can be implemented, when so desired, without mechanically moving parts, and such embodiments do not pose similar restrictions on the mechanical characteristics of the materials as do actuators based on mechanical movement of the surface. Accordingly, some embodiments of the invention are applicable to a wide variety of surfaces of different shapes. For instance, the surface shape of the electrode and/or insulator attached to it may be planar, rounded, spherical or concave. Likewise, the insulator material can be selected from a variety of materials having characteristics particularly suitable for the chosen application. As regards mechanical characteristics, the surface material can be hard, soft, stiff, bending, transparent or flexible. The surface, as well as the material being used as the conductor, can also be transparent.

[0018] An individual electrode of the apparatus and/or the insulator attached to the electrode can have a surface area of 0.1, 1, 10 or 100 cm² or more. The apparatus can comprise multiple insulated electrodes which can be arranged in an array forming an X-Y coordinate system. Each electrode of such a system can, when so desired, be controlled by a control logic according to some embodiments of the invention, for example. The electrodes can be fixedly mounted or movable.

[0019] The apparatus may comprise means for varying the variation frequency of the electric field, for example by modulating the high-voltage alternating current or by moving the electrodes of the MEMS device according to the control signal.

[0020] The insulator to be arranged between the electrode of the apparatus and the body member can have a thickness of at least 0.01 mm, 0.05 mm, 0.1 mm or 0.5 mm and at most 10 mm, 20 mm or 50 mm. The insulator material can be selected according to the intended use and/or voltage to be used, for example.

[0021] In some embodiments the insulator comprises multiple layers. For instance, the inventors have discovered that the bulk of the insulator layer between the electrode and the body part approaching or touching it may comprise glass but glass is not optimal as the insulator's surface material. In the present context, optimal means an insulator material which best supports the creation of the electro-sensory sensation. A glass insulator works much better if covered with a plastic film.

[0022] The inventive apparatus can be implemented such that its power consumption is low. For example, the power required to cause a sensory stimulus may be 1 mW, 5 mW or 10 mW or more. Power consumption can be measured on the basis of the electric power applied to the electrode when a human touches the apparatus surface or when a capacitively grounded 50 pF capacitor is connected to the apparatus surface.

[0023] The apparatus may comprise means for measuring the capacitance of the capacitive coupling being formed. The apparatus may further comprise means for adjusting the characteristics of the electric field, such as intensity or variation frequency, based on the obtained measurement information.

[0024] The inventive apparatus for sensory stimulation can be integrated as a part of some other apparatus or system. For instance, a prior art touch display can be complemented by apparatuses according to some embodiments of the present invention. This way it is possible to provide a touch display which produces a sensation of touch even if the display is not physically touched. Control components of the feedback system can be combined, or they may be arranged to exchange information with one another. An advantageous embodiment of the presently disclosed method and apparatus is a control device based on touch or proximity, such as a touch display that produces a feedback which can be sensed via the sense of touch.

[0025] In some embodiments of the invention, the local

charge/field can be controlled by means of capacitive grounding. In various embodiments of the invention, it is possible to take into account the fact that the dependence of the electric coupling on the insulated electrode, ie, capacitance, depends on several factors. The capacitance value affects the potential difference between the finger and electrode if the apparatus or subject (such as human) is not grounded, and their ground potential is determined via stray capacitances. Prior art implementations ignore control and processing of the distribution of capacitances and voltages, and some embodiments of the present invention aim at alleviating this separate problem.

[0026] For example, the invention differs from prior art solutions in that no touching or mechanical movement or vibration is required to generate the stimulus. Accordingly, the invention provides advantages over solutions which are based on, say, stroking the finger over the electrodes and on locally varying friction caused by the electric field. Furthermore, the various embodiments of the invention support solutions which are based not only on alternating current but also on direct current. Yet further, the inventive solution can be provided with a functionality to detect proximity and touch, whereby the same component can be used for input and output functions. In addition, various embodiments of the invention may utilize thick insulators, for example, which are mechanically stronger than thin insulators. Moreover, it has been discovered in connection with several embodiments of the invention that it is beneficial to use particular variation frequencies for the electric field, as they will enable smaller energy consumption in the generation of the stimulus.

[0027] In one embodiment the electrical input also comprises a high-frequency component having a frequency which is higher than the frequency of the low-frequency component and lower than 500 kHz. This embodiment may also comprise a modulator or other means for modulating the high-frequency component by the low-frequency component.

[0028] The electrical input to the one or more conducting electrodes has a peak-to-peak voltage of 750 to 100,000 Volts and the insulator should be dimensioned accordingly. In practical implementations with currently available materials the insulator thickness is typically between 0.1 mm and 50 mm.

[0029] In order to convey time-variant information, as opposed to a steady-state sensation, the apparatus may comprise means for modulating the electrical input according to the time-variant information.

[0030] A simple but effective implementation of the invention comprises precisely one conducting electrode for each spatially distinct area of the body member. There may be more than one conducting electrode such that each conducting electrode stimulates a spatially distinct area of one or more body members. The apparatus may comprise an enclosure which contains the high-voltage source which is common to all the several conducting electrodes and wherein the enclosure also contains means for conveying the electrical input to zero or more

of the several conducting electrodes simultaneously. The inventive apparatus and/or the one or more conducting electrodes may be positioned such that the body member most likely to be affected is part of a human hand. For example, five conducting electrodes under control of a common controller, may stimulate, at different times, zero to five fingertips in parallel. The five conducting electrodes thus convey five bits of information in parallel. The apparatus may be implemented as part of an input/output peripheral device connectable to a data processing equipment.

Brief description of the drawings

[0031] In the following the invention will be described in greater detail by means of specific embodiments with reference to the attached drawings, in which

Figure 1 illustrates the operating principle of a capacitive electro-sensory interface ("CEI");
 Figure 2 illustrates an embodiment of the CEI;
 Figure 3 shows an enhanced embodiment with multiple independently-controllable electrodes;
 Figure 4 shows a specific implementation of the embodiment shown in Figure 3;
 Figure 5 is a graph which schematically illustrates the sensitivity of a test subject to sensations produced by the inventive capacitive electrosensory interface at various frequencies;
 Figure 6 is a graph which further clarifies the operating principle of the CEI;
 Figures 7A and 7B show an implementation of the CEI wherein the strength of the capacitive coupling is adjusted by electrode movement;
 Figure 8 shows an implementation of the CEI wherein the charges of different electrodes have opposite signs;
 Figure 9 shows an implementation of the CEI wherein a group of electrodes are organized in the form of a matrix;
 Figure 10 illustrates distribution of an electric field-generating potential in capacitive couplings when the apparatus is grounded;
 Figure 11 illustrates distribution of an electric field-generating potential in capacitive couplings when the apparatus is floating (not grounded);
 Figure 12 illustrates distribution of an electric field-generating potential in capacitive couplings when the apparatus is floating and the user is sufficiently close to the apparatus and capacitively grounded to the ground (reference) potential of the apparatus;
 Figure 13 shows an arrangement wherein capacitive couplings are utilized to detect touching; and
 Figures 14 and 15 illustrate embodiments in which a single electrode and temporal variations in the intensity of the electro-sensory stimulus can be used to create illusions of a textured touch screen surface.

Detailed description of specific embodiments

[0032] Figures 1 through 15 relate to the operation and implementation of a capacitive electro-sensory interface ("CEI") which can be employed in the inventive touch screen interface.

[0033] Figure 1 illustrates the operating principle of the CEI. Reference numeral 100 denotes a high-voltage amplifier. The output of the high-voltage amplifier 100, denoted OUT, is coupled to an electrode 106 which is insulated against galvanic contact by an insulator 108 which comprises at least one insulation layer or member. Reference numeral 120 generally denotes a body member to be stimulated, such as a human finger. Human skin, which is denoted by reference numeral 121, is a relatively good insulator when dry, but the CEI provides a relatively good capacitive coupling between the electrode 106 and the body member 120. The capacitive coupling is virtually independent from skin conditions, such as moisture. The inventors' hypothesis is that the capacitive coupling between the electrode 106 and the body member 120 generates a pulsating Coulomb force. The pulsating Coulomb force stimulates vibration-sensitive receptors, mainly those called Pacinian corpuscles which reside under the outermost layer of skin in the ipodermis 121. The Pacinian corpuscles are denoted by reference numeral 122. They are shown schematically and greatly magnified.

[0034] The high-voltage amplifier 100 is driven by an input signal IN which results in a substantial portion of the energy content of the resulting Coulomb forces to reside in a frequency range to which the Pacinian corpuscles 122 are sensitive. For humans this frequency range is between 10 Hz and 1000 Hz, preferably between 50 Hz and 500 Hz and optimally between 100 Hz and 300 Hz, such as about 240 Hz. The frequency response of the Pacinian corpuscles is further discussed in connection with Figures 5 and 6.

[0035] It should be understood that, while "tactile" is frequently defined as relating to a sensation of touch or pressure, the electrosensory interface according to the present CEI, when properly dimensioned, is capable of creating a sensation of vibration to a body member even when the body member 120 does not actually touch the insulator 108 overlaying the electrode 106. This means that unless the electrode 106 and/or insulator 108 are very rigid, the pulsating Coulomb forces between the electrode 106 and body member 120 (particularly the Pacinian corpuscles 122) may cause some slight mechanical vibration of the electrode 106 and/or insulator 108, but the method and apparatus according to the CEI are capable of producing the electrosensory sensation independently of such mechanical vibration.

[0036] The high-voltage amplifier and the capacitive coupling over the insulator 108 are dimensioned such that the Pacinian corpuscles or other mechanoreceptors are stimulated and an electrosensory sensation (a sensation of apparent vibration) is produced. For this, the

high-voltage amplifier 100 must be capable of generating an output of several hundred volts or even several kilovolts. In practice, the alternating current driven into the body member 120 has a very small magnitude and can be further reduced by using a low-frequency alternating current.

[0037] Figure 2 illustrates an apparatus which implements an illustrative embodiment of the present CEI. In this embodiment the high-voltage amplifier 100 is implemented as a current amplifier 102 followed by a high-voltage transformer 104. In the embodiment shown in Figure 2, the secondary winding of the high-voltage transformer 104 is in a more or less flying configuration with respect to the remainder of the apparatus. The amplifier 100, 102 is driven with a modulated signal whose components are denoted by 112 and 114. The output of the high-voltage amplifier 100 is coupled to an electrode 106 which is insulated against galvanic contact by the insulator 108. Reference numeral 120 generally denotes a member to be stimulated, such as a human finger. Human skin, which is denoted by reference numeral 121, is a relatively good insulator when dry, but the CEI provides a relatively good capacitive coupling between the electrode 106 and the electrically conductive tissue underneath the skin surface 121. Mechanoreceptors, such as the Pacinian corpuscles 122, reside in this conductive tissue. In Figures 1 and 2, the Pacinian corpuscles 122 are shown schematically and greatly magnified.

[0038] A benefit of the capacitive coupling between the electrode 106 and the electrically conductive tissue underneath the skin surface, which is known as the Corneus Layer and which contains the Pacinian corpuscles 122, is that the capacitive coupling eliminates high local current densities to finger tissue, which would result from contact that is conductive at direct current.

[0039] It is beneficial, although not strictly necessary, to provide a grounding connection which helps to bring the subject to be stimulated, such as the user of the apparatus, closer to a well-defined (non-floating) potential with respect to the high-voltage section of the apparatus. In the embodiment shown in Figure 2, the grounding connection, denoted by reference numeral 210, connects a reference point REF of the high-voltage section to a body part 222 which is different from the body part(s) 120 to be stimulated. In the embodiment shown in Figure 2, the reference point REF is at one end of the secondary winding of the transformer 104, while the drive voltage for the electrode(s) 206A, 206B, 206C is obtained from the opposite end of the secondary winding.

[0040] In an illustrative implementation, the apparatus is a hand-held device which comprises a touch display activated by finger(s) 120. The grounding connection 210 terminates at a grounding electrode 212. An illustrative implementation of the grounding electrode 212 is one or more ground plates which are arranged such that they are conveniently touched one hand 222 of the user while the apparatus is manipulated by the other hand. The ground plate(s) may be positioned on the same side of

the apparatus with the touch display and next to the touch display, or it/they may be positioned on adjacent or opposite side(s) from the side which comprises the touch display, depending on ergonomic considerations, for example.

[0041] In real-world apparatuses, the coupling 210 between the reference point REF and the non-stimulated body part 222 may be electrically complex. In addition, hand-held apparatuses typically lack a solid reference potential with respect to the surroundings. Accordingly, the term "grounding connection" does not require a connection to a solid-earth ground. Instead the grounding connection means any connection which helps to decrease the potential difference between the reference potential of the apparatus and a second body member distinct from the body member(s) to be stimulated. This definition does not rule out any capacitive parallel or stray elements, so long as the grounding connection 210 helps bring the user of the apparatus, along with the non-stimulated body part 222, to a potential which is reasonably well defined with respect to the high-voltage section of the apparatus. A capacitive grounding connection will be discussed in connection with Figure 12. In the present context, the reasonably well-defined potential should be understood in view of the voltage OUT which drives the electrode(s) 206A, 206B, 206C. If the electrode drive voltage OUT is, say, 1000 V, a potential difference of, say, 100 V, between the user's body and the reference point REF may not be significant.

[0042] The non-capacitive coupling 210 between the reference point REF of the high-voltage section and the non-stimulated body part 222 greatly enhances the electro-sensory stimulus experienced by the stimulated body part 120. Conversely, an equivalent electro-sensory stimulus can be achieved with a much lower voltage and/or over a thicker insulator when the non-capacitive coupling 210 is being used.

[0043] The amplifier 100, 102 is driven with a high-frequency signal 112 which is modulated by a low-frequency signal 114 in a modulator 110. The frequency of the low-frequency signal 114 is such that the Pacinian corpuscles, which reside in the electrically conductive tissue underneath the skin surface, are responsive to that frequency. The frequency of the high-frequency signal 112 is preferably slightly above the hearing ability of humans, such as 18 to 25 kHz, more preferably between about 19 and 22 kHz. If the frequency of the signal 112 is within the audible range of humans, the apparatus and/or its drive circuit may produce distracting sounds. On the other hand, if the frequency of the signal 112 is far above the audible range of humans, the apparatus drives more current into the member 120. A frequency of about 20 kHz is advantageous in the sense that components designed for audio circuits can generally be used, while the 20 kHz frequency is inaudible to most humans. Experiments carried out by the inventors suggest that such modulation is not essential for the CEI. Use of a high-frequency signal with low-frequency mod-

ulation, such as the one schematically shown in Figure 2, as opposed to a system which relies on the low-frequency signal alone, provides the benefit that the relatively high alternating voltage (a few hundred volts or a few kilovolts) can be generated with a relatively small transformer 104.

[0044] Terms like frequency or kHz should not be understood such that the high- or low-frequency signals 112, 114 are restricted to sinusoidal signals, and many other waveforms can be used, including square waves. The electrical components, such as the modulator 110, amplifier 102 and/or transformer 104 can be dimensioned such that harmonic overtones are suppressed. The inventors have discovered that pulses with durations of 4 ms (approximately one half-cycle of the low-frequency signal) or longer can be readily detected and with a practical insulator thickness the peak-to-peak voltage in the electrode 106 needs to be at least about 750 V. Unloaded peak-to-peak voltage measured in the electrode 106 should be in the range of approximately 750 V - 100 kV. Near the lower limit of this voltage range, the insulator thickness may be 0.05 - 1 mm, for example. As material technology and nanotechnology develop, even thinner durable insulating surfaces may become available. This may also permit a reduction of the voltages used.

[0045] The elements of Figures 1 and 2 described so far produce a steady-state electrosensory sensation as long as the body member, such as the finger 120, is in the vicinity of the electrode 106. In order to convey useful information, the electrosensory sensation must be modulated. In some simple embodiments, such modulation can be implemented by positioning the electrode 106 such that useful information is conveyed by the fact that the finger 120 can sense the presence of the electrode 106. For example, the electrode 106 can be positioned over a switch, or in the vicinity of it, such that the switch can be detected without having to see it.

[0046] In other embodiments, such information-carrying modulation can be provided by electronically controlling one or more operating parameters of the inventive apparatus. The information-carrying modulation should not be confused with the modulation of the high-frequency signal 112 by the low-frequency signal 114, the purpose of which is to reduce the size of the transformer 104. In the schematic drawing shown in Figure 2, such information-carrying modulation is provided by controller 116, which controls one or more of the operating parameters of the inventive apparatus. For instance, the controller 116 may enable, disable or alter the frequency or amplitude of the high- or low-frequency signals 112, 114, the gain of the amplifier 102, or it may controllably enable or disable the power supply (not shown separately) or controllably break the circuit at any point.

[0047] Figure 3 shows an enhanced embodiment of the inventive apparatus with multiple independently-controllable electrodes. In Figure 3, elements with reference numerals less than 200 have been described in connection with Figures 1 and 2, and a repeated description is

omitted. This embodiment comprises multiple independently-controllable electrodes 206A, 206B and 206C, of which three are shown but this number is purely arbitrary. Reference numeral 216 denotes an implementation of a controller which controls a switch matrix 217 which provides the high-voltage signal OUT to the electrodes 206A, 206B and 206C under control of the controller 216. The controller 216 may be responsive to commands from an external device, such as a data processing equipment (not shown separately).

[0048] A benefit of the embodiment shown in Figure 3 is that virtually all the drive circuitry, including the high-voltage amplifier 100, controller 216, and switch matrix 217, can be integrated into a common enclosure which is denoted by reference numeral 200. In this embodiment only the electrodes 206A, 206B and 206C and a single connecting wire for each electrode are outside the enclosure 200. As stated earlier, the electrodes need to be nothing more than simple conducting or semi-conducting plates covered by appropriate insulators. Therefore the enclosure 200 can be positioned in virtually any convenient position because the only elements external to it are very simple electrodes and connecting wires (and, in some implementations a power supply, not shown separately).

[0049] Some prior art systems provide direct stimulation of nerves via galvanic current conduction to the outermost layer of the skin. Because of the galvanic current conduction, such systems require two electrodes to stimulate an area of skin. In contrast to such prior art systems, the embodiment described in connection with Figure 3 involves multiple electrodes 206A, 206B and 206C, but each electrode alone stimulates a distinct area of skin, or more precisely, the mechanoreceptors, including the Pacinian corpuscles underlying the outermost layers of skin. Therefore a configuration of n electrodes conveys n bits of information in parallel.

[0050] Figure 4 shows a specific implementation of the embodiment shown in Figure 3. In this implementation the switch matrix 217 comprises a bank of triacs 207A, 207B and 207C, but other types of semiconductor switches can be used, including semiconductor relays. Conventional electromechanical relays can be used as well. In this embodiment the switches (triacs) 207A, 207B and 207C are positioned logically after the transformer 104, ie, in the high-voltage circuitry. This implementation requires high-voltage switches (several hundred volts or several kilovolts) but it provides the benefit that the remainder of the circuitry, including the elements 100 through 114, can serve all of the electrodes 206A, 206B and 206C. As shown in Figure 4, the controller 216 may be connectable to a data processing equipment, an example of which is shown here as a personal computer PC.

[0051] Figure 5 is a graph which schematically illustrates the sensitivity of a randomly selected test subject to sensations produced by an apparatus substantially similar to the one shown in Figure 2. The x-axis of the graph shows frequency of the low-frequency signal (item

114 in Figure 2) multiplied by two, while the y-axis shows the amplitude required to detect an electrosensory stimulation. The amplitude scale is relative. The small dip at 75 Hz may be a measurement anomaly. The reason for placing the doubled low-frequency signal on the x-axis is that the Coulomb forces between the electrode 106 and the body member 120 have two intensity peaks for each cycle of a sinusoidal low-frequency signal, as will be schematically illustrated in connection with Figure 6.

[0052] The relative sensitivity at various frequencies is remarkably similar to the one published in section 2.3.1 (figure 2.2) of Reference document 1. Reference document 1 relates to vibrotactile (mechanical) stimulation of skin, but the similarity of the frequency response shown in Figure 5 to the one published in Reference 1 suggests that the present CEI operates such that the electrode 106 and the sensitive member 120 (see Figure 1) form a capacitor over the insulator 108, and in that capacitor the oscillating Coulomb forces are converted to mechanical vibrations which are sensed by mechanoreceptors, including the Pacinian corpuscles. The inventors have also studied an alternative hypothesis wherein the Pacinian corpuscles are stimulated by current flowing through them, but this hypothesis does not explain the observations as well as the one which is based on Coulomb forces acting on the Pacinian corpuscles. However, the technical CEI described herein does not depend on the correctness of any particular hypothesis attempting to explain why the CEI operates the way it does.

[0053] Figure 6 is a graph which further clarifies the operating principle of the CEI and the interpretation of frequencies in connection with the present CEI. Reference numeral 61 denotes the low-frequency input signal to the modulator 110 (shown as item 114 in Figure 2). Reference numeral 62 denotes the output of the modulator, ie, the high-frequency input signal as modulated by the low-frequency input signal.

[0054] Reference numerals 63 and 64 denote the resulting Coulomb forces in the capacitive coupling between the electrode 106 and the body member 120 over the insulator 108. Because the two sides of the capacitive coupling have opposite charges, the Coulomb force between the two sides is always attractive and proportional to the square of the voltage. Reference numeral 63 denotes the actual Coulomb force while reference numeral 64 denotes its envelope. The envelope 64 is within the range of frequencies to which the Pacinian corpuscles are sensitive, but because the Coulomb force is always attractive, the envelope 64 has two peaks for each cycle of the modulator output signal 62, whereby a frequency-doubling effect is produced. Because the Coulomb force is proportional to the square of the voltage, any exemplary voltages disclosed herein should be interpreted as effective (RMS) values in case the voltages are not sinusoidal.

[0055] The statement that the two sides of the capacitive coupling have opposite charges whereby the Coulomb force is always attractive holds for a case in which

the apparatus and the body member to be stimulated are at or near the same potential. High static charges can cause deviations from this ideal state of affairs, which is why some form of grounding connection between a reference potential of the high-voltage source and the body element other than the one(s) to be stimulated is recommended, as the grounding connection helps to lower the potential differences between the apparatus and its user.

[0056] The CEI can be implemented as part of an input/output peripheral device which is connectable to a data processing equipment. In such a configuration the data processing equipment can provide prompting and/or feedback via electrically-controllable electrosensory sensation.

[0057] Figures 7A and 7B show implementations of the CEI wherein the strength of the capacitive coupling is adjusted by electrode movement. Generation of the electric field, and its variation as necessary, is effected via a set of electrodes 704 which comprises individual electrodes 703. The individual electrodes 703 are preferably individually controllable, wherein the controlling of an electrode affects its orientation and/or protrusion. Figure 7A shows an implementation wherein a group of electrodes 703 are oriented, via the output signal from the controller 216, such that the electrodes 703 collectively form a plane under the insulator 702. In this situation the high-voltage current (DC or AC) from the high-voltage amplifier 100 to the electrodes 703 generates an opposite-signed charge of sufficient strength to a body member (eg the finger 120) in close proximity to the apparatus. A capacitive coupling between the body member and the apparatus is formed over the insulator 702, which may give rise to a sensory stimulus.

[0058] Figure 7B shows the same apparatus shown in Figure 7A, but in this case the strength of the capacitive coupling generated with the current from the high-voltage amplifier 100 is minimized by orienting the electrodes (now shown by reference numeral 714) such that they do not form a plane under the insulator 702. In some implementations of the present invention, the electric field alternating with a low frequency can be generated by alternating the state of the apparatus between the two states shown in Figures 7A and 7B. The frequency of the state alternation can be in the order of several hundred, eg 200 to 300 full cycles per second.

[0059] Figure 8 shows an implementation of the CEI wherein the individual electrodes 803 in the set of electrodes 804 may have charges of opposite signs. The charges of individual electrodes 803 may be adjusted and controlled via the controller 216. The individual electrodes 803 may be separated by insulator elements 806, so as to prevent sparking or shorting between the electrodes. The capacitive coupling between the CEI and the body member proximate to it may give rise to areas having charges with opposite signs 801. Such opposing charges are mutually attractive to one another. Hence it is possible that Coulomb forces stimulating the Pacinian corpuscles may be generated not only between the CEI

and the body member but between infinitesimal areas within the body member itself.

[0060] Figure 9 shows an implementation of the CEI wherein a group of individually controllable electrodes 910a through 910i are organized in the form of a matrix. Such a matrix can be integrated into a touch screen device, for example. Since the CEI described above does not require direct connection (touching) between the CEI and a body member of its user, the electrodes of the CEI apparatus can be positioned behind the touch screen, wherein "behind" means the side of the touch screen opposite to the side facing the user during normal operation. Alternatively, the electrodes can be very thin and/or transparent, whereby the electrodes can overlay the touch screen on the side normally facing the user. The electric charges, which are conducted from the high-voltage amplifier 100 to the electrodes 910a through 910i via the switch array 217, may all have similar signs or the charges conducted to different electrodes may have different signs, as illustrated in connection with Figure 8. For instance, the controller 216 may control the switches in the switch array individually, or certain groups may form commonly-controllable groups. The surface of an individual electrode and/or its associated insulator can be specified according to the intended range of operations or applications. The minimum practical area is about 0.01 cm², while the practical maximum is roughly equal to the size of a human hand. It is expected that surface areas between 0.1 and 1 cm² will be found most usable in practice.

[0061] The matrix of electrodes 910a through 910i and the switch array 217 provide a spatial variation of the electro-sensory stimulation. In other words, the sensory stimulation provided to the user depends on the location of the user's body member, such as a finger, proximate to the CEI apparatus which is integrated to the inventive touch screen. The spatially varying sensory stimulation provides the user with an indication of the layout of the touch-sensitive areas of the touch screen interface.

[0062] In addition to the spatially varying sensory stimulation, the controller 216 may direct the switch array 217 to produce a temporally varying (time-dependent) electro-sensory stimulation, which can be used for a wide variety of useful effects. For instance, the temporally varying electro-sensory stimulation can be used to indicate a detected activation of a touch-sensitive area ("key press"). This embodiment address a common problem associated with prior art touch screen devices, namely the fact that a detection of a key press produces no tactile feedback. Prior art application-level programs used via touch screen devices may provide visual or aural feedback, but such types of feedback exhibit the various problems described earlier. In addition, production of the visual or aural feedback from the application-level program causes a burden on the programming and execution of those programs. In some implementations of the invention, an interface-level or driver-level program provides a tactile feedback from a detected activation of a touch-

sensitive area by using the temporally and spatially variant electro-sensory stimulation, and such interface-level or driver-level programs can be used by any application-level programs. For example, the application-level programs can be coupled to the inventive touch screen interface via an application programming interface ("API") whose set of available functions includes the feedback generation described above.

[0063] The temporally and spatially variant electro-sensory stimulation can also be used to change the layout of the touch-sensitive areas "on the fly". In hindsight, this operation may be considered roughly analogous to changing the keyboard or keypad layout depending on the application program or user interface screen currently executed. However, when prior art touch screen devices change keyboard or keypad layout on the fly, the new layout must be somehow indicated to the user, and this normally requires that the user sees the touch screen device.

[0064] Some embodiments of the inventive touch screen device eliminate the need to see the touch screen device, assuming that the layout of the touch-sensitive areas is sufficiently simple. For instance, up to about two dozen different "key legends" can be indicated to the user by providing different patterns for the temporally and spatially variant electro-sensory stimulation. As used herein, the expression "key legend" refers to the fact that prior art touch screen devices, which produce no tactile feedback, normally produce visual cues, and these are commonly called "legends". In some embodiments of the present invention, the function of the key legends can be provided via different patterns. For instance, the following patterns can be identified with one fingertip: pulses with low, medium or high repetition rate; sweeps to left, right, up or down, each with a few different repetition rates; rotations clockwise or anti-clockwise, each with a few different repetition rates.

[0065] From the above, it is evident that the inventive electro-sensory interface can produce a large number of different touch-sensitive areas, each with a distinct "feel" (technically: a different pattern for the temporal and spatial variation of the electro-sensory stimulus). Hence the screen section of a conventional touch screen is not absolutely needed in connection with the present invention, and the term touch device interface should be interpreted as an interface device which, among other things, is suitable for applications commonly associated with touch screen devices, although the presence of the screen is not mandatory.

[0066] Moreover, the strength of the capacitive coupling between the inventive CEI and a body member of its user (or the capacitive coupling between an individual electrode or a group of electrodes and the user's body member) can be determined by direct or indirect measurements. This measurement information can be utilized in various ways. For instance, the strength of the capacitive coupling can indicate the body member's proximity to the electrode, or it can indicate touching the electrode

by the body member. Such measurement functionality can be provided by a dedicated measurement unit (not shown) or it can be integrated into one of the blocks described earlier, such as the switch matrix 217. The switch matrix 217 (or the optional dedicated measurement unit) can send the measurement information to the controller 216 which can utilize it to vary the electric fields generated by the electrodes, by varying the voltage or frequency. In addition or alternatively the controller 216 may forward the measurement information, or some information processed from it, to a data processing equipment, such as the personal computer PC shown in Figure 4.

[0067] Yet further two or more inventive touch device interfaces can be interconnected via some communication network(s) and data processing equipment. In such an arrangement, the electro-sensory stimulation provided to the users of the touch screen devices may be based on some function of all users' contribution to the proximity to their respective devices. In one illustrative example, such an interconnection of two (or more) touch screen devices can provide their users with tactile feedback whose strength depends on the sum of the areas of hands touch the touch-sensitive areas. This technique simulates a handshake whose strength reflects the sum of hand pressure exerted by both (or all) users. In another illustrative example, a music teacher might "sense" how a remotely located student presses the keys of a simulated piano keyboard.

[0068] Figures 10 through 13 are equivalent circuits (theoretical models) which may be useful in dimensioning the parameters of the capacitive coupling. Figure 10 illustrates distribution of an electric field-generating potential in capacitive couplings when the apparatus is grounded. The underlying theory is omitted here, and it suffices to say that in the arrangement shown in Figure 10, the drive voltage e of an electrode is divided based on the ratio of capacitances C_1 and C_2 , wherein C_1 is the capacitance between the finger and the electrode and C_2 is the stray capacitance of the user. The electric field experienced by the finger is caused by voltage U_1 :

$$U_1 = \frac{C_2}{C_1 + C_2} e$$

[0069] This voltage is lower than the drive voltage e from the voltage source. In a general case the reference potential of the apparatus may be floating, as will be shown in Figure 11. This arrangement further decreases the electric field directed to the body member, such as finger.

[0070] For these reasons some embodiments of the invention aim at keeping the capacitance C_1 low in comparison to that of C_2 . At least capacitance C_1 should not be significantly higher than C_2 . Some embodiments aim at adjusting or controlling C_2 , for instance by coupling the reference potential of the apparatus back to the user,

as shown in Figure 12.

[0071] Further analysis of the actual value of capacitance C_1 shows that it can be treated as a capacitance consisting of three series-coupled partial capacitances: C_i of the insulator material, C_a of the air gap between insulator and finger, and C_s formed by the outmost skin layer that is electrically insulating the inner, conducting tissue from the environment. Each partial capacitance is given by:

$$C = \epsilon \frac{S}{d}$$

[0072] Herein, ϵ is the permittivity (dielectric constant) of the insulating material, S is the (effective) surface area and d is the distance between the surfaces of the capacitor. In a series arrangement of capacitances, the smallest one of the individual capacitances dominates the overall value of the total capacitance C_1 . When the body member does not touch the surface of the insulated electrode but only approaches it, the capacitive coupling is weak. Thus the value of C_1 is small and mainly determined by the air gap, C_a . When the body member touches the surface, the effective air gap is small (approximately the height ridges of the fingerprint profile on the skin surface). As capacitance is inversely proportional to the distance of the conducting surfaces forming the capacitor, corresponding C_a obtains a high value, and the value of C_1 is determined by C_i and C_s . Thus the effectiveness of the electro-sensory stimulus generation can be enhanced by appropriate selection of insulator material, particularly in terms of thickness and dielectric properties. For instance, selecting a material with a relatively high dielectric constant for the insulator reduces the electric field in the material but increases the electric field strength in the air gap and skin.

[0073] Furthermore, in applications where the surface is likely to be touched while the electro-sensory stimulation or response is given, the effectiveness of the electro-sensory stimulus generation can be enhanced by optimal selection of the material that will be touched by the body member. This is particularly significant in connection with insulators which are good volume insulators (insulators in the direction of the surface's normal) but less so in the direction along the surface.

[0074] An insulator's insulation capability along the surface may be negatively affected by surface impurities or moisture which have a negative effect on the apparent strength of the sensation felt by the body member to be stimulated. For instance, glass is generally considered a good insulator, but its surface tends to collect a thin sheet of moisture from the air. If the electrode of the CEI is insulated with glass, the electro-sensory effect is felt in close proximity (when there is still an air gap between body member and the glass surface). However, when the glass surface is touched, even lightly, the electro-

sensory tends to weaken or disappear altogether. Coating the outer insulating surface with a material having a low surface conductance remedies such problems. The inventors speculate that if the surface having some surface conductivity is touched, it is the conductive layer on the surface that experiences the coulomb force rather than the body member touching the surface. Instead the touching body member acts as a kind of grounding for the conductive surface layer, for example via the stray capacitance of the body.

[0075] Instead of the measures described in connection with Figures 10 through 12, or in addition to such measures, stray capacitances can be controlled by arrangements in which several electrodes are used to generate potential differences among different areas of the touch screen surface. By way of example, this technique can be implemented by arranging the touch-sensitive surface of a hand-held device (eg the top side of the device) to a first potential, while the opposite side is arranged to a second potential, wherein the two different potentials can be the positive and negative poles of the device. Alternatively, a first surface area can be the electric ground (reference potential), while a second surface area is charged to a high potential.

[0076] Moreover, within the constraints imposed by the insulator layer(s), it is possible to form minuscule areas of different potentials, such as potentials with opposite signs or widely different magnitudes, wherein the areas are small enough that the user's body member, such as finger, is simultaneously subjected to the electric fields from several areas with different potentials.

[0077] Figure 13 shows an embodiment in which the capacitive coupling is utilized to detect touching or approaching by the user's body member, such as finger. A detected touching or approaching by the user's body member can be passed as an input to a data processing device. In the embodiment shown in Figure 13, the voltage source is floating. A floating voltage source can be implemented, via inductive or capacitive coupling and/or with break-before-make switches. A secondary winding of a transformer is an example of a simple yet effective floating voltage source. By measuring the voltage U_4 , it is possible to detect a change in the value(s) of capacitance(s) C_1 and/or C_2 . Assuming that the floating voltage source is a secondary winding of a transformer, the change in capacitance(s) can be detected on the primary side as well, for example as a change in load impedance. Such a change in capacitance(s) serves as an indication of a touching or approaching body member.

[0078] In one implementation, the apparatus is arranged to utilize such indication of the touching or approaching body member such that the apparatus uses a first (lower) voltage to detect the touching or approaching by the body member and a second (higher) voltage to provide feedback to the user. For instance, such feedback can indicate any of the following: the outline of the/each touch-sensitive area, a detection of the touching or approaching body member by the apparatus, the sig-

nificance of (the act to be initiated by) the touch-sensitive area, or any other information processed by the application program and which is potentially useful to the user.

[0079] Figure 14 schematically illustrates an embodiment in which a single electrode and temporal variations in the intensity of the electro-sensory stimulus can be used to create illusions of a textured touch screen surface. Reference numeral 1400 denotes a touch-sensitive screen which, for the purposes of describing the present embodiment, comprises three touch-sensitive areas A_1 , A_2 and A_3 . The approaching or touching by the touch-sensitive areas A_1 , A_2 and A_3 of a user's finger 120 is detected by a controller 1406.

[0080] According to an embodiment of the invention, a conventional touch-sensitive screen 1400 can be complemented by an interface device according to the invention. Reference numeral 1404 denotes an electrode which is an implementation of the electrodes described in connection with previously-described embodiments, such as the electrode 106 described in connection with Figures 1 and 2. A supplemental insulator 1402 may be positioned between the touch-sensitive screen 1400 and the inventive electrode 1404, in case the touch-sensitive screen 1400 itself fails to provide sufficient insulation.

[0081] In addition to conventional touch-screen functionality, namely detection of approaching or touching by the touch-sensitive areas by the user's finger, the controller 1406 uses information of the position of the finger 120 to temporally vary the intensity of the electro-sensory stimulation invoked by the electrode 1404 on the finger 120. Although the intensity of the electro-sensory stimulation is varied over time, time is not an independent variable in the present embodiment. Instead, timing of the temporal variations is a function of the position of the finger 120 relative to the touch-sensitive areas (here: A_1 , A_2 and A_3). Thus it is more accurate to say that the present embodiment is operable to cause variations in the intensity of the electro-sensory stimulation invoked by the electrode 1404 on the finger 120, wherein the variations are based on the position of the finger 120 relative to the touch-sensitive areas.

[0082] The bottom side of Figure 14 illustrates this functionality. The three touch-sensitive area A_1 , A_2 and A_3 are demarcated by respective x coordinate pairs $\{x_1, x_2\}$, $\{x_3, x_4\}$ and $\{x_5, x_7\}$. Processing in the y direction is analogous and a detailed description is omitted. The controller 1406 does not sense the presence of the finger, or senses the finger as inactive, as long as the finger is to the left of any of the touch-sensitive areas A_1 , A_2 and A_3 . In this example the controller 1406 responds by applying a low-intensity signal to the electrode 1404. As soon as the finger 120 crosses the x coordinate value x_1 , the controller 1406 detects the finger over the first touch-sensitive area A_1 and starts to apply a medium-intensity signal to the electrode 1404. Between the areas A_1 and A_2 (between x coordinates x_2 and x_3), the controller again applies a low-intensity signal to the electrode 1404. The second touch-sensitive area A_2 is processed similarly to

the first touch-sensitive area A_1 , but the third touch-sensitive area A_3 is processed somewhat differently. As soon as the controller 1406 detects the finger 120 above or in close proximity to the area A_3 , it begins to apply the medium-intensity signal to the electrode 1404, similarly to areas A_1 and A_2 . But the user decides to press the touch screen 1400 at a point x_6 within the third area A_3 . The controller 1406 detects the finger press (activation of the function assigned to the area A_3) and responds by applying a high-intensity signal to the electrode 1404.

[0083] Thus the embodiment shown in Figure 14 can provide the user with a tactile feedback which creates an illusion of a textures surface, although only a single electrode 1404 was used to create the electro-sensory stimulus. A residual problem is, however, that the user has to memorize the significance of the several touch-sensitive areas or obtain visual or aural information on their significance.

[0084] Figure 15 shows a further enhanced embodiment from the one described in connection with Figure 14. The embodiment shown in Figure 15 uses different temporal variations of the intensity of the electro-sensory stimulus, wherein the different temporal variations provide the user with a tactile feedback indicating the significance of the touch-sensitive areas.

[0085] The operation of the embodiment shown in Figure 14 differs from the one described in connection with Figure 1-5 in that the controller, here denoted by reference numeral 1506, applies different temporal variations to the intensity of the signal to the electrode 1404. In this example, the first touch-sensitive area A_1 is processed similarly to the preceding embodiment, or in other words, the intensity of the electro-sensory stimulus depends only on the presence of the finger 120 in close proximity to the area A_1 . But in close proximity to areas A_2 and A_3 , the controller 1506 also applies temporal variations to the intensity of the electro-sensory stimulus. For example the significance (coarsely analogous with a displayed legend) of area A_2 is indicated by a pulsed electro-sensory stimulus at a first (low) repetition rate, while the significance of area A_3 is indicated by a pulsed electro-sensory stimulus at a second (higher) repetition rate. In an illustrative example, the three touch-sensitive areas A_1 , A_2 and A_3 can invoke the three functions in a yes/no/cancel-type user interface, wherein the user can sense the positions of the user interface keys (here: the three touch-sensitive areas) and the indication of an accepted input only via tactile feedback. In other words, the user needs no visual or aural information on the positions of the touch-sensitive areas or on the selected function. The embodiment described in connection with Figure 15 is particularly attractive in car navigators or the like, which should not require visual attention from their users.

[0086] In the embodiments shown in Figures 14 and 15, when the user's finger 120 has selected the function assigned to area A_3 and the controller CTRL 1406, 1506 generates the high-intensity electro-sensory stimulus via the electrode 1404, the high-intensity stimulus is sensed

via any of the areas A_1 , A_2 and A_3 . In other words, if one finger of the user presses the area A_3 , other finger(s) in close proximity to the other areas A_2 and/or A_3 will also sense the high-intensity stimulus. In cases where this is not desirable, the embodiments shown in Figures 14 and 15 can be combined with the multi-electrode embodiment disclosed in connection with Figure 9, such that the signal to each of several electrodes (shown in Figure 9 as items 910a through 910i) is controlled individually.

[0087] It is readily apparent to a person skilled in the art that, as the technology advances, the inventive concept can be implemented in various ways. The invention and its embodiments are not limited to the examples described above but may vary within the scope of the claims.

References

[0088]

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Claims

1. An apparatus for producing an electrosensory sensation to at least one body part (120) to be stimulated, the apparatus comprising:
 - one or more conducting electrodes (106), each conducting electrode being provided with an insulator (108) wherein, when the at least one body part (120) to be stimulated is proximate to the conducting electrode, the insulator prevents flow of direct current from the conducting electrode to the body part to be stimulated and a capacitive coupling over the insulator (108) is formed between the conducting electrode (106) and the at least one body part (120) to be stimulated;
 - a high-voltage source (100, 102, 104) for applying an electrical input (OUT) to the one or more conducting electrodes, wherein the electrical input has at least a portion of its energy content in a frequency range between 10 Hz and 1000 Hz;
 - wherein the capacitive coupling and electrical input are dimensioned to produce an electrosensory sensation; and
 - whereby the electrosensory sensation is produced independently of any mechanical vibration of the one or more conducting electrodes (106) or insulators (108);

characterized by a grounding connection (210) between:

- a reference voltage (REF) of the high-voltage source (100, 102, 104) other than the electrical input (OUT) to the one or more conducting electrodes; and
 - at least one grounding electrode (212) separate from the one or more conducting electrodes (106), wherein the grounding electrode (212) is positioned so as to be touched by a second body part (222) distinct from each of the at least one body part to be stimulated (120; 220A, 220B, 220C).
2. An apparatus according to claim 1, wherein:
- the capacitive coupling and electrical input are dimensioned to produce an electrosensory sensation to the at least one body part when the at least one body part is proximate in respect to the one or more conducting electrodes;
 - whereby the electrosensory sensation is produced independently of any touching or mechanical movement between the at least one body part and the one or more conducting electrodes.
3. An apparatus according to any one of the preceding claims, wherein the apparatus comprises one conducting electrode for each spatially distinct body part to be stimulated (120; 220A, 220B, 220C).
4. An apparatus according to any one of the preceding claims, wherein the apparatus comprises one conducting electrode (206A, 206B, 206C) for each of several spatially distinct body parts to be stimulated (220A, 220B, 220C).
5. An apparatus according to any one of the preceding claims, wherein the apparatus comprises means (116, 216) for conveying information via the electrosensory sensation by modulating the electrical input according to said information.
6. An apparatus according to any one of the preceding claims, further comprising an enclosure (200) which contains the high-voltage source (100, 102, 104) which is common to all the several conducting electrodes (206A, 206B, 206C) and wherein the enclosure (200) also contains means (217) for conveying the electrical input (OUT) to zero or more of the several conducting electrodes simultaneously, under control of a common controller (216).
7. An apparatus according to claim 6, wherein the apparatus is part of an input/output peripheral device connectable to a data processing equipment.

8. An apparatus according to any one of the preceding claims, further comprising:

- a surface (1400) arranged so as to be touched or approached by the body part to be stimulated (120), wherein the surface has at least one touch-sensitive area (A1, A2, A3), each touch-sensitive area having a predetermined position (x1-x2; x3-x4; x5-x7);
- wherein the apparatus comprises or is operatively connectable to means for assigning at least one function to the least one touch-sensitive area; and
- wherein the apparatus further comprises means (1406, 1506) for varying the intensity of the electro-sensory stimulus spatially and/or temporally based on a detected touching or approaching of the at least one touch-sensitive area (A1, A2, A3) by the body part to be stimulated (120);
- whereby the interface device is able to produce a feedback to a user via the body part to be stimulated.

9. An apparatus according to claim 8, wherein said means (1406, 1506) for varying the intensity of the electro-sensory stimulus spatially and/or temporally comprises means (1406, 1506) for varying the intensity of the electro-sensory stimulus temporally.

10. An apparatus according to claim 9, wherein:

- said means for assigning at least one function are operable to dynamically change the at least one function assigned to the least one touch-sensitive area; and
- the apparatus is operable to vary the feedback based on the function assigned to the least one touch-sensitive area.

11. An apparatus according to any one of the preceding claims, wherein the electrical input comprises a low-frequency component (114) in a frequency range between 10 Hz and 1000 Hz and a high-frequency component (112) having a frequency which is higher than the frequency of the low-frequency component (114) and lower than 500 kHz.

12. An apparatus according to claim 11, comprising means (110) for modulating the high-frequency component (112) by the low-frequency component (114).

13. An apparatus according to any one of the preceding claims, wherein the electrical input to the one or more conducting electrodes (106) has a peak-to-peak voltage of 750 to 100,000 Volts.

14. An apparatus according to any one of the preceding

claims, wherein the insulator has a thickness between 0.1 mm and 50 mm.

15. An apparatus according to any one of the preceding claims, wherein at least one insulator comprises a first layer and a second layer such that the first layer is closer to the conducting electrode than the second layer, and wherein the second layer has a lower surface conductivity than the first layer.

16. A method for causing an electrosensory sensation to at least one body part (120) to be stimulated, the method comprising:

- providing one or more conducting electrodes (106), each conducting electrode being provided with an insulator (108) wherein, when the at least one body part (120) to be stimulated is proximate to the conducting electrode, the insulator prevents flow of direct current from the conducting electrode to the body part to be stimulated and a capacitive coupling over the insulator (108) is formed between the conducting electrode (106) and the body part (120) to be stimulated;
- providing a high-voltage source (100, 102, 104) for applying an electrical input (OUT) to the one or more conducting electrodes, wherein the electrical input has at least a portion of its energy content in a frequency range between 10 Hz and 1000 Hz;
- wherein the capacitive coupling and electrical input are dimensioned to produce an electrosensory sensation; and
- whereby the electrosensory sensation is produced independently of any mechanical vibration of the one or more conducting electrodes (106) or insulators (108);

characterized by providing a grounding connection (210) between:

- a reference voltage (REF) of the high-voltage source (100, 102, 104) other than the electrical input (OUT) to the one or more conducting electrodes; and
- at least one grounding electrode (212) separate from the one or more conducting electrodes (106), wherein the grounding electrode (212) is positioned so as to be touched by a second body part (222) distinct from each of the at least one body part to be stimulated (120; 220A, 220B, 220C).

Patentansprüche

1. Vorrichtung zur Erzeugung einer elektrosensori-

schen Empfindung in wenigstens einem zu stimulierenden Körperteil (120), wobei die Vorrichtung Folgendes umfasst:

- eine oder mehrere leitende Elektroden (106), wobei jede leitende Elektrode mit einem Isolator (108) bereitgestellt wird, wobei - wenn sich der wenigstens eine zu stimulierende Körperteil (120) benachbart zur leitenden Elektrode befindet - der Isolator das Fließen von Gleichstrom von der leitenden Elektrode zu dem zu stimulierenden Körperteil verhindert und eine kapazitive Kopplung zwischen der leitenden Elektrode (106) und dem wenigstens einen zu stimulierenden Körperteil (120) über den Isolator (108) gebildet wird;
- eine Hochspannungsquelle (100, 102, 104) zum Einspeisen einer elektrischen Eingabe (OUT) in die eine oder die mehreren leitenden Elektroden, wobei die elektrische Eingabe wenigstens einen Teil ihrer Energie in einem Frequenzbereich zwischen 10 Hz und 1000 Hz aufweist;
- wobei die kapazitive Kopplung und die elektrische Eingabe zum Erzeugen einer elektrosensorischen Empfindung ausgelegt sind; und
- wobei die elektrosensorische Empfindung unabhängig von irgendeiner mechanischen Vibration der einen oder der mehreren leitenden Elektroden (106) oder Isolatoren (108) erzeugt wird;

gekennzeichnet durch eine Masseverbindung (210) zwischen:

- einer Referenzspannung (REF) der Hochspannungsquelle (100, 102, 104), die sich von der elektrischen Eingabe (OUT) in die eine oder die mehreren leitenden Elektroden unterscheidet; und
- wenigstens einer Masseelektrode (212), die von der einen oder den mehreren leitenden Elektroden (106) getrennt ist, wobei die Masseelektrode (212) so positioniert ist, dass sie von einem zweiten Körperteil (222) berührt wird, der von jedem des wenigstens einen zu stimulierenden Körperteils (120; 220A, 220B, 220C) verschieden ist.

2. Vorrichtung nach Anspruch 1, wobei:

- die kapazitive Kopplung und die elektrische Eingabe so ausgelegt sind, dass sie eine elektrosensorische Empfindung in dem wenigstens einen Körperteil produzieren, wenn sich der wenigstens eine Körperteil benachbart zu der einen oder zu den mehreren leitenden Elektroden befindet;
- wobei die elektrosensorische Empfindung un-

abhängig von irgendeiner Berührung oder mechanischen Bewegung zwischen dem wenigstens einen Körperteil und der einen oder den mehreren leitenden Elektroden erzeugt wird.

3. Vorrichtung nach einem der vorhergehenden Ansprüche, wobei die Vorrichtung eine leitende Elektrode für jeden räumlich gesonderten, zu stimulierenden Körperteil (120; 220A, 220B, 220C) umfasst.
4. Vorrichtung nach einem der vorhergehenden Ansprüche, wobei die Vorrichtung eine leitende Elektrode (206A, 206B, 206C) für jeden von mehreren räumlich gesonderten, zu stimulierenden Körperteilen (220A, 220B, 220C) umfasst.
5. Vorrichtung nach einem der vorhergehenden Ansprüche, wobei die Vorrichtung Mittel (116, 216) zur Vermittlung von Informationen über die elektrosensorische Empfindung durch Modulation der elektrischen Eingabe gemäß den Informationen umfasst.
6. Vorrichtung nach einem der vorhergehenden Ansprüche, die weiterhin eine Verkleidung (200) umfasst, die die Hochspannungsquelle (100, 102, 104) enthält, welche allen von den mehreren leitenden Elektroden (206A, 206B, 206C) gemeinsam ist, und wobei die Verkleidung (200) ebenfalls Mittel (217) zur gleichzeitigen Vermittlung der elektrischen Eingabe (OUT) in null oder mehr der mehreren leitenden Elektroden unter Steuerung durch einen gemeinsamen Regler (216) umfasst.
7. Vorrichtung nach Anspruch 6, wobei die Vorrichtung Bestandteil eines Eingabe-/Ausgabe-Peripheriegeräts ist, das mit einer Datenverarbeitungseinrichtung verbunden werden kann.
8. Vorrichtung nach einem der vorhergehenden Ansprüche, die weiterhin Folgendes umfasst:
 - eine Oberfläche (1400), die so angeordnet ist, dass der zu stimulierende Körperteil (120) sie berührt oder sich ihr annähert, wobei die Oberfläche wenigstens eine berührungsempfindliche Fläche (A1, A2, A3) aufweist, wobei jede berührungsempfindliche Fläche eine vorbestimmte Position (x1-x2; x3-x4; x5-x7) aufweist;
 - wobei die Vorrichtung Mittel zum Zuordnen wenigstens einer Funktion zu der wenigstens einen berührungsempfindlichen Fläche umfasst oder betriebsfähig mit diesen verbunden werden kann; und
 - wobei die Vorrichtung weiterhin Mittel (1406, 1506) zum räumlichen und/oder zeitlichen Variieren der Intensität des elektrosensorischen Stimulus auf Basis einer detektierten Berührung oder Annäherung an die wenigstens eine berüh-

rungsempfindliche Fläche (A1, A2, A3) durch den zu stimulierenden Körperteil (120) umfasst; - wobei die Schnittstelleneinrichtung in der Lage ist, eine Rückmeldung an einen Nutzer über den zu stimulierenden Körperteil zu erzeugen.

9. Vorrichtung nach Anspruch 8, wobei die Mittel (1406, 1506) zum räumlichen und/oder zeitlichen Variieren der Intensität des elektrosensorischen Stimulus Mittel (1406, 1506) zum zeitlichen Variieren der Intensität des elektrosensorischen Stimulus umfasst.
10. Vorrichtung nach Anspruch 9, wobei:
 - die Mittel zum Zuordnen wenigstens einer Funktion dazu betrieben werden können, die wenigstens eine Funktion, die der wenigstens einen berührungsempfindlichen Fläche zugeordnet ist, dynamisch zu ändern; und
 - die Vorrichtung dazu betrieben werden kann, die Rückmeldung auf Basis der Funktion, die der wenigstens einen berührungsempfindlichen Fläche zugeordnet ist, zu variieren.
11. Vorrichtung nach einem der vorhergehenden Ansprüche, wobei die elektrische Eingabe eine niederfrequente Komponente (114) in einem Frequenzbereich zwischen 10 Hz und 1000 Hz und eine hochfrequente Komponente (112), die eine Frequenz aufweist, die höher als die Frequenz der niederfrequenten Komponente (114) und niedriger als 500 kHz ist, umfasst.
12. Vorrichtung nach Anspruch 11, die Mittel (110) zur Modulation der hochfrequenten Komponente (112) durch die niederfrequente Komponente (114) umfasst.
13. Vorrichtung nach einem der vorhergehenden Ansprüche, wobei die elektrische Eingabe in die eine oder die mehreren leitenden Elektroden (106) eine Spitze-Spitze-Spannung von 750 bis 100.000 Volt aufweist.
14. Vorrichtung nach einem der vorhergehenden Ansprüche, wobei der Isolator eine Stärke zwischen 0,1 mm und 50 mm aufweist.
15. Vorrichtung nach einem der vorhergehenden Ansprüche, wobei wenigstens ein Isolator eine erste Schicht und eine zweite Schicht umfasst, so dass sich die erste Schicht näher an der leitenden Elektrode als die zweite Schicht befindet, und wobei die zweite Schicht eine geringere Oberflächenleitfähigkeit als die erste Schicht aufweist.
16. Verfahren zum Verursachen einer elektrosensorischen Empfindung in wenigstens einem zu stimulie-

renden Körperteil (120), wobei das Verfahren Folgendes beinhaltet:

- das Bereitstellen einer oder mehrerer leitender Elektroden (106), wobei jede leitende Elektrode mit einem Isolator (108) bereitgestellt wird, wobei - wenn sich der wenigstens eine zu stimulierende Körperteil (120) benachbart zu der leitenden Elektrode befindet - der Isolator das Fließen von Gleichstrom von der leitenden Elektrode zu dem zu stimulierenden Körperteil verhindert und eine kapazitive Kopplung zwischen der leitenden Elektrode (106) und dem zu stimulierenden Körperteil (120) über den Isolator (108) gebildet wird;
- das Bereitstellen einer Hochspannungsquelle (100, 102, 104) zum Einspeisen einer elektrischen Eingabe (OUT) in die eine oder die mehreren leitenden Elektroden, wobei die elektrische Eingabe wenigstens einen Teil ihrer Energie in einem Frequenzbereich zwischen 10 Hz und 1000 Hz aufweist;
- wobei die kapazitive Kopplung und die elektrische Eingabe zum Erzeugen einer elektrosensorischen Empfindung ausgelegt sind; und
- wobei die elektrosensorische Empfindung unabhängig von irgendeiner mechanischen Vibration der einen oder der mehreren leitenden Elektroden (106) oder Isolatoren (108) erzeugt wird;

gekennzeichnet durch das Bereitstellen einer Masseverbindung (210) zwischen:

- einer Referenzspannung (REF) der Hochspannungsquelle (100, 102, 104), die sich von der elektrischen Eingabe (OUT) in die eine oder die mehreren leitenden Elektroden unterscheidet; und
- wenigstens einer Masseelektrode (212), die von der einen oder den mehreren leitenden Elektroden (106) getrennt ist, wobei die Masseelektrode (212) so positioniert ist, dass sie von einem zweiten Körperteil (222) berührt wird, der von jedem des wenigstens einen zu stimulierenden Körperteils (120; 220A, 220B, 220C) verschieden ist.

Revendications

1. Appareil pour produire une sensation électrosensorielle dans au moins une partie du corps (120) devant être stimulée, l'appareil comprenant :

- une ou plusieurs électrodes conductrices (106), chaque électrode conductrice étant dotée d'un isolateur (108) dans lequel, lorsque la ou au moins une partie du corps (120) devant être sti-

mulée est à proximité de l'électrode conductrice, l'isolateur empêche la circulation de courant continu de l'électrode conductrice à la partie du corps devant être stimulée et un couplage capacitif sur l'isolateur (108) est formé entre l'électrode conductrice (106) et l'au moins une partie du corps (120) devant être stimulée ;

- une source haute tension (100, 102, 104) pour appliquer une entrée électrique (OUT) à la ou aux électrodes conductrices, dans lequel l'entrée électrique a au moins une partie de sa teneur en énergie dans une plage de fréquences entre 10 Hz et 1 000 Hz ;

- dans lequel le couplage capacitif et l'entrée électrique sont dimensionnés pour produire une sensation électrosensorielle ; et

- moyennant quoi la sensation électrosensorielle est produite indépendamment de toute vibration mécanique de la ou des électrodes conductrices (106) ou du ou des isolateurs (108) ;

caractérisé par une connexion de mise à la terre (210) entre :

- une tension de référence (REF) de la source haute tension (100, 102, 104) autre que l'entrée électrique (OUT) vers la ou les électrodes conductrices ; et

- au moins une électrode de mise à la terre (212) séparée de la ou des électrodes conductrices (106), dans lequel l'électrode de mise à la terre (212) est positionnée de façon à être touchée par une seconde partie du corps (222) distincte de chacune de la ou des parties du corps devant être stimulées (120 ; 220A, 220B, 220C).

2. Appareil selon la revendication 1, dans lequel :

- le couplage capacitif et l'entrée électrique sont dimensionnés pour produire une sensation électrosensorielle dans l'au moins une partie du corps lorsque l'au moins une partie du corps est à proximité de la ou des électrodes conductrices ;

- moyennant quoi la sensation électrosensorielle est produite indépendamment de tout mouvement tactile ou mécanique entre l'au moins une partie du corps et la ou les électrodes conductrices.

3. Appareil selon l'une quelconque des revendications précédentes, dans lequel l'appareil comprend une électrode conductrice pour chaque partie du corps distincte dans l'espace devant être stimulée (120 ; 220A, 220B, 220C).

4. Appareil selon l'une quelconque des revendications précédentes, dans lequel l'appareil comprend une électrode conductrice (206A, 206B, 206C) pour chacune des plusieurs parties du corps distinctes dans

l'espace devant être stimulée (220A, 220B, 220C).

5. Appareil selon l'une quelconque des revendications précédentes, dans lequel l'appareil comprend un moyen (116, 216) pour acheminer des informations via la sensation électrosensorielle en modulant l'entrée électrique selon lesdites informations. 5
6. Appareil selon l'une quelconque des revendications précédentes, comprenant en outre une enceinte (200) qui contient la source haute tension (100, 102, 104) qui est commune à toutes les plusieurs électrodes conductrices (206A, 206B, 206C) et dans lequel l'enceinte (200) contient également un moyen (217) pour acheminer simultanément l'entrée électrique (OUT) vers zéro des plusieurs électrodes conductrices ou plus, sous la commande d'une unité de commande commune (216). 10 15
7. Appareil selon la revendication 6, dans lequel l'appareil fait partie d'un dispositif périphérique d'entrée/de sortie pouvant être connecté à un équipement de traitement de données. 20
8. Appareil selon l'une quelconque des revendications précédentes, comprenant en outre : 25
 - une surface (1400) agencée de façon à être touchée ou approchée par la partie du corps devant être stimulée (120), dans lequel la surface a au moins une aire tactile (A1, A2, A3), chaque aire tactile ayant une position prédéterminée (x1-x2 ; x3-x4 ; x5-x7) ;
 - dans lequel l'appareil comprend un moyen d'attribution d'au moins une fonction à l'au moins une aire tactile ou peut être opérationnellement connecté à celui-ci ; et
 - dans lequel l'appareil comprend en outre un moyen (1406, 1506) pour varier l'intensité du stimulus électrosensoriel spatialement et/ou temporellement en se basant sur la détection d'un toucher ou d'une approche de l'au moins une aire tactile (A1, A2, A3) par la partie du corps devant être stimulée (120) ;
 - moyennant quoi le dispositif d'interface peut produire un retour vers un utilisateur via la partie du corps devant être stimulée. 30 35 40 45
9. Appareil selon la revendication 8, dans lequel ledit moyen (1046, 1506) pour varier l'intensité du stimulus électrosensoriel spatialement et/ou temporellement comprend un moyen (1406, 1506) pour varier l'intensité du stimulus électrosensoriel temporellement. 50 55
10. Appareil selon la revendication 9, dans lequel :
 - ledit moyen d'attribution d'au moins une fonc-

tion est opérationnel pour changer dynamiquement l'au moins une fonction attribuée à l'au moins une aire tactile ; et

- l'appareil est opérationnel pour varier le retour en se basant sur la fonction attribuée à l'au moins une aire tactile.

11. Appareil selon l'une quelconque des revendications précédentes, dans lequel l'entrée électrique comprend une composante basse fréquence (114) dans une plage de fréquences entre 10 Hz et 1 000 Hz et une composante haute fréquence (112) ayant une fréquence qui est supérieure à la fréquence de la composante basse fréquence (114) et inférieure à 500 kHz. 5
12. Appareil selon la revendication 11, comprenant un moyen (110) permettant de moduler la composante haute fréquence (112) par la composante basse fréquence (114) ; 10
13. Appareil selon l'une quelconque des revendications précédentes, dans lequel l'entrée électrique vers la ou les électrodes conductrices (106) a une tension de crête à crête de 750 à 100 000 volts. 15
14. Appareil selon l'une quelconque des revendications précédentes, dans lequel l'isolateur a une épaisseur entre 0,1 mm et 50 mm. 20
15. Appareil selon l'une quelconque des revendications précédentes, dans lequel au moins un isolateur comprend une première couche et une seconde couche de sorte que la première couche soit plus proche de l'électrode conductrice que la seconde couche, et dans lequel la seconde couche a une conductivité de surface inférieure à celle de la première couche. 25
16. Procédé permettant de provoquer une sensation électrosensorielle dans au moins une partie du corps (120) devant être stimulée, le procédé comprenant :
 - la fourniture d'une ou plusieurs électrodes conductrices (106), chaque électrode conductrice étant dotée d'un isolateur (108) dans lequel, lorsque l'au moins une partie du corps (120) devant être stimulée est à proximité de l'électrode conductrice, l'isolateur empêche la circulation de courant continu de l'électrode conductrice à la partie du corps devant être stimulée et un couplage capacitif sur l'isolateur (108) est formé entre l'électrode conductrice (106) et la partie du corps (120) devant être stimulée ;
 - la fourniture d'une source haute tension (100, 102, 104) pour appliquer une entrée électrique (OUT) à la ou aux électrodes conductrices, dans lequel l'entrée électrique a au moins une partie de sa teneur en énergie dans une plage de fré-

quences entre 10 Hz et 1 000 Hz ;
- dans lequel le couplage capacitif et l'entrée électrique sont dimensionnés pour produire une sensation électrosensorielle ; et
- moyennant quoi la sensation électrosensorielle est produite indépendamment de toute vibration mécanique de la ou des électrodes conductrices (106) ou du ou des isolateurs (108) ;
caractérisé par la fourniture d'une connexion de mise à la terre (210) entre :
- une tension de référence (REF) de la source haute tension (100, 102, 104) autre que l'entrée électrique (OUT) vers la ou les électrodes conductrices ; et
- au moins une électrode de mise à la terre (212) séparée des une ou plusieurs électrodes conductrices (106), dans lequel l'électrode de mise à la terre (212) est positionnée de façon à être touchée par une seconde partie du corps (222) distincte de chacune de la ou des parties du corps devant être stimulées (120 ; 220A, 220B, 220C).

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Fig. 1

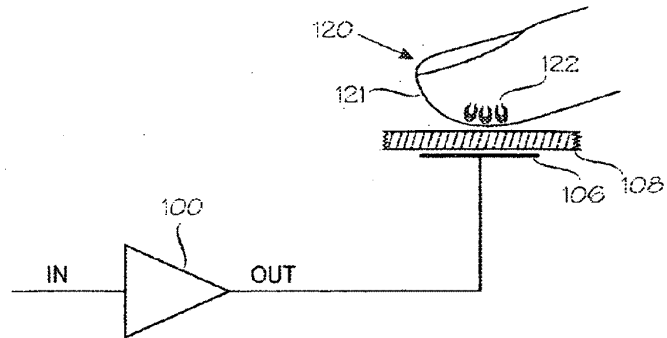


Fig. 2

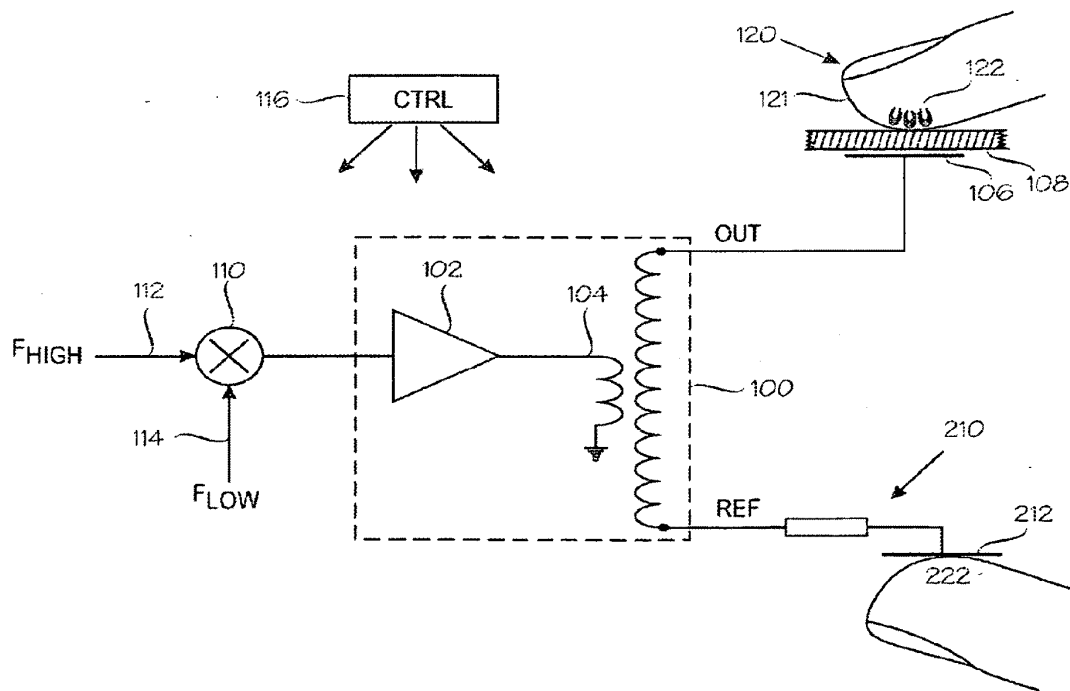


Fig. 3

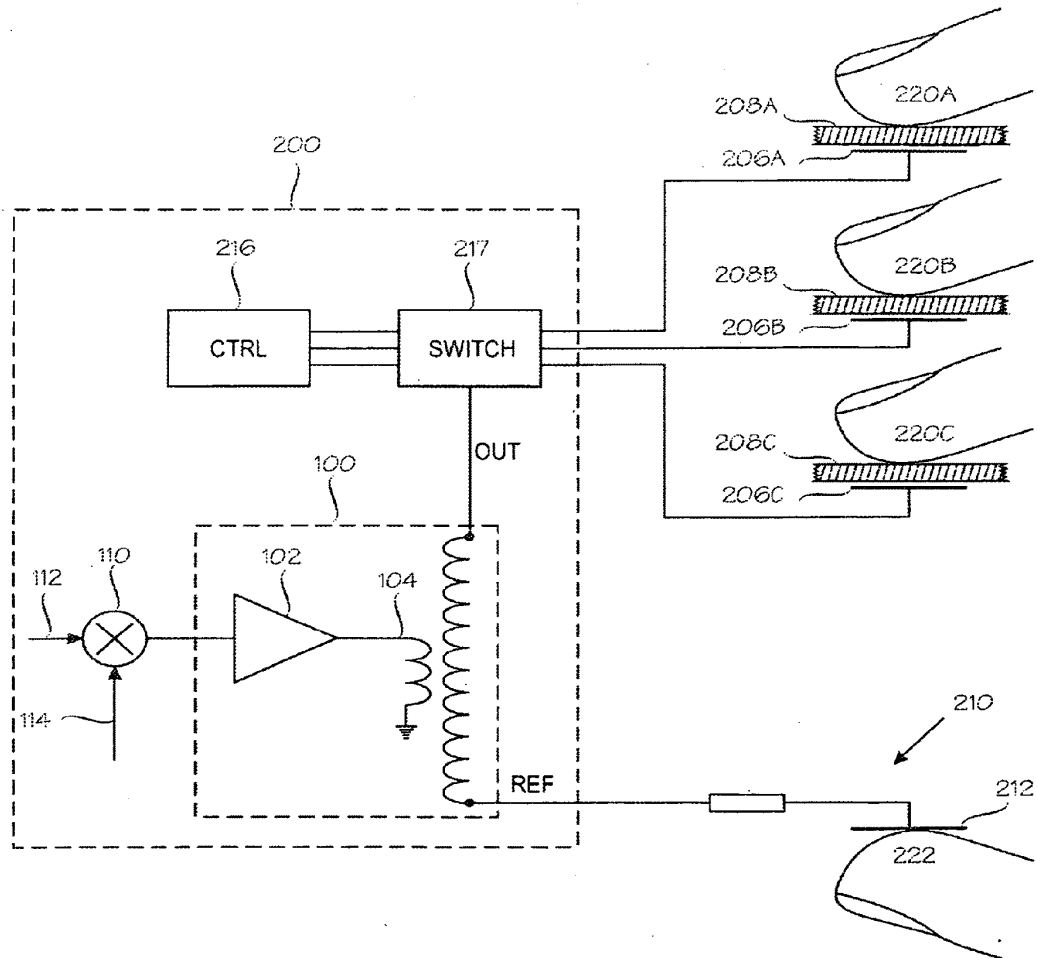


Fig. 4

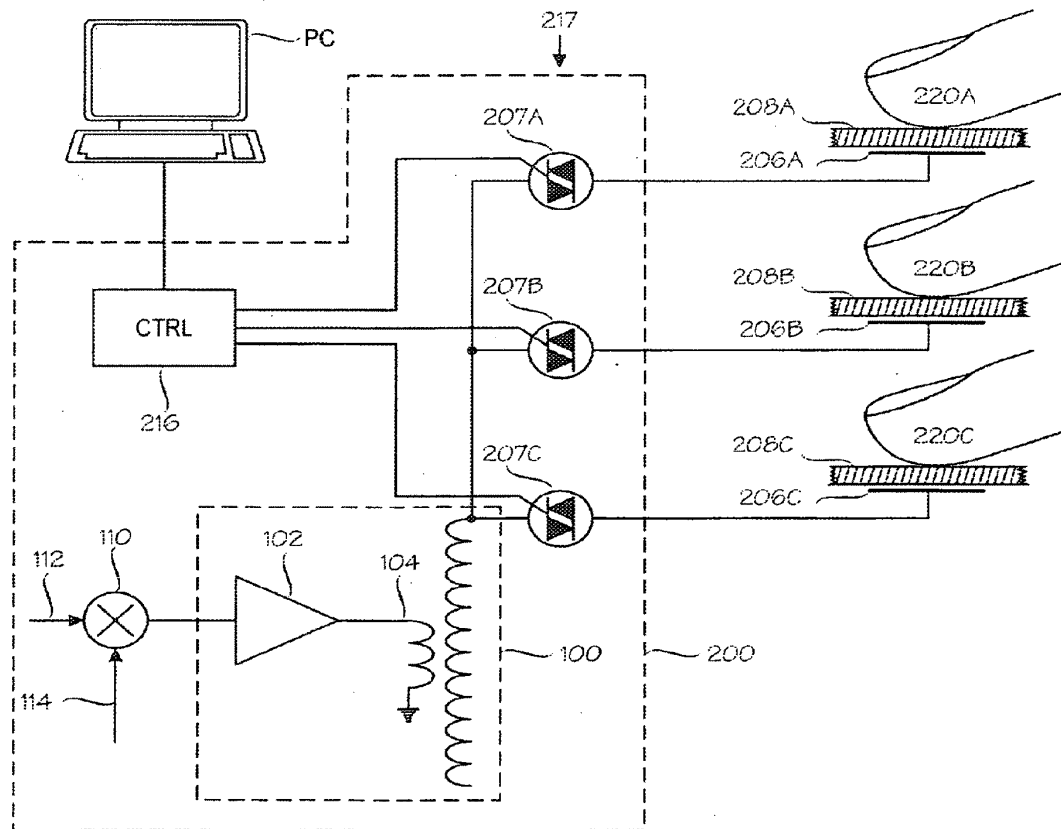


Fig. 5

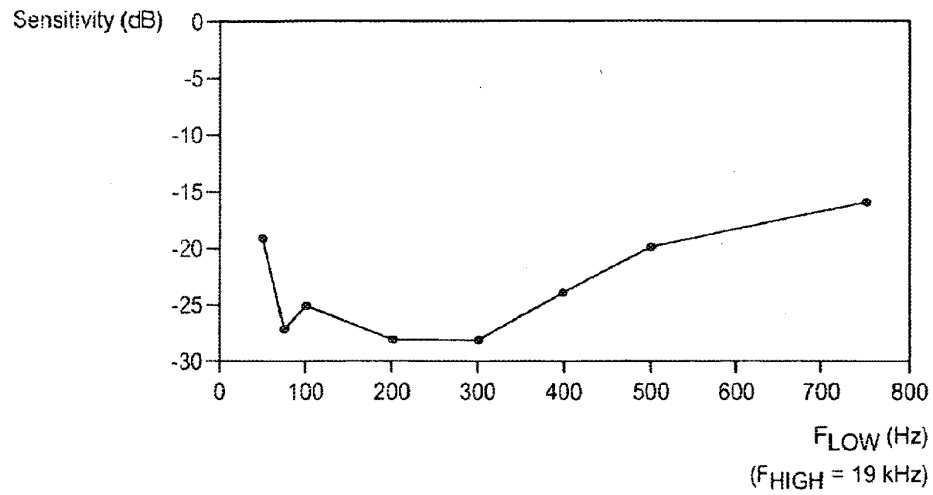


Fig. 6

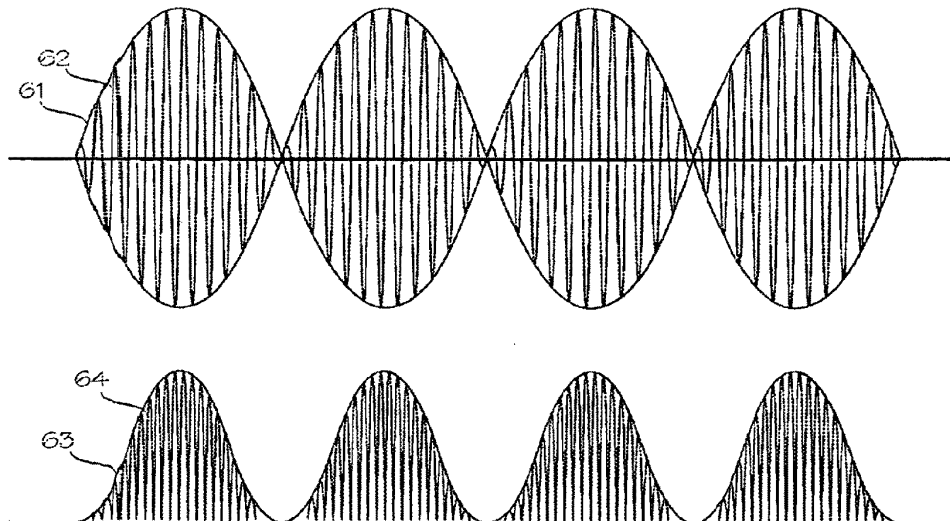


Fig. 7A

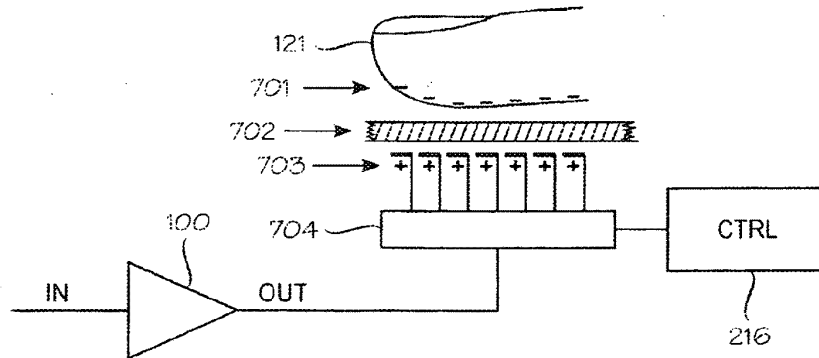


Fig. 7B

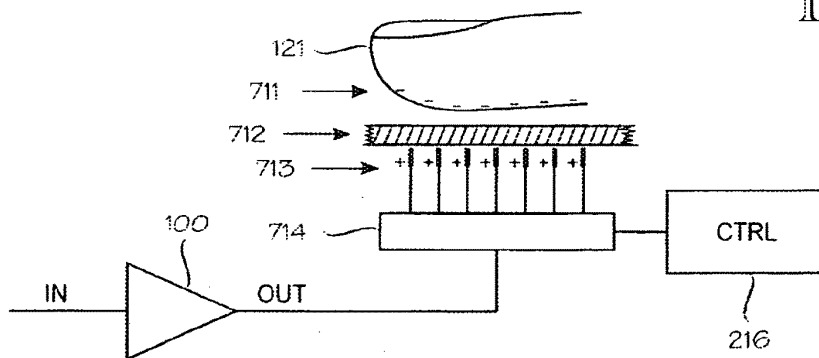


Fig. 8

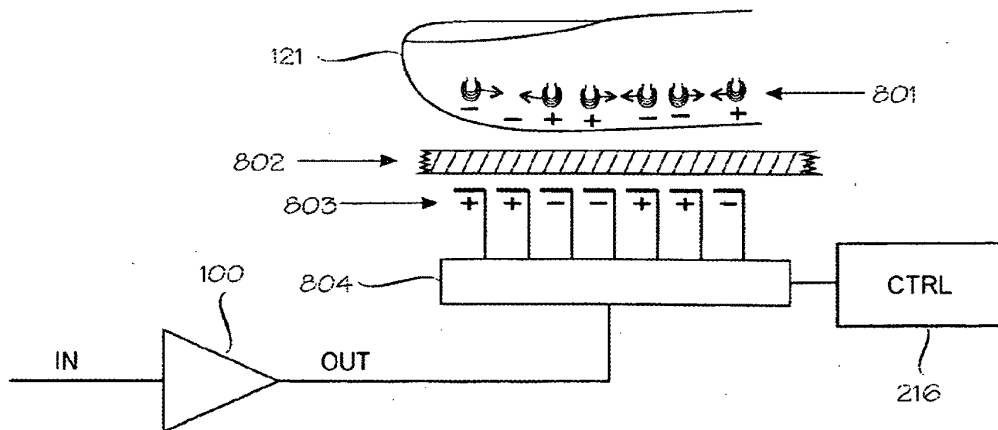


Fig. 9

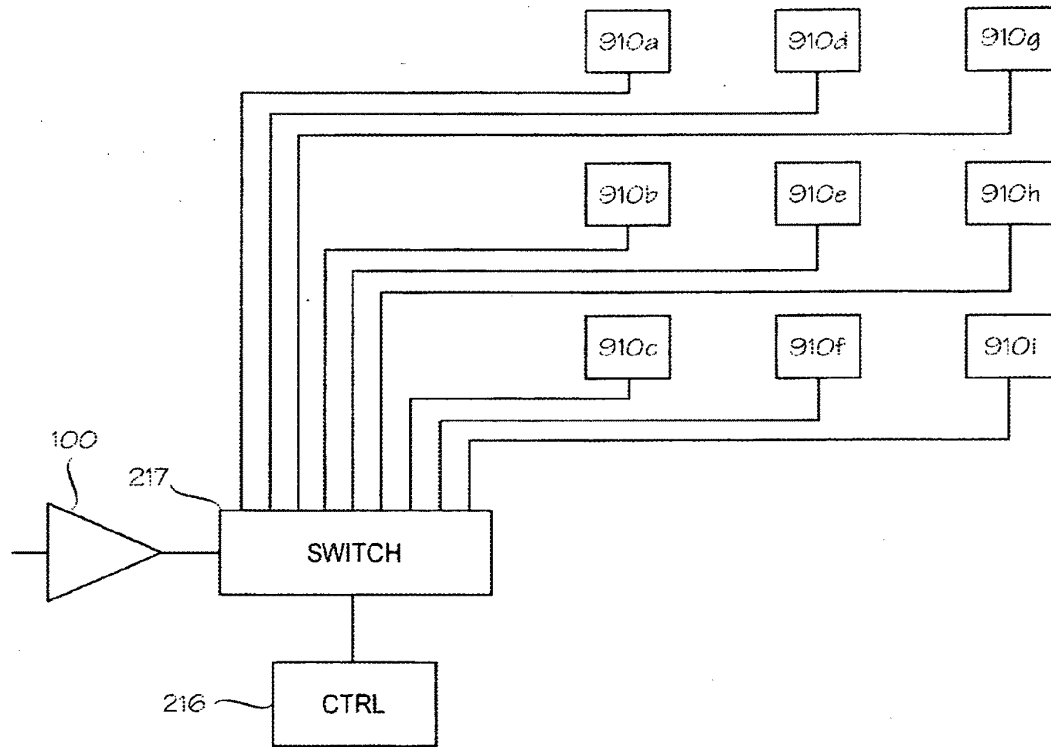


Fig. 10

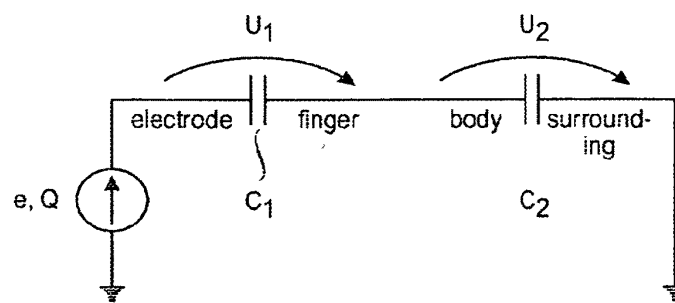


Fig. 11

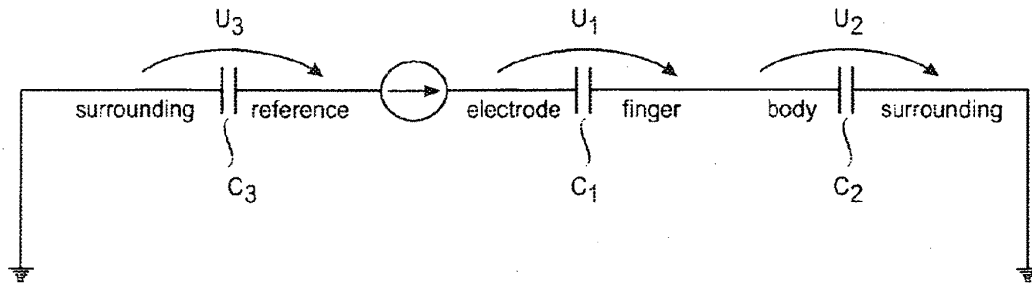


Fig. 12

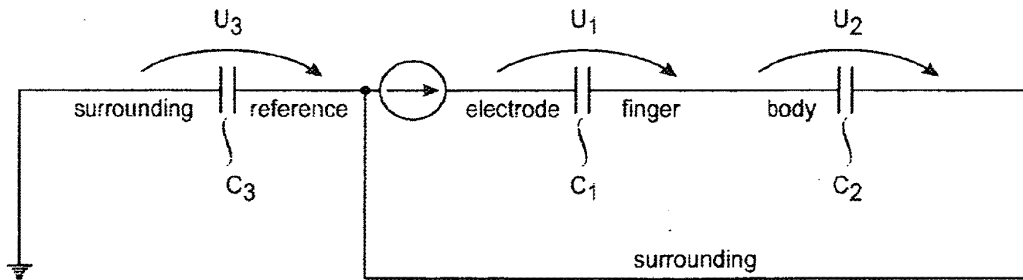


Fig. 13

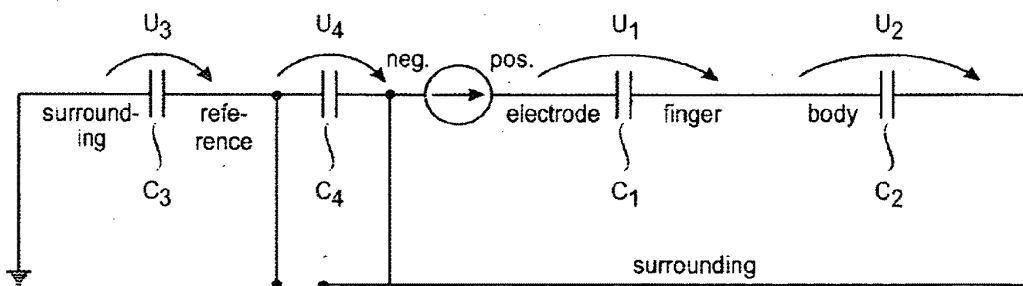


Fig. 14

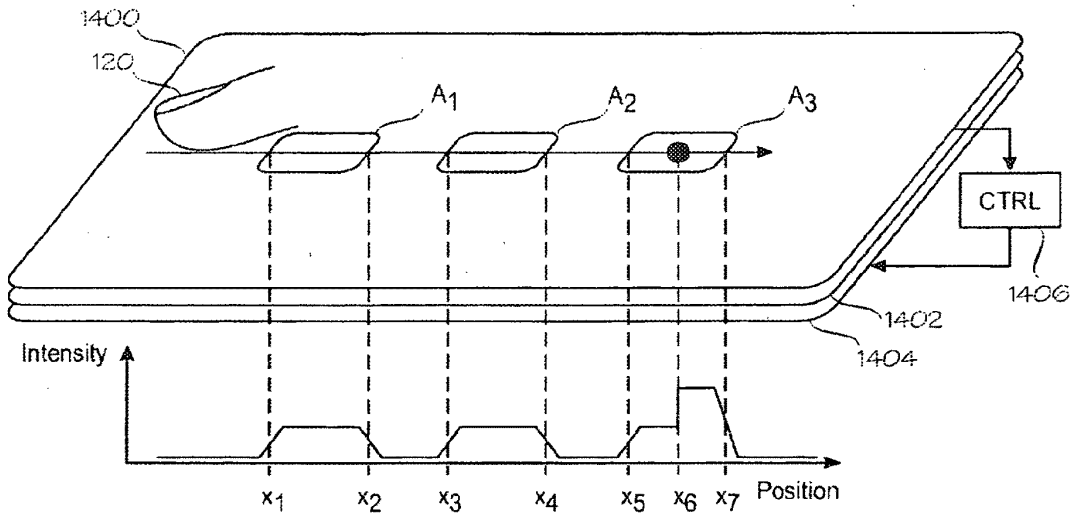
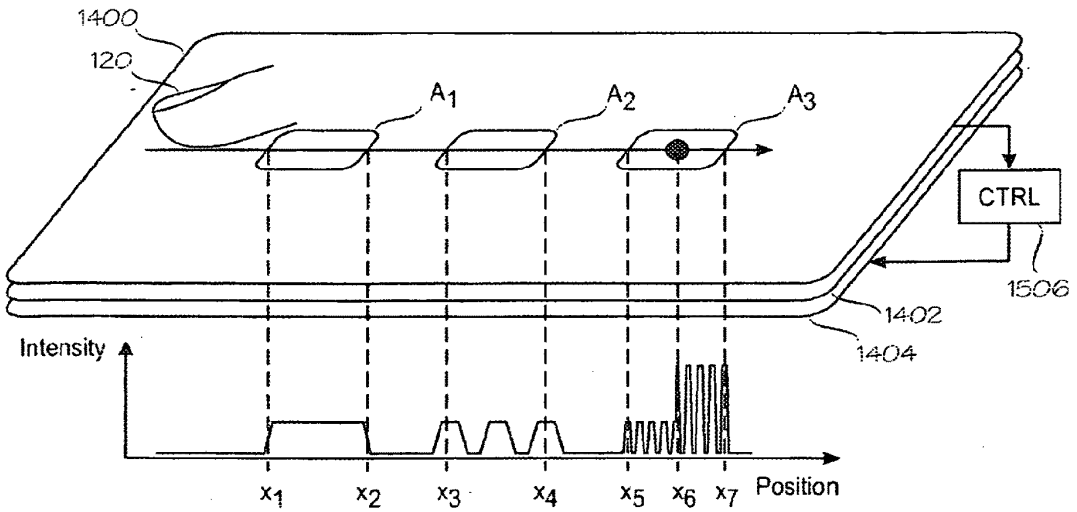


Fig. 15



REFERENCES CITED IN THE DESCRIPTION

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(71) Applicants: UNIVERSITY OF PITTSBURGH-OF THE COMMONWEALTH SYSTEM OF HIGHER EDUCATION [US/US]; 1st Floor Gardner Steel Conference Center, 130 Thackeray Avenue, Pittsburgh, Pennsylvania 15260 (US). UPMC [US/US]; 600 Grant Street, Pittsburgh, PA 15219 (US).

(72) Inventors: SIEGLE, Greg J.; 2523 Elkridge Drive, Wexford, Pennsylvania 15090 (US). RABIN, David Mayer Lowell; 1506 Beechwood Blvd, Pittsburgh, Pennsylvania 15217 (US).

(74) Agents: AGARWAL, Brij K. et al; Eckert Seamans Cherin & Mellott, LLC, 600 Grant Street, 44th Floor, Pittsburgh, Pennsylvania 15219 (US).

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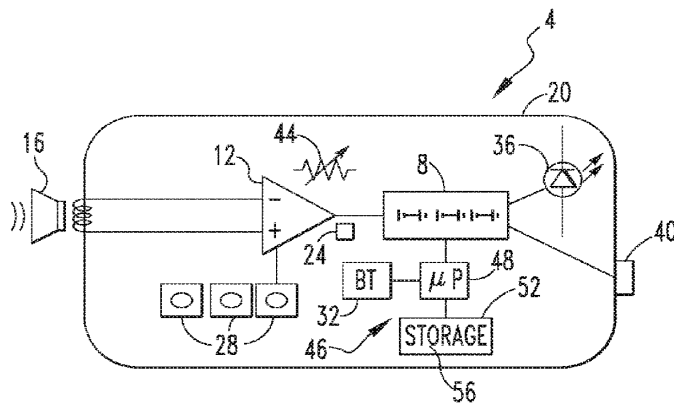


FIG. 1

(57) Abstract: A peripheral device for regulating neural correlates of arousal and emotion regulation to be worn or held against the body is disclosed. The device can be triggered by either physiological signs or manual intervention and produces cutaneous signals such as vibration or electricity using novel combinations of physiologically reactive frequencies without effort on the part of the user. One embodiment includes combining sensors that measure changes in physiological signals of stress such as speech rate and pitch, galvanic skin response, or heart rate variability, and, using a machine learning algorithm on personalized data, can determine whether these changes are likely to benefit from regulation. If they are outside an idiosyncratic predetermined range, the device produces stimulation and the person will feel regulated if they are touching / wearing the device, or can choose to use the device if it is not currently being touched or worn.

REGULATORY DEVICE AND ASSOCIATED METHOD

CROSS-REFERENCE TO RELATED APPLICATION

This application claims priority under 35 U.S.C. § 119(e) from U.S. provisional patent application serial no. 62/316,695, entitled "Emotion Prosthetics" and filed on April 1, 2016, the contents of which are incorporated herein by reference.

GOVERNMENT CONTRACT

This invention was made with government support under grant #s MH082998 and MH096334 awarded by the National Institute of Health and under grant # IIP-1449702 awarded by the National Science Foundation. The government has certain rights in the invention.

BACKGROUND OF THE INVENTION

1. Field of the invention

This application generally relates to devices that can be held against the body or attached to something connected to the body to promote change in at least one of emotional state, arousal state, and cognition.

2. Background of the invention

Stress is a specific global impairing problem with no globally effective solution. Approximately a third of the US population describes having more stress than they would like to without effective coping strategies. Chronic unmanaged stress results in time missed from work and impaired productivity, and can lead to debilitating mental and physical illnesses from depression and anxiety to heart disease and dementia. Interventions for stress primarily consist of psychological therapies/techniques and drug/prophylactic therapies. Psychological techniques (e.g., as taught in psychotherapy or meditation) depend on the user attending to their mental events and emotions, and applying learned techniques in the moment. Literature suggests such interventions do not work for many people. For example, individuals who tend to ruminate do most poorly in even the best psychological therapies. Drug/prophylactic therapies depend on an agent taken at one time point to have effects much later when they are needed. These treatments have many side effects and are often addictive. A common observation is that most psychiatric medications, in tolerable doses, are not strong enough to prevent or even improve in-the-moment reactivity to stressors. What is needed is an intervention that becomes effective at times of stress, intervenes without requiring strong presence of

mind on the part of the user, and then stops being active when the stress dissipates. It would be desirable to provide a technology that is applicable to solving problems throughout multiple fields and markets broadly spanning from the medical field (e.g., psychiatry, psychology), to enterprise applications (e.g., HR and training), military applications, consumer models (e.g., stress management), and the entertainment business (e.g., emotionally augmented adaptive virtual reality).

SUMMARY OF THE INVENTION

The invention regards regulation of physiological states using cutaneous transducers (vibration or electricity) at times of stress or deviation from a target emotion state (e.g., "calm"). Thus, included in the invention are 1) regulatory devices that provide specific types of physiologically reactive stimulation useful for regulating arousal and stress, 2) invocation via manual switching or sensors and algorithms to determine its need, and 3) individualized calibrations and learning algorithms to determine optimal parameters for sensing and regulating a given person's arousal, stress, or distance from a target physiological state such as calm. A more general utility of the same technologies regards techniques that associate physiological reactivity profiles with stored idiosyncratic emotion states (e.g., "calm"), yield dynamic quantification of distance from these target states, and provide physiological stimulation that returns users to these target emotion states via closed loop stimulation.

According to an aspect of the present intervention, a regulatory device touching the skin of a user, or something that is touching the skin or body of the user, provides stimulation at frequencies demonstrated in the published literature to change sympathetic and parasympathetic tone. The device can be worn, e.g., on a wrist, the neck, or the sternum, all of which have been demonstrated to yield increases in vagal / parasympathetic tone or sympathetic tone with certain frequencies of cutaneous oscillation. The transducer for cutaneous oscillation is strong enough to produce non-ignorable signals. Electricity and vibration can both serve that function. The invention thus includes software for generating an acoustic signal with specific oscillatory characteristics, a transceiver (e.g., Bluetooth receiver) for acoustic signals generated, by the device wirelessly, an amplifier, and any tactile transducer capable of feeding the amplified acoustic signal to the body in a way that is not ignorable.

The mechanisms by which vibration and electrical stimulation can induce changes in stress and parasympathetic tone are well described in the literature. The skin has other receptors that process touch (mechanoreceptors), pain (nociceptors), pleasure (c-tactile fibers) and temperature (thermoreceptors). Information gathered by skin

receptors travels to the brain's somatosensory cortex and in parallel, to areas of the brain involved in cognitive processes, motor processes, social processes, and networks more involved in emotional functions, including recognizing and generating emotion (the amygdala, insula, and striatum, for example), and regulating emotion (the prefrontal cortex, for instance). (Davidson, 2000, *American Psychologist*, 55(1) 196-1214). Emotions can be generated not just from present inputs but from our interpretation of bodily cues (Damasio, 1999, xii, 386 p.) based on previous experiences as well. There are numerous other pathways by which tactile stimulation could affect brain function. For example, deep tactile stimuli can affect specific nerves directly yielding predictable neural effects.

5 Slow moving touch around the carotid sinus (e.g., via "carotid massage") can potentiate vagus nerve function (Ha, et al., 2015, *Am J Emerg Med*, 33(7), 963-5, McDonald, et al., 2014, *J Am Geriatr Soc*, 62(10), 1988-9, Laine Green and Weaver, 2014, *J Clin Neurosci*, 21(1), 179-80, Cronin and Blake, 2011, *J Cardiovasc Electrophysiol*, 22(5), 600) possibly via direct nerve stimulation or other routes such as stimulation of

10 underlying muscles (Scali, et al., 2013, *Spine J*, 13(5), 558-63). Manual therapies like massage have implicated varying mechanisms such as release of endocannabinoids (Lindgren, et al., 2015, *BMC Res Notes*, 8(504). Different styles of massage to the same area have been found to activate different brain networks (Sliz, et al., 2012, *Brain Imaging Behav*, 6(1), 77-87) suggesting a more complex picture of the touch-brain

15 relationship. Deep chest pressure (e.g., as used in "hug machines") directly appears to affect baroreceptors (Edelson, et al., 1999, *Am J Occup Ther*, 53(2), 145-52) yielding decreased blood pressure and feelings of calm. Accupressure, which involves deep touch has been conceptualized from a variety of perspectives and also appears to affect peripheral physiology such as heart rate variability (McFadden, et al., 2012, *Complement*

20 *Ther Med*, 20(4), 175-82, Huang, et al., 2005, *Am J Chin Med*, 33(1), 157-64) suggesting potential vagus nerve involvement. Electrical stimulation, in particular, activates lamina 1 fibers (McMahon and Wall, 1984, *Pain*, 19(3), 235-47) which convey pain, itch, sensual touch, and temperature through the spinal cord to the primitive brain areas like the amygdala, yielding emotional reactions and, through the thalamus, to the insula to yield

25 awareness of our body's reactions (Craig, 2002, *Nat Rev Neurosci*, 3(8), 655-66). The insula passes this info on to cortical regions that govern our attention and emotion regulation such as the orbitofrontal cortex (Cavada, et al., 2000, *Cereb Cortex*, 10(3), 220-42). Electricity likely produces opioids (Chen, et al., 1996, *J Pharmacol Exp Ther*, 277(2), 654-60) along with beta endorphins (Bossut, et al., 1986, *Am J Vet Res*, 47(3), 669-76), which affect emotion and pain thresholds (Lundeberg, et al., 1989, *Am J Chin Med*, 17(3-4), 99-110). Electrical stimulation also activates the locus coeruleus (Snow, et

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al., 1999, Arch Ital Biol, 137(1), 1-28) which is responsible for norepinephrine production which could moderate stress responses.

In particular, this invention relies on beat frequencies in the 0.01-20 Hz range which are well-documented to be psychophysiologically reactive. Slow whole-body vibration, in the 0.01 to 0.3 Hz range, is associated with increased ratings of pleasantness and increased parasympathetic tone at lower frequencies with increasing predominance of sympathetic tone approaching 0.6 Hz (Uchikune, 2004, Journal of Low Frequency Noise Vibration and Active Control, 23(2), 133-138, Uchikune, 2002, Journal of Low Frequency Noise Vibration and Active Control, 21(1), 29-36). That said, whole-body stimulation at 1 Hz has been observed to produce increased parasympathetic tone (Takahashi, et al., 2011, J Hum Ergol (Tokyo), 40(1-2), 119-28), with the specific observation of being able to produce vibration-synchronized heart beats. The 0.1 Hz frequency may be particularly useful stimulate at to promote parasympathetic tone, based on biofeedback literature. The highest amplitude of RSA is achieved at 0.1 Hz (6 breaths/minute), because this is the optimal respiratory rate for oxygenation and removal of CO₂ from the body. As such, 0.1 Hz is known as the frequency of cardiac resonance (high-amplitude synchronous oscillations at a single frequency). This cardiac resonance is achieved with generally lower frequency stimulation in tall people/men and generally higher frequency stimulation in smaller people/women (Vaschillo, et al., 2006, Appl Psychophysiol Biofeedback, 31(2), 129-42). Thus, it has been suggested that "any source of rhythmic stimulation that affects the cardiovascular system should produce the same effect (achieving cardiac resonance of 0.1 Hz)." (Lehrer and Gevirtz, 2014, Front Psychol, 5(756). Thus, stimulation via rhythmic muscle tension at 0.1 Hz has been found to increase high frequency heart rate variability (Lehrer, et al., 2009, Biol Psychol, 81(1), 24-30, Vaschillo, et al., 2011, Psychophysiology, 48(7), 927-36) as has rhythmic visual stimulation at 0.1 Hz (Vaschillo, et al., 2008, Psychophysiology, 45(5), 847-58). Wrist-worn vibratory cues in this range have been shown to affect hemodynamics following stressful tasks (Nogawa, et al., 2007, Conf Proc IEEE Eng Med Biol Soc, 2007(5323-5). Increased heart rates have been found for whole-body vibration at lower frequencies (3-6 Hz) (Maikala, et al., 2006, Int Arch Occup Environ Health, 79(2), 103-114) though individual differences in cardiac effects at these frequencies have been observed (Ullsperger and Seidel, 1980, Eur J Appl Physiol Occup Physiol, 43(3), 183-92). Vibration in the 6-10 Hz range appears to decrease parasympathetic tone, as measured by high frequency heart rate variability (Jiao, et al., 2004, Int Arch Occup Environ Health, 77(3), 205-12, Bjor, et al., 2007, Int Arch Occup Environ Health, 81(2), 193-9) and is specifically associated in increased low-to-high frequency heart rate variability ratios,

potentially suggestive of increased sympathetic tone (Watanabe and Ujike, 2012, Health, 4(11), 1029-1035). Increasingly peripheral stimulation at 10hz is being used to modulate activity in the vagus nerve, which governs heart-rate variability, and thus parasympathetic tone (Ma, et al., 2016, J Neurol Sci, 369(27-35, Bauer, et al., 2016, Brain Stimul, 9(3), 356-63, Jiang, et al., 2016, Neurochem Int, 97(73-82, He, et al., 2016, Cardiovasc Ther, 34(3), 167-71).

This invention also relies on base frequencies in the 20-300 Hz range which are also well-documented to be physiologically reactive. A large literature devoted to whole-body vibration has primarily examined the 20-36 Hz range, which is generally associated with increased heart rates (e.g., Gojanovic, et al., 2014, Physiol Res, 63(6), 779-92, Cochrane, et al., 2008, Arch Phys Med Rehabil, 89(5), 815-21). 25Hz whole-body vibration is associated with decreased heart rate and baroreceptor activity consistent with parasympathetic response, particularly in obese people (Dipla, et al., 2016, Exp Physiol, 101(6), 717-30), though another study found no change in HRV for 20-36Hz following exercise (Cheng, et al., 2010, J Sports Med Phys Fitness, 50(4), 407-15). That said, electrical stimulation in the 10 Hz range has been found to produce increased HF HRV (Stein, et al., 2011, Auton Neurosci, 165(2), 205-8). Typical personal massage devices operate at about 100 Hz (Prause, et al., 2012, Sexual and Relationship Therapy, 27(1), pp), with the goal of producing subjective and muscle relaxation. Stimulation at this frequency activates the posterior insula (Coghill, et al., 1994, J Neurosci, 14(7), 4095-108) which is associated with increased attention to interoception, as promoted in many meditative traditions. Vibrator massage is associated with both increased heart rate but also increased theta and alpha EEG associated with relaxation (Diego, et al., 2004, Int J Neurosci, 114(1), 31-44). Electroacupuncture produces the sensation of rapid vibration; stimulation at 100 Hz is associated with increased subsequent high frequency heart rate variability (Hideaki, et al., 2015, Acupunct Med, 33(6), 451-6) though TENS unit stimulation at 100 Hz has been observed to produce decreased high frequency heart rate variability (Stein, et al., 2011, Auton Neurosci, 165(2), 205-8). Facial vibration at 89 Hz has specifically been associated with increased parasympathetic tone (Hiraba, et al., 2014, Biomed Res Int, 2014(910812).

According to another aspect of the present intervention, the regulatory device combines low and high frequencies described as physiologically reactive in the literature to yield unique superadditive sensations. For example, complex musical and complex vibroacoustic stimuli have been shown to modulate a variety of neural responses associated with vagal tone (Bergstrom-Isacsson, et al., 2014, Res Dev Disabil, 35(6),

1281-91). Vibroacoustic stimulation has been shown to affect electroencephalographic recordings as well as positive mood (Sandler, et al., 2016, Brain Topogr, 29(4), 524-38).

According to another aspect of the present intervention, use of intervention is invoked by detecting a predetermined condition, such as a manual switching on the regulatory device or the detection by the regulatory device of a predetermined condition in the form of physiological changes associated with an increase or decrease in arousal or stress. Manual switching is done by invoking software, e.g., on a smartphone, or via a switch on the device. Many physiological parameters can be used to detect emotion and arousal states such as stress or fatigue, including but not limited to changes in vocal tone, galvanic skin response, and heart rate variability, pupil dilation, and gamma band EEG. These parameters are interpretable in the presence of a baseline measurement, e.g., of stressed, relaxed, and fatigued states to which similarities on assessed parameters can be inferred. The invention thus includes software for establishing an individual's resting, stressed, fatigued, or user-defined target profiles on available physiological measurements, and for comparing, in real time, measurements of derived parameters to these states, and inferring the extent to which a current state appears similar to those stored states (e.g., stress or fatigue) with respect to individually titrated parameters.

According to another aspect of the invention, individuals differ in the extent to which different frequencies affect physiological reactions. Thus the invention includes calibration procedures to assess subjective and, when possible, physiological reactivity to different combinations of frequencies to allow best-suited regulatory stimulation.

According to another aspect of the invention, an individual's physiological features associated with potentially user-defined emotion and arousal states along with stimulation parameters that optimally restore those states can be stored in a library for later recall by that or another individual. For example, if an individual is having a particularly good day, physiology associated with that state can be stored, and stimulation parameters that optimally maintain that state or move from stressed or fatigued states towards that state can be stored in the library for later recall.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG 1: Example implemented regulatory device with Vibratory Transducer.

FIG 2: Example implemented regulatory device with Electrical Transducer

FIGS 3A and 3B: Data showing average valence and arousal ratings associated with multiple types of stimulation in 38 volunteers experiencing chest and wrist

stimulation using combined oscillations, indicated as main frequency, modulating frequency.

FIG 4: Example of user interface of software for detection of physiological stress for use with any commercial hardware that records skin conductance and pulse plethysmograph, e.g., Arduino or Bitalino, the data from which can be read, e.g., as a serial stream.

FIG 5: Example of user interface of software for detection of vocal stress.

FIG 6: Data showing clear physiological changes associated with stress onset that can easily be classified by looking at slopes of change.

FIGS 7A, 7B, 7C, and 7D: Data showing individual differences in which patterns are most calming and arousing for different individuals, supporting the utility of individual customization.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the figures to be discussed, the associated boxes and arrows represent functions of the process according to the present invention, which may be implemented as electrical circuits and associated wires or via wireless protocols such as Bluetooth, which transport acoustic signals. Alternatively, one or more associated arrows may represent communication (e.g., data flow) between software routines, particularly when the present method or apparatus of the present invention is a digital process.

Regulatory device

The regulatory device 4 depicted generally in FIG 1 includes a rechargeable 6000mAh Li-Ion Battery Pack 8, 12V DC, With Charger, a DC 10-22V AC 10-16V 25W 4 Ohm Audio Speaker HIFI Digital Amplifier Board 12 w/ SD card input, a tactile transducer 16 which, for instance, is a Bass Shaker 8 Ohm which can be extended from the interior via wires from the amplifier board 12, a 3D printed casing 20 with beveled opening for wires from the transducer 16, an SD Card 24 containing pre-loaded stimulation waveforms including: 20, 33, 40, 89, 100, 200 Hz modulated by 0, 0.1, 1, and 4 Hz, Buttons 28 for manually scrolling through pre-loaded waveforms and for providing other inputs to the regulatory device 4, a Bluetooth receiver 32, an LED 36 showing whether the regulatory device 4 is in an ON state, a Switch 40 to turn the regulatory device 4 to the ON state, a Dial 44 to manually modulate waveform intensity, and a processor apparatus 46 having a processor 48 and a storage 52 having stored therein software in the form of a number of routines 56 that generate a number of oscillation signals. As employed herein, the expression "a number of" and variations thereof shall refer to any non-zero quantity, including a quantity of one. The Bluetooth receiver 32 is most

advantageous when the device that generates the oscillation signals is remote from the casing 20, such as a smart phone or other computerized device, which communicates via its own Bluetooth transmitter the oscillation signals to the Bluetooth receive 32. The routines 56 can be in the form of a non-transitory storage medium which, when executed
5 on computerized device, causes the computerized device to perform operations such as the operations noted herein.

The regulatory software routines 56 emit a combination of sine wave oscillations of different frequencies to result in a beat frequency that is output to the user. The combination of oscillations comprise a main oscillation in the range of about 20-300 Hz
10 and at least one modulation oscillation in the range of about 0.01-10 Hz yielding a beat output that provides to the user a feeling of slow waves of stimulation at a frequency determined to be arousing or calming via the calibration software. Any of multiple base waveform types described as being physiologically active in the literature (the implemented device in Fig 1 can generate as a main oscillation any of 20, 33, 40, 89,
15 100, and 200 Hz) and modulatory frequencies also referenced in the literature (the implemented device in Fig 1 can also generate modulation oscillations of 0.1, 1, and 4 Hz), any of which can be selected via the buttons 28 on the device in Fig 1 or an external software program that may be executed on, for instance, a smart phone or any other remote computerized device.

20 The Bluetooth receiver 32 pairs with whatever device generates the chosen waveforms via external software that runs on a computer or smartphone.

The battery 8 is rechargeable and is sufficient to power the amplifier 12 and transducer 16, e.g., 6000mAh Li-Ion battery pack.

The amplifier 12 boosts the oscillation signals to a level that is useable by the
25 transducer 16. For vibratory stimulation, which is applied as an output to the body of the user, the amplifier 12 converts the oscillation signals to a level that a 20W 8 ohm tactile transducer can faithfully reproduce. For electrical stimulation, which is applied as an output to the user's skin, the amplifier converts audio signals to pulse-width-modulated versions (250 ~~B~~ pulses separated by 5 ~~I~~ gaps) to prevent skin heating, using standard
30 algorithms, and amplifies them to a physiologically detectable threshold (approx. 2 mAmps) and includes optical isolation and voltage limitation for safety.

The vibratory tactile transducer 16 is designed to be used over any area of the body, which might respond to oscillations produced by the software. The tactile transducer 16 may also deliver whole-body vibrations by being attached to a chair or
35 bed. By way of description and not limitation, FIG 1 illustrates one embodiment of one vibratory transducer. The vibratory transducer 16 is to be used on the neck, sternum,

advantageous when the device that generates the oscillation signals is remote from the casing 20, such as a smart phone or other computerized device, which communicates via its own Bluetooth transmitter the oscillation signals to the Bluetooth receive 32. The routines 56 can be in the form of a non-transitory storage medium which, when executed on computerized device, causes the computerized device to perform operations such as the operations noted herein.

The regulatory software routines 56 emit a combination of sine wave oscillations of different frequencies to result in a beat frequency that is output to the user. The combination of oscillations comprise a main oscillation in the range of about 20-300 Hz and at least one modulation oscillation in the range of about 0.01-10 Hz yielding a beat output that provides to the user a feeling of slow waves of stimulation at a frequency determined to be arousing or calming via the calibration software. Any of multiple base waveform types described as being physiologically active in the literature (the implemented device in Fig 1 can generate as a main oscillation any of 20, 33, 40, 89, 100, and 200 Hz) and modulatory frequencies also referenced in the literature (the implemented device in Fig 1 can also generate modulation oscillations of 0.1, 1, and 4 Hz), any of which can be selected via the buttons 28 on the device in Fig 1 or an external software program that may be executed on, for instance, a smart phone or any other remote computerized device.

The Bluetooth receiver 32 pairs with whatever device generates the chosen waveforms via external software that runs on a computer or smartphone.

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The amplifier 12 boosts the oscillation signals to a level that is useable by the transducer 16. For vibratory stimulation, which is applied as an output to the body of the user, the amplifier 12 converts the oscillation signals to a level that a 20W 8 ohm tactile transducer can faithfully reproduce. For electrical stimulation, which is applied as an output to the user's skin, the amplifier converts audio signals to pulse-width-modulated versions (250 μ s pulses separated by 5 μ s gaps) to prevent skin heating, using standard algorithms, and amplifies them to a physiologically detectable threshold (approx. 2 mAmps) and includes optical isolation and voltage limitation for safety.

The vibratory tactile transducer 16 is designed to be used over any area of the body, which might respond to oscillations produced by the software. The tactile transducer 16 may also deliver whole-body vibrations by being attached to a chair or bed. By way of description and not limitation, FIG 1 illustrates one embodiment of one vibratory transducer. The vibratory transducer 16 is to be used on the neck, sternum,

wrist or another user-determined position and is described herein as being a device that can be used, for instance, at will by resting a body part (e.g., neck when lying down or wrist when in a chair) on the device or, for instance, by holding it against the body (e.g., sternum). The tactile transducer 16 is capable of generating low frequency oscillations
 5 (to 20 Hz) with sufficient displacement to be not-easily-ignored, and is covered by a sleeve that can be removed and cleaned easily and which provides insulation from the bare metal of the transducer (e.g., fleece).

Another regulatory device 104 depicted generally in FIG 2 is similar to the regulatory device 4, except that the regulatory device 104 includes an electrical
 10 transducer. The regulatory device 104 includes a 9V alkaline battery 108, amplifier 112, and an electrical transducer 116 which, for instance, is a pair of adhesive electrodes 160 and 164 which can be extended from the interior via wires from the amplifier board 112, a 3D printed casing 120 with beveled opening for wires from the transducer 116, an SD Card 124 containing pre-loaded stimulation waveforms including: 20, 33, 40, 89, 100,
 15 200 Hz modulated by 0, 0.1, 1, and 4 Hz, Buttons 128 for manually scrolling through pre-loaded waveforms and for providing other inputs to the regulatory device 104, a Bluetooth receiver 132, an LED 136 showing whether the regulatory device 104 is in an ON state, a Switch 140 to turn the regulatory device 104 to the ON state, a Dial 144 to manually modulate waveform intensity, and a processor apparatus 146 having a
 20 processor 148 and a storage 152 having stored therein software in the form of a number of routines 156 that generate a number of oscillation signals. The electrical transducer regulatory device 104 is illustrated as being a wearable device and is to be worn on the wrist of the user. It consists of two electrodes 160 and 164 that allow the pulse-width modulated signal from the amplifier to pass from one electrode to the other in the form of
 25 a voltage between the electrodes 160 and 164 applied to the skin of the user. FIG 2 illustrates an exemplary embodiment of the electrical transducer regulatory device 104 for communications of oscillations to the skin of the user.

Initial data supports the use of a vibratory device for regulating stress and its physiological correlates. In an experiment with N=38 individuals of whom 9 were
 30 associates and 29 were community participants who were compensated for participation, vibratory stimulation at a main frequency of 100 Hz modulated by a modulation frequency of 0.1 Hz, delivered to the wrist, improved performance reliably ($p < .05$) and, to the chest, marginally ($p \leq .1$) during a stressful (paced auditory serial attention) task above and beyond a no-stimulation condition for those whose performance was at least
 35 moderate (above 1-standard deviation below the mean) during the no-stimulation condition. Vibration at this frequency also moderated changes in heart-rate variability

(which is a proxy for parasympathetic tone), with statistically significant ($p < .05$) increases in heart rate variability delivered to the wrist in the full sample and delivered to the sternum in the compensated sample ($p = .09$ in the full sample). Vibration at this frequency delivered to the sternum also decreased self-reported stress in those whose
5 stress was at least moderate (above 1 standard deviation below the mean) compared to the no stimulation condition ($p < .05$).

Physiological detection and calibration

The physiological detection suite involves using custom and commercial software and hardware to acquire physiological parameters and analyzing them in real time to
10 detect the onset of individualized signatures of stress, fatigue, or other (e.g., user specified) emotion or arousal states.

FIG 4 shows an example of implemented software for detection of physiological profiles associated with an emotion state and generation of reactive stimulation. FIG 4 depicts a user interface, illustrated based on a screen capture of the software, wherein
15 the user has selected a threshold of three, as is indicated by the "THRESHOLD" indicator, and which is reflected by the dashed line in the bar graph of FIG 4. An exemplary stress level pattern is depicted at the top of FIG 4, and the bar indicator in the bar graph demonstrates that the threshold has not been reached. It is noted that FIG 4 further depicts the user-selectable option to have either a tactile output in the form of a
20 tactile-vibration/electrical stimulation or an audible output in the form of a chime when the user is determined to be in a stressed state. In the event of such a chime or no output, a user can manually enter an input using the buttons to trigger the outputting of the therapeutic stimulation. Alternatively, the user can select "NONE", which is selected in FIG 4. The event of the detected state of the user in a being stress (or other user
25 selected emotion/arousal) condition with "Vibration" selected, will automatically result in outputting of the associated calibrated therapeutic stimulation.

In one implementation, software for detection of physiological states takes in pulse plethysmograph and galvanic skin response (GSR) inputs, sampled at 1000Hz, from existing hardware (e.g., Bitlino, Arduino) implemented as generic serial streams.
30 The pulse plethysmograph detects a heartbeat signal that is representative of the heartbeat of the user.

GSR data are preprocessed via spike removal and smoothing (4 second kernel) to yield a smooth running estimate of GSR which is associated with sympathetic nervous system reactivity and stress.

Plethysmograph data are preprocessed via spike removal and peak detection to yield heartbeats which are converted to an inter-beat interval series. The inter-beat series includes a time duration between each successive beat in the detected heartbeat signal.

5 The inter-beat interval series is subjected to calculation of heart rate (# beats per second).

 The inter-beat interval series for 30 seconds is subjected to continuous Morlet waveform transform to yield a running estimate of power in the high frequency heart rate variability (HF-HRV) band (0.18-0.4 Hz), which is associated with parasympathetic nervous system activity and emotion regulation capability, and which can be referred to as an emotional regulation parameter or value. It is noted that other spectral analysis techniques such as Fourier transformation and the like can be employed without departing from the spirit of the disclosed and claimed concept.

15 One aspect of the algorithm for detection of physiological stress includes quantifying change or slope over a period of time, i.e., 100ms to 30 seconds, in physiological parameters to detect state onset.

 The algorithm for detecting physiological stress is initially seeded for stress detection as reflecting increasing detected current physical parameters such as GSR or heart rate without a corresponding or subsequent change in HF-HRV, i.e.:

20
$$\text{estimated-stress} = \beta_0 + \beta_1 \text{AGSR}_{5 \text{ seconds}} + \beta_2 \Delta \text{Heart Rate}_{65 \text{ seconds}} - \beta_3 |\text{AHF-HRV}_{15 \text{ seconds}}|$$

 where the coefficients are initially $\beta_0=0$, $\beta_1=0.5$, $\beta_2=0.5$, $\beta_3=1$ and GSR, HR, and HF-HRV are normalized based on their mean and variability during an initial resting calibration period of 30-seconds. Other detected current physical parameters could include a number of audio parameters that are representative of vocal stress, and other such parameters.

25 Another aspect of the algorithms includes a calibration operation using software that guides the user to experience resting, stressed, fatigued or other user-specified states, and which includes brief exposure to a stress induction known to provoke increases in sympathetic tone and decreases in parasympathetic tone (e.g., paced serial attention task), to yield an individually calibrated profile for these states (e.g., "stress profile"). For instance, a number of calibration physical parameters of the user such as heart rate signal, GSR signal, and other such parameters, may be detected and stored in the storage 52. The software that performs the guiding can be executed on the regulatory device or can be deployed on a smart phone or other computerized device remote from the regulatory device.

Another aspect of the algorithms includes machine learning to derive individualized best-fit profiles for what stress-onset, fatigue onset, or other user-determined states look like for the individual. In the implemented software, as an example, a machine learning algorithm such as a three-layer pattern recognition neural network with 8 input nodes, 4 hidden nodes, and 1 output node is used to estimate how GSR, Heart Rate, HF-HRV, and estimated change in each of these in the previous 5 seconds combine to predict based on the calibration task described in the preceding paragraph. Effectively this algorithm allows a quantized (sigmoid) ridge-regression estimation of parameters for main effects of each of these parameters, and their potential

10 n-way interactions:

$$\begin{aligned} \text{estimated-stress} &= \beta_0 + \beta_1 \text{AGSR5 seconds} + \beta_2 \text{AHeart Rates seconds} + \beta_3 \text{AHF-HRV 5 seconds} + \beta_4 \text{GSR5} \\ &\text{seconds} + \beta_5 \text{sHeart Rates seconds} + \beta_6 \text{HF-HRVs seconds} + \beta_7 \Delta \text{GSR5 seconds} * \Delta \text{Heart Rate5 seconds} + \beta_8 \Delta \text{GSR5} \\ &\text{seconds} * \text{AHF-HRVs seconds} + \beta_9 \Delta \text{GSR5 seconds} * \Delta \text{Heart Rate5 seconds} * \text{AHF-HRVs seconds} + \beta_{10} \text{GSR5 seconds} * \\ &\text{Heart Rates seconds} * \text{HF-HRVs seconds} \end{aligned}$$

15 To derive beta weights for the preceding equation, stress values are set to zero during rest and one (1) during the target state, e.g., stress. Thus, "estimated-stress" represents the extent to which a current state is more like the stress vs the resting state. The same type of analysis can be performed for a fatigue or user-specified period. The various β coefficients that are derived through the use of the pattern recognition neural network form a part of the individually calibrated profile that can be used to detect the onset of a period of stress or fatigue. It is understood that additional elements can be added to the above equation in order to derive additional coefficients for use with calibration physical parameters and current physical parameters that are indicative of vocal stress in the user.

25 Another aspect of the algorithms includes real-time comparison of incoming physiological data in the form of current physical parameters of the user to the individualized best-fit profiles to determine when an individual is beginning to look stressed, fatigued, or a critical distance from a user defined state, so as to trigger the delivery of therapeutic stimulation. Stimulation is signaled whenever the stress index is outside 1.5 standard deviations from its mean, which refers to the aforementioned threshold of "3" in FIG 4. Stimulation is signaled at lower and higher stress levels if the threshold is set lower or higher, respectively, than "3".

FIG 6 shows that we can derive a classifier that detects the onset of stress during a stressful serial addition task.

35 **Vocal detection and calibration**

FIG 5 shows an example of implemented software for detection of vocal stress.

One aspect of the vocal stress detection algorithm is that speech is recorded in 5-second segments. These segments are processed to extract common vocal parameters such as speech rate, pitch, mean frequency, frequency of the first fundamental, variance of the first fundamental, etc. using publicly available code. The speech data from any 5-second segment is not saved after parameters are extracted, and thus no lasting voice recordings are made.

Another aspect is that a 4-layer pattern-network classifier was trained to recognize the emotion associated with short vocalizations (neutral, calm, happy, sad, fearful, angry, disgusted, surprised) using the "RAVDESS" speech corpus (<http://smail11laboratory.ofq/ravdess/desjCnieatures/>) preprocessed to be z-scores normalized by the mean of vocalizations and divided by the standard deviation. Outliers were Windsorized to the next good value outside the Tukey Hinges. The network had 15 inputs for vocal parameters, 2 hidden layers with 15 and 10 units respectively, and 8 outputs - one per classified emotion and was trained with a standard back-propagation algorithm. Classification was 30-80% accurate for specific valences depending on the valence.

Another aspect of the algorithm is that extracted speech parameters are normalized by subtracting the mean of a set of six five-second "neutral" calibration vocalizations and dividing by the standard deviation these vocalizations.

Another aspect of the vocal stress detection algorithm is that it begins with a calibration consisting of recording 30 seconds of silence in a specific room. The variance of incoming 5-second vocalizations are, at each iteration, compared to the variance of the "silence" recording. Audio waveforms with variability outside 2 standard deviations (SD) from the silence recording are considered to be vocalizations; otherwise they are considered silence and not categorized.

Another aspect of the vocal stress detection algorithm is that a second calibration records an individual person, who is the subject of measurement, speaking in a neutral tone for 30 seconds.

Another aspect of the algorithm is that when more than a user-selected number of the vocal parameters (the user can select from 2-8 parameters) are outside 2 SD from the mean of neutral vocalizations, and when the person is deemed, via classification based on the RAVDESS corpus classifier, to have a negative tone (fear, sadness, disgust), the software provides user-selected stimulation waveforms to the stimulation generator. This is depicted in the user interface capture from the software that is depicted in FIG 5 wherein the user has selected a threshold of four parameters, as is indicated by the "THRESHOLD" indicator, and which is reflected by the dashed line in

the bar graph of FIG 5. An exemplary vocal wave pattern is depicted at the top of FIG 5, and the bar indicator in the bar graph demonstrates that the threshold has not been reached. It is noted that FIG 5 further depicts the user-selectable option to have either a tactile output in the form of a vibration or an audible output in the form of a chime when the user is determined to be in a stressed state. In the event of such an output, a user can manually enter an input using the buttons to trigger the outputting of the therapeutic stimulation. Alternatively, the user can select "NONE", which is selected in FIG 5. In the Vibration condition, and in the event of the detected state of the user being stress or another user-specified condition, this will automatically result in the outputting of the therapeutic stimulation.

Stimulation calibration

The stimulation calibration algorithm performs a customization operation that involves presenting individuals with a plurality of customization stimulations in the form of a range of stimulation parameters and allowing them to rate the emotionality and arousal associated with these types of stimulation. In response to each customization stimulation, the user inputs to the software a number of responses using a single selection on a grid. The number of responses are representative of how the user perceived the customization stimulation on an arousal scale between very calming and very arousing, and are further representative of how the user tolerated the customization stimulation on a valence scale between very negatively and very positively. To best tune stimulation to an individuals' preferences, the software selects stimulation patterns based on these ratings. The pattern which is rated as maximally positive and maximally calming (sqrt of the squared distance on each axis from neutral) is used as the calming stimulation pattern for that individual in the event of detecting that the individual is experiencing a stress condition. The pattern which is maximally arousing, regardless of its valence, is used as the arousing stimulation pattern for that individual in the event of detecting that the individual is experiencing a fatigue condition.

FIGS 7A, 7B, 7C, AND 7D show that there are reliable overall differences in emotion and arousal as a function of oscillation patterns for the vibrating transducer and that there are individual differences in which patterns are most calming and arousing for different individuals. Each data point in such figures is representative of how the user perceived the customization stimulation on an arousal scale between very calming and very arousing, and additionally how the user tolerated the customization stimulation on a valence scale between very negatively and very positively.

State storage and use in "restoring" saved states

Physiological parameters in the form of baseline physical parameters associated with named target emotional states (e.g., "stress" or "positive affect calm") can be stored for later recall as targets (triggers stimulation that decreases distance to the state when it is determined that a number of current physical parameters are more than a predetermined distance of those of the target emotional state) or alarms (triggers stimulation that increases distance from the state when it is determined that a number of current physical parameters are within a predetermined distance of those of the target emotional state).

Another aspect of the invention includes software that allows subjective and physiologically based storage of stimulation parameters that optimally yield approach or departure from target or alarm states.

Another aspect of the present invention includes software that allows users to specify potentially new or idiosyncratic target or alarm emotion states for storage in a library which includes associated physiological profiles and stimulation parameters.

Another aspect of the present invention is that physiological profiles can be used to gauge distance from normed and idiosyncratically named categories by the cosine of current physiological parameters with those for calibrated states, e.g., yielding a "Closeness" value C for each parameter, e.g., $C_{GSR} = (GSR_{current} -$

$GSR_{session_mean}) * (GSR_{calibration_state} - GSR_{calibration_session_mean})$ and deriving the "Closeness" to a state as $B_{GSR} * C_{GSR} + B_{HRV} * C_{HRV} + B_{vocal_pitch} * C_{vocal_pitch}$ where associated B weights are derived via neural network classifiers as described herein before.

This algorithm provides distance from target states. Before calibration, *a priori* rules are used to specify output transduction to optimally restore a state via minimizing distance (e.g., Euclidean) of current data from template vectors as described herein before.

Another aspect of the present invention includes software that allows users to share emotion state names, associated physiological profiles, and stimulation parameters for approaching or avoiding them.

Possible Practical Applications

A source for generating physiologically reactive oscillation patterns (e.g., smartphone) wherein the oscillation patterns are frequencies in the range of 20-300 Hz modulated by frequencies from 0.01-10 Hz.

The source generates oscillations and transmits them via Bluetooth.

Software is used to calibrate and store what vibration patterns maximally yield specific emotional states, including those specified by a user, such as arousal, or positive-affect calm for a given individual, or that individual's state on a given day, to which they would like to return in the future.

5 This software can store what vibration patterns individuals are using and dynamically update its calibration to "learn" if users choose to use patterns not suggested by the previous calibration.

 A Bluetooth receiver for oscillation patterns generated by the source.

 A switch, software control, or physiological/vocal measurement device to
10 determine when the oscillation patterns are delivered.

 The software computes the magnitude and slope of physiological or vocal measures over a local window (0.5-30 seconds) to determine onsets of emotion state deviations from a neutral state (e.g., stress, fatigue).

 The software compares incoming physiological measurements to an individually
15 calibrated profile to determine likelihood of onset of an emotion state and the appropriate reaction.

 The software has a calibration routine that requires the individual to attain relaxed/neutral, stressed (e.g., via stressful cognitive task), or fatigued states, and record data for profile derivation.

20 The software uses machine learning algorithms (e.g., neural networks) to derive individually calibrated emotion state (e.g., stress) indices from the calibration data used as a training set.

 The software stores learned physiological patterns in a library that can be recalled in combination with associated stimulation patterns as described to allow
25 "restoration" of "saved" states.

 A battery to power the amplifier.

 An amplifier that raises the received oscillation patterns to a non-ignorable level.

 Transducers that provide one of vibratory and electrical stimulation.

 A sleeve for the vibratory transducer that can be removed and washed.

30 The sleeve may allow the device to be attached to the individual, e.g., via a band or other means for securing the device to the body part without disrupting the transducer's functionality.

 In the claims, any reference signs placed between parentheses shall not be construed as limiting the claim. The word "comprising" or "including" does not exclude
35 the presence of elements or steps other than those listed in a claim. In a device claim enumerating several means, several of these means may be embodied by one and the

same item of hardware. The word "a" or "an" preceding an element does not exclude the presence of a plurality of such elements. In any device claim enumerating several means, several of these means may be embodied by one and the same item of hardware. The mere fact that certain elements are recited in mutually different
5 dependent claims does not indicate that these elements cannot be used in combination. Although the invention has been described in detail for the purpose of illustration based on what is currently considered to be the most practical and preferred embodiments, it is to be understood that such detail is solely for that purpose and that the invention is not limited to the disclosed embodiments, but, on the contrary, is intended to cover
10 modifications and equivalent arrangements that are within the spirit and scope of the appended claims. For example, it is to be understood that the present invention contemplates that, to the extent possible, one or more features of any embodiment can be combined with one or more features of any other embodiment.

CLAIMS

What is claimed is:

1. A method of employing a regulatory device to provide stimulation therapy to a user, comprising:
 - detecting on the regulatory device a predetermined input; and
 - responsive to the predetermined input, generating with the regulatory device a therapeutic stimulation in the form of at least one of vibrational output applied to the user's body and an electrical output applied as a voltage to the user's skin, the therapeutic stimulation comprising a combination of oscillations that include at least a main oscillation at a first frequency in the range of about 20-300 Hz and a modulation oscillation at a second frequency different than the first frequency in the range of about 0.05-10 Hz that together form a beat output.
2. The method of Claim 1 wherein the therapeutic stimulation comprises an electrical output in the form of a pulse-width-modulation waveform.
3. The method of Claim 1 wherein the predetermined input is one of a manual input by the user that is received on the regulatory device and a detection of a predetermined condition of the user.
4. The method of Claim 1 wherein the predetermined input is a detection of a predetermined condition of the user, and further comprising:
 - detecting with the regulatory device a number of current physical parameters of the user; and
 - making a determination based at least in part upon the number of current physical parameters that the predetermined condition exists in the user.
5. The method of Claim 4, further comprising:
 - detecting with the regulatory device as at least a part of the number of current physical parameters a heartbeat signal that is representative of a heartbeat of the user;
 - determining a number of values of the user that are representative of at least one of sympathetic and parasympathetic nervous system activity of the user and that is based at least in part upon the heartbeat signal; and
 - determining the existence of the predetermined condition in the user based at least in part upon the number of values derived from the heartbeat signal.
6. The method of Claim 5, further comprising:

detecting with the regulatory device as at least a part of the number of current physical parameters a Galvanic Skin Response (GSR) signal that is representative of a galvanic skin response in the skin of the user; and

determining the existence of the predetermined condition in the user when a change in the GSR signal is detected in conjunction with values derived from the heartbeat signal.

7. The method of Claim 6, further comprising:

detecting with the regulatory device as at least a part of the number of current physical parameters one or more audio parameters that are representative of vocal tone in the user; and

determining the existence of the predetermined condition in the user when a change in vocal parameters is detected in conjunction with changes in the GSR signal and values derived from the heartbeat signal.

8. The method of Claim 4, further comprising:

detecting with the regulatory device as at least a part of the number of current physical parameters a vocal signal that is representative of a vocal output of the user;

determining a number of values of the user that are representative of at least one of sympathetic and parasympathetic nervous system activity of the user and that is based at least in part upon the vocal signal; and

determining the existence of the predetermined condition in the user based at least in part upon the number of values derived from the vocal signal.

9. The method of Claim 1, further comprising performing a calibration operation by:

guiding the user through a plurality of states of the user including at least two of a resting state, a stressed state, and a fatigued state;

detecting with the regulatory device a number of calibration physical parameters of the user in each state of the plurality of states; and

deriving an individually calibrated profile for the user based at least in part upon at least some of the calibration physical parameters of the number of calibration physical parameters.

10. The method of Claim 9 wherein the deriving of the individually calibrated profile comprises subjecting at least some of the calibration physical parameters to a machine learning algorithm to derive a number of coefficients that are a part of the individually calibrated profile.

11. The method of Claim 9, further comprising:

detecting with the regulatory device a number of current physical parameters of the user;

making a determination based at least in part upon the number of current physical parameters and the individually calibrated profile that a predetermined condition exists in the user; and

responsive to the determination, performing at least one of:

employing the determination as the predetermined input, and

outputting at least one of a visible indication, an audible indication, and a tactile indication that the predetermined condition exists in the user, and awaiting a manual input from the user before initiating the generating.

12. The method of Claim 9, further comprising performing the guiding of the user through the plurality of states by employing an application deployed on at least one of the regulatory device and a separate computerized device.

13. The method of Claim 1, further comprising performing a customization operation by:

outputting with the regulatory device a plurality of customization stimulations, each customization stimulation being in the form of at least one of a vibrational output applied to the user's body and an electrical output applied as a voltage to the user's skin, the customization stimulation comprising a combination of oscillations that include at least a main oscillation at a first frequency in the range of about 20-300 Hz and a modulation oscillation at a second frequency different than the first frequency in the range of about 0.01 - 10 Hz apart that together form a beat output;

for each customization stimulation of the plurality of customization stimulations, receiving from the user an input that is representative of how the user perceived the customization stimulation on an arousal scale between very calming and very arousing, and receiving from the user another input that is representative of how the user tolerated the customization stimulation on a valence scale between very negatively and very positively.

14. The method of Claim 13, further comprising:

identifying a particular customization stimulation from among the plurality of customization stimulations as having the greatest combination of being closest to very calming on the arousal scale and very positively on the valence scale; and

outputting the particular customization stimulation as the therapeutic stimulation.

15. The method of Claim 14 wherein the predetermined input is a detection of a stress condition of the user, and further comprising:

detecting with the regulatory device a number of current physical parameters of the user; and

making a determination based at least in part upon the number of current physical parameters that the stress condition exists in the user.

16. The method of Claim 13, further comprising:

identifying a specific customization stimulation from among the plurality of customization stimulations as being closest to very arousing on the arousal scale; and
outputting the specific customization stimulation as the therapeutic stimulation.

17. The method of Claim 16 wherein the predetermined input is a detection of a fatigue condition of the user, and further comprising:

detecting with the regulatory device a number of current physical parameters of the user; and

making a determination based at least in part upon the number of current physical parameters that the fatigue condition exists in the user.

18. The method of Claim 1, further comprising:

detecting with the regulatory device a number of baseline physical parameters of the user;

recording the number of baseline physical parameters as a target emotional state; and

detecting with the regulatory device a number of current physical parameters of the user;

making a determination that the number of current physical parameters exceed a predetermined distance from the target emotional state; and

employing the determination as the predetermined input.

19. The method of Claim 1, further comprising:

detecting with the regulatory device a number of baseline physical parameters of the user;

recording the number of baseline physical parameters as a target emotional state; and

detecting with the regulatory device a number of current physical parameters of the user;

making a determination that the number of current physical parameters is within a predetermined distance of the target emotional state; and

employing the determination as the predetermined input.

20. A regulatory device structured to provide stimulation therapy to a user, the regulatory device comprising a processor apparatus having a processor and a storage, the storage having stored therein one or more routines which, when executed on the processor, cause the therapeutic apparatus to perform operations comprising:

detecting on the regulatory device a predetermined input; and
responsive to the predetermined input, generating with the regulatory device a therapeutic stimulation in the form of at least one of vibrational output applied to the user's body and an electrical output applied as a voltage to the user's skin, the therapeutic stimulation comprising a combination of oscillations that include at least a main oscillation at a first frequency and a modulation oscillation at a second frequency different than the first frequency that together form a beat output.

21. A non-transitory machine readable storage medium having stored therein instructions which, when executed on a processor of a regulatory device, cause the regulatory device to perform operations comprising:

detecting on the regulatory device a predetermined input; and
responsive to the predetermined input, generating with the regulatory device a therapeutic stimulation in the form of at least one of vibrational output applied to the user's body and an electrical output applied as a voltage to the user's skin, the therapeutic stimulation comprising a combination of oscillations that include at least a main oscillation at a first frequency and a modulation oscillation at a second frequency different than the first frequency that together form a beat output.

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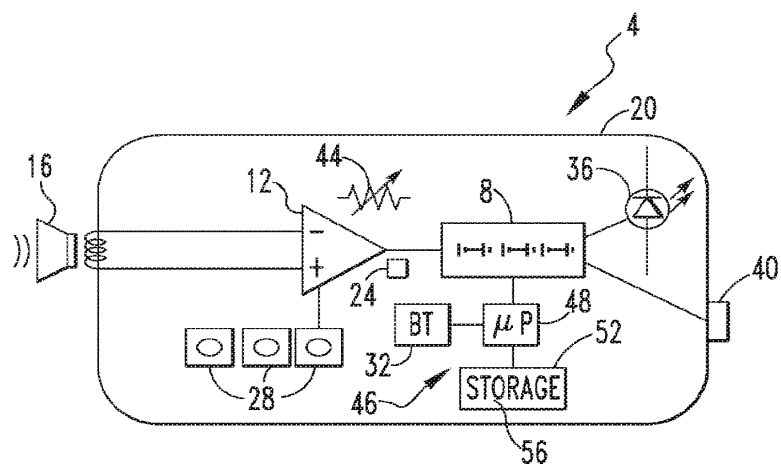


FIG. 1

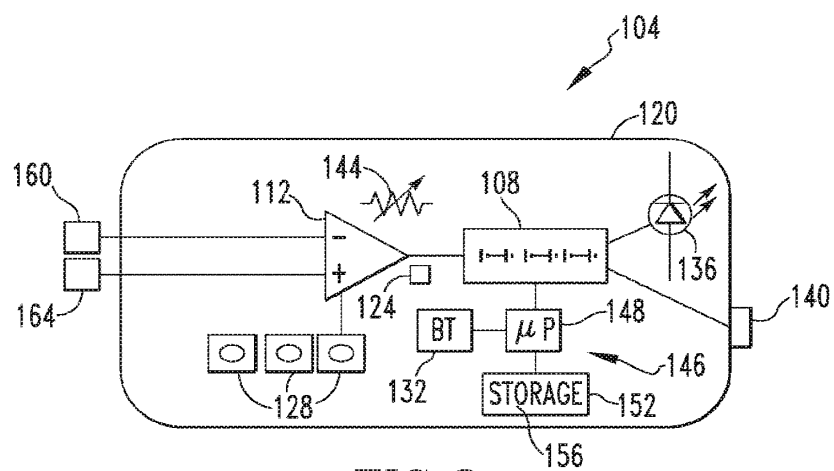


FIG. 2

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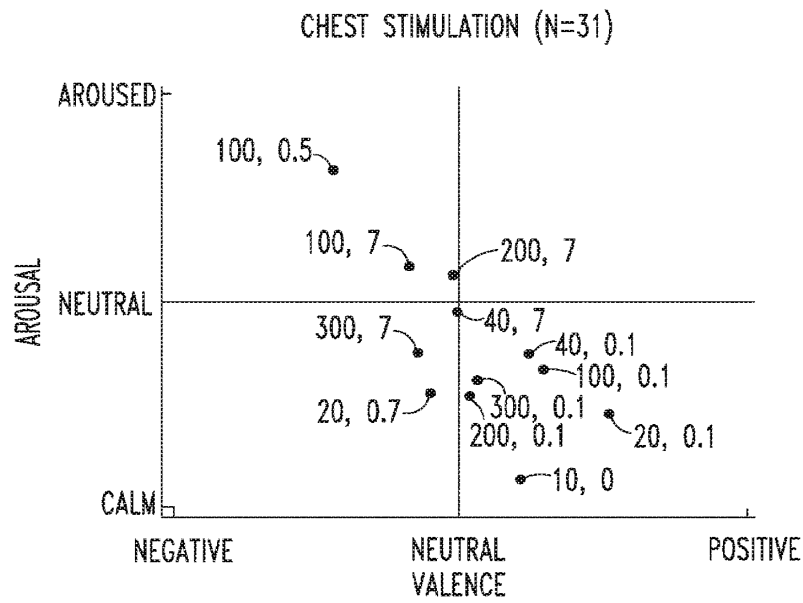


FIG. 3A

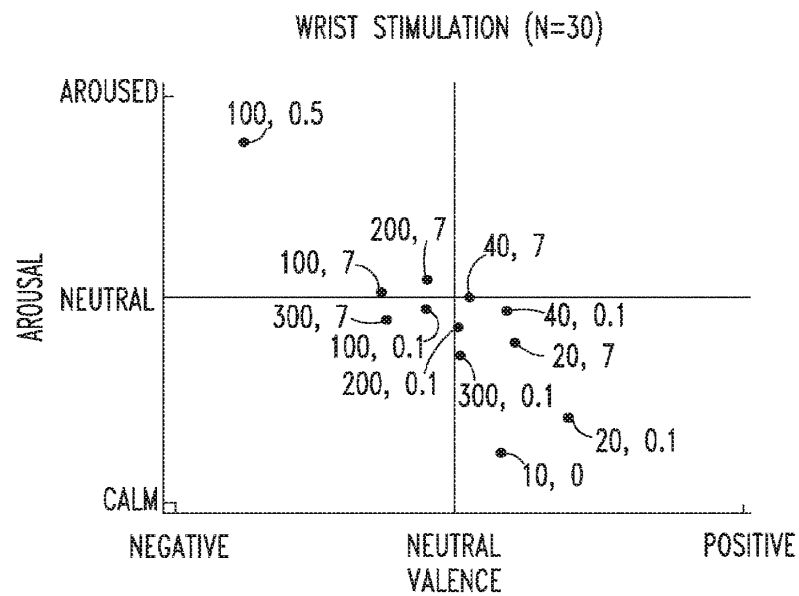


FIG. 3B

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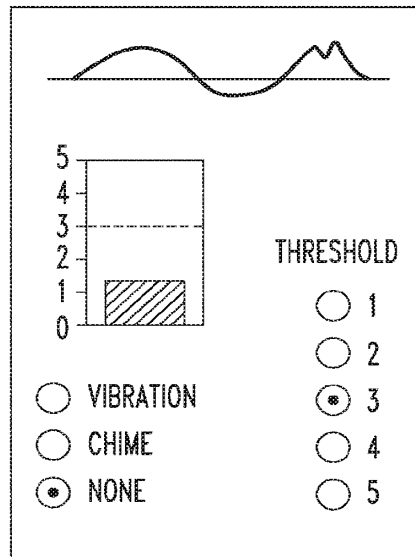


FIG. 4

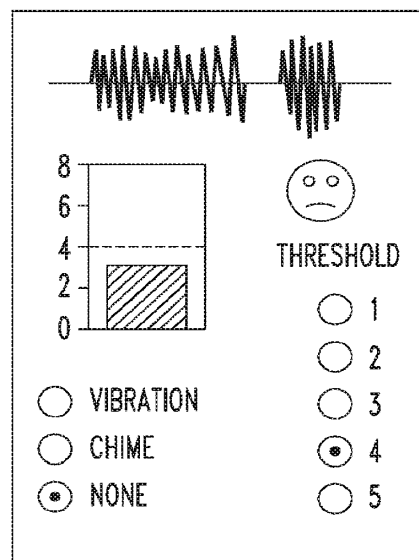
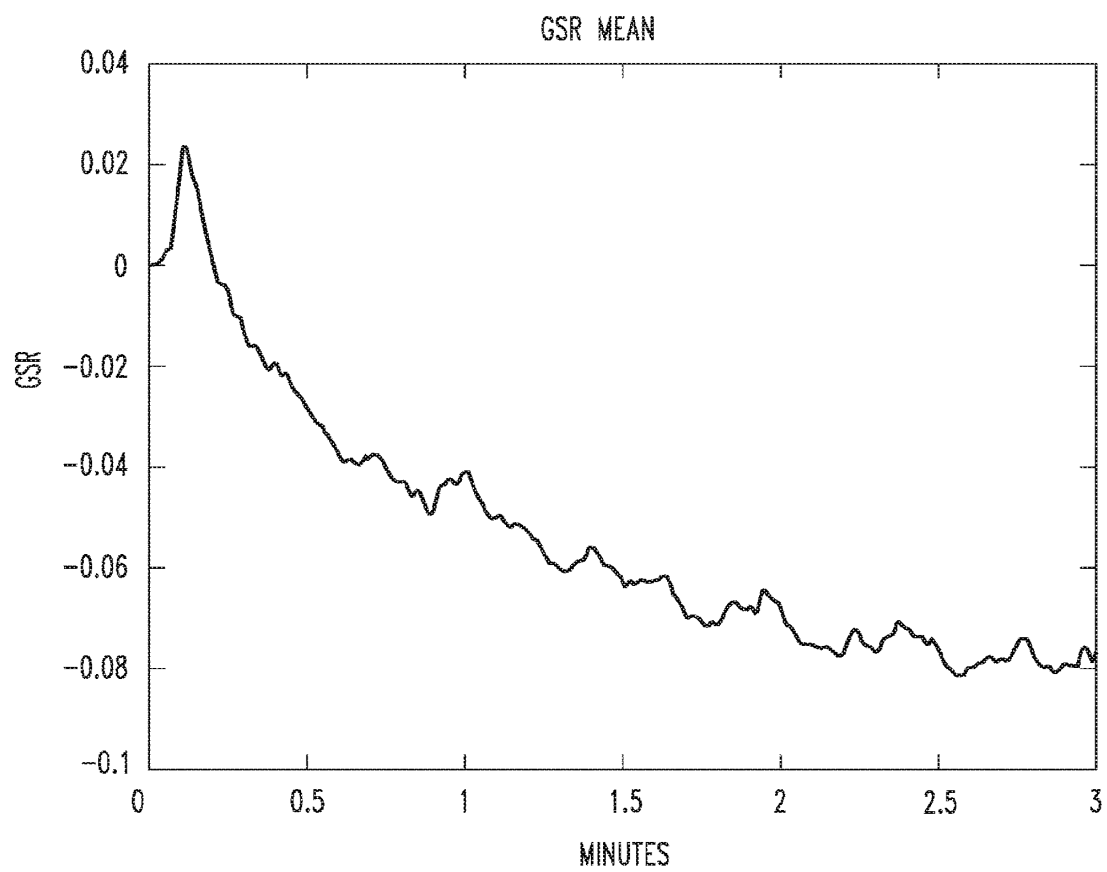


FIG. 5

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*FIG. 6*

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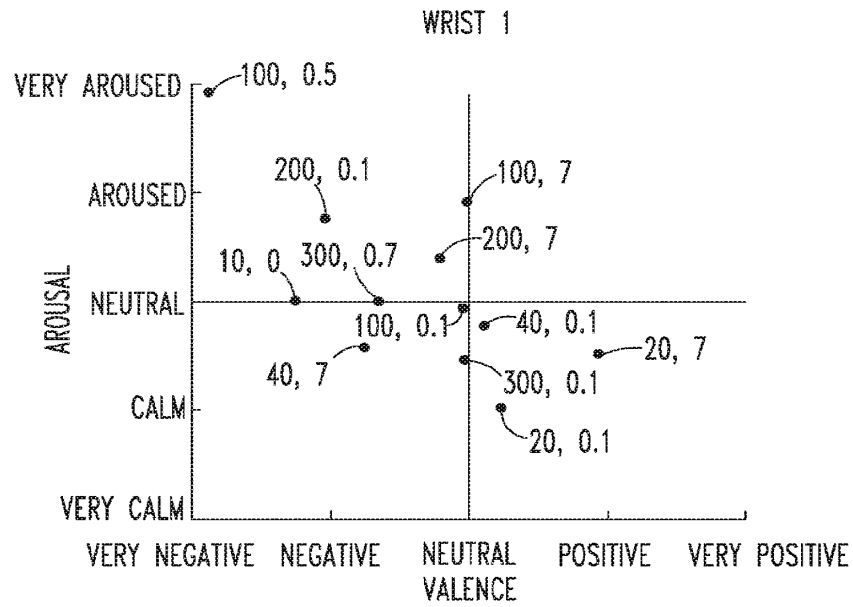


FIG. 7A

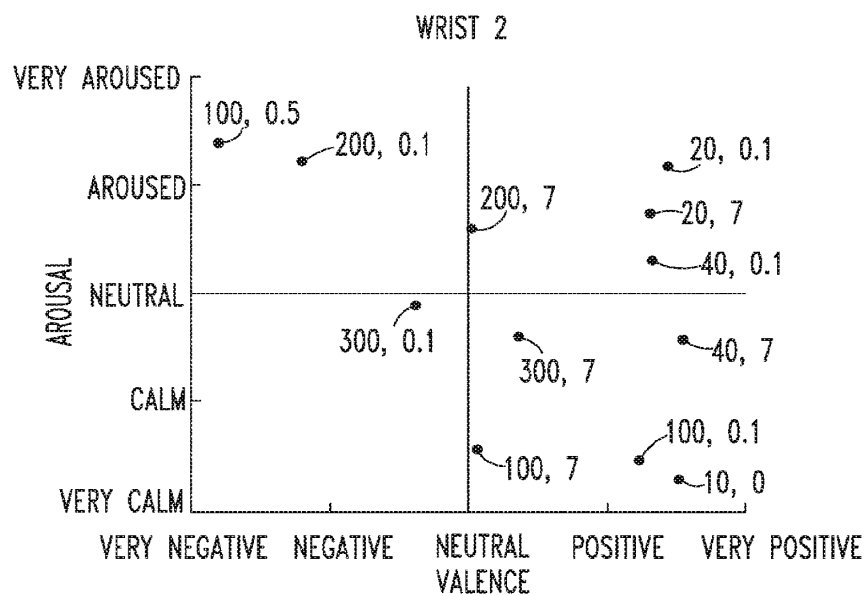


FIG. 7B

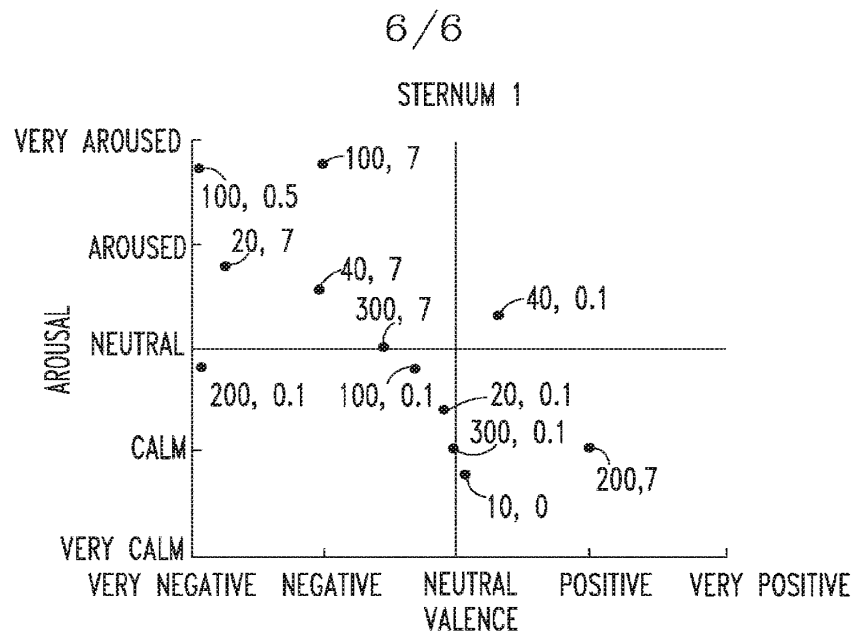


FIG. 7C

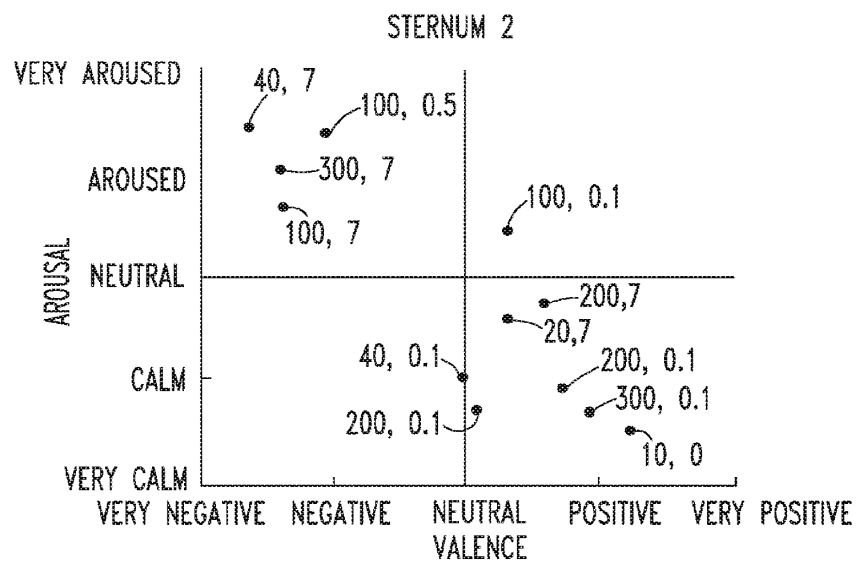


FIG. 7D

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 17/25702

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - A61 N 1/00 (201 7.01)

CPC - A61 M 21/02; A61 M 2021/0005; A61 N 1/36017; A61 N 1/00; A61N 1/36096; A61 B 5/7285

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

See Search History Document

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

See Search History Document

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

See Search History Document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y --- A	US 2007/0219470 A1 (TALISH et al.) 20 September 2007 (20.09.2007), entire document, especially; para [0004], [0032], [0034], [0038], [0040], [0041], [0049]-[0052] [0057]	1-6, 9-21 ----- 7, 8
Y --- A	US 2014/0163439 A1 (URYASH et al.) 12 June 2014 (12.06.2014), entire document, especially; para [0002], [0091], [0099], [0100].	1-6, 9-21 ----- 7, 8
Y	US 2003/0083599 A1 (KITOV) 01 May 2003 (01.05.2003), entire document, especially; para [0001], [0048]	2
Y --- A	US 2012/0149973 A1 (HOLLOWAY) 14 June 2012 (14.06.2012), entire document, especially; para [0003], [0061], [0063], [0064], [0076]-[0079]	5, 6, 18, 19 ----- 7
Y	US 2014/0148872 A1 (GOLDWASSER et al.) 29 May 2014 (29.05.2014), entire document, especially, para [0003], [0021]-[0024], [0020], [0033], [0000], [0044]	9-12, 15, 17

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

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Date of the actual completion of the international search

04 July 2017

Date of mailing of the international search report

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PTO/SB/08a (01-22)

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	Filing Date		2023-12-01
	First Named Inventor	Matthew Robert Leaper	
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	First Named Inventor	Matthew Robert Leaper		
	Art Unit			
	Examiner Name			
	Attorney Docket Number	DF-P01-US08		

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Signature	/MATTHEW R. LEAPER/	Date (YYYY-MM-DD)	2023-12-01
Name/Print	Matthew R. Leaper	Registration Number	73,966
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90 Woodridge Crescent, Apt. 218, Nepean, Ontario K2B 7T1 (CA).

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(74) Agent: **ROBIC**; 55 St-Jacques, Montréal, Québec H2Y 3X2 (CA).

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(71) Applicant (for all designated States except US): **POLY-VALOR S.E.C.** [CA/CA]; 3744, rue Jean-Brillant, Bureau 6332, Montréal, Québec H3T 1P1 (CA).

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(72) Inventors; and

(75) Inventors/Applicants (for US only): **SAWAN, Mo-hamad** [CA/CA]; 597 Bord-de-l'Eau, Laval, Québec H7X 1T9 (CA). **HARVEY, Jean-François** [CA/CA]; 19 de Vaudreuil, Blainville, Québec J7C 4A8 (CA). **ROY, Martin** [CA/CA]; 4378 Parthenais, Montréal, Québec H2H 2G5 (CA). **COULOMBE, Jonathan** [CA/CA]; 7808 Henri-Julien, Montréal, Québec H2R 2B7 (CA). **SAVARIA, Yvon** [CA/CA]; 2705 Charny, Montréal, Québec H3M 1J6 (CA). **DONFACK, Colince** [CA/CA];

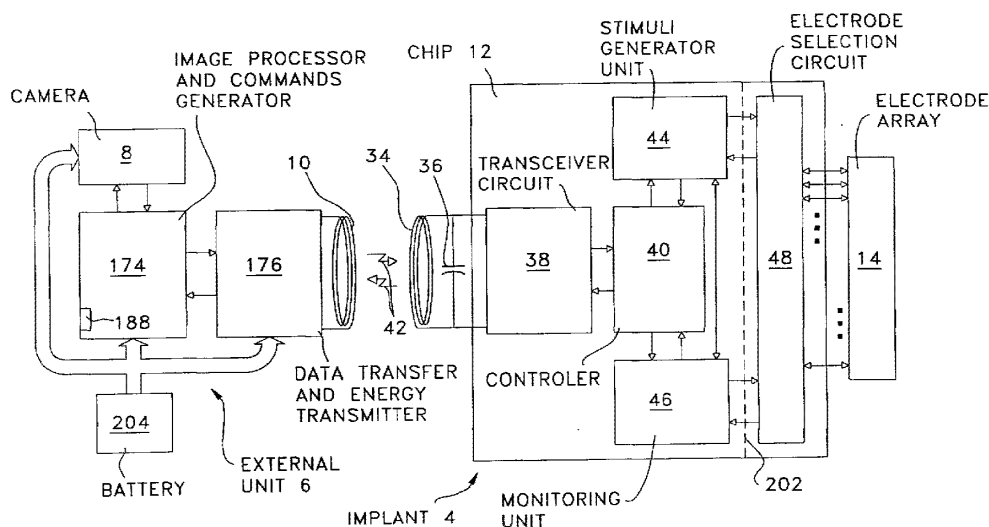
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(54) Title: BODY ELECTRONIC IMPLANT AND ARTIFICIAL VISION SYSTEM THEREOF



(57) Abstract: A miniaturized body electronic implant for providing artificial vision to a blind person or for other uses as neuromuscular sensors and microstimulators. The implant has a high resolution electrode array connected to a chip integrating implant stimulation and monitoring circuits, mounted on the back of the electrode array. The implant is powered by and communicates with an external unit through an inductive bi-directional link.

WO 02/40095 A1

BODY ELECTRONIC IMPLANT AND ARTIFICIAL VISION SYSTEM THEREOF

FIELD OF THE INVENTION

The present invention relates to body electronic implants, and more particularly to a body electronic implant that can be used to stimulate the visual cortex of a blind person for providing artificial vision, or to stimulate other body organs or tissues or nerves for other purposes, and that can also be used as a monitoring instrument for diagnostic purposes.

10 BACKGROUND

Blindness is still nowadays difficult to cure. Technologies such as speech synthesizers, 3D tactile displays and dedicated scanners improve the quality of life of blind persons by allowing them to read text and manipulate money. However, for seeing, the situation is still the same as a hundred, or even a thousand years ago.

Since electrical stimulation techniques are applied in many circumstances to enhance or restore organ function, a few research teams are working on the recuperation of a
20 limited but functional vision to totally blind persons. A functional vision means that the person will be able to do, without assistance, most of the tasks being part of every day life. It will be limited since no system in the near future will be able to replace the natural vision system with the same accuracy. The required resolution and data processing capabilities are simply too large.

A person is considered legally blind if a visual
dysfunction is present and sufficient to greatly affect his
everyday life. The medical criterions vary from one country
30 to another but, in general, those who are considered legally
blind include a specific group of totally blind persons. This

means that they do not see anything and live in a world of complete darkness. The causes of blindness are numerous. Some causes originate in the eye and others are related to the visual pathways.

The history of human visual stimulation began in 1960 when it was found that when a specific part of the human brain was stimulated with an electrical current, a fixed light spot appeared in the visual field of the patient. The part of the brain was later identified as the visual cortex and the light spots are called phosphenes. In 1968, results of clinical experiments related to visual stimulation were first published. The experiments were done with different voltage sources and spacing between electrodes through an array of 81 platinum electrodes. In all cases, the electrical stimulation was done on the surface of the visual cortex. As research progressed, notable discoveries were made and can be summarized as follows: current based intracortical stimulation leads to a significant current reduction, more stable phosphenes and a phosphene intensity that is proportional to the current. To accomplish the visual stimulation, two main steps are necessary. The first is to acquire a real life scene and generate stimulation information, or stimulation command words. The second is to inject the proper electrical current to do the stimulation according to the command words.

There are at least three undertaken research activities intended to create adequate vision using electrical stimulation. Each one has its own distinctive characteristics, which are the following:

- 1) Retina stimulation, where an electrode array is inserted into the light sensitive retina. The advantage of this method is to use most of the natural visual pathway. It is an advantage but also an inconvenience since the visual pathway must be intact and functioning properly. Some of the

best challenges of this method of stimulation are mechanical. Since the electrode array is located on the retina, it will be subjected to the very large angular accelerations of the eye. The electrode array must be secured in place very firmly to avoid damaging the retina. Furthermore, to have a good contact with the retina, the electrode array must not be planar but must match the spherical nature of the eye. This approach seems to be dedicated to vision enhancement because the visual pathway is intact. For example, it would be ideal
10 for patients losing the sensitivity of their peripheral vision.

2) Cortical stimulation, where the electrode array is inserted into the brain visual cortex. This method is also dedicated to totally blind persons. Its only requirement is that the visual cortex be intact, which seems to be the case more than 90% of the time. Research is under progress to determine long term stimulation effects on the brain and cell damage due to a high density of electrodes, but the preliminary results are encouraging. A critical step to this
20 method is the insertion of the electrode array into the visual cortex. The current approach suggests a pneumatic system.

3) Optical nerve stimulation is a new stimulation strategy recently introduced. Obviously, the visual pathway must be intact from the optic nerve to the visual cortex. The exact nature of the signals carried by the optic nerve is not thoroughly known and more research is needed before feasibility can be demonstrated.

Known in the art are US patents Nos. 4,551,149
30 (Sciarra); 4,628,933 (Michelson); 5,159,927 (Schmid); 5,215,088 (Normann et al.); 5,324,315 (Grevious); 5,324,316 (Schulman et al.); 5,876,425 (Gord et al.); 5,800,535 (Howard, III); 5,807,397 (Barreras); 5,873,901 (Wu et al.); 5,935,155 (Humayun et al.); UK patent application

GB 2,016,276 assigned to W H Ross Foundation (Scotland) for Research into Blindness and published on September 26, 1979; and Canadian patent no. 908,750 (Brindley et al.) issued on August 29, 1972, depicting the state of the art.

The above patent documents show that various implants have been designed, at least on a theoretical basis. However, many problems arise when the time comes to put them into practice. Difficulties in the production of electronic implants lay for example in the integration of the various required functions and the miniaturisation of the whole system. The existing implants exhibit high power consumption as they are built using separate electronic modules that further take significant space. The RF part, operating at high speed, is generally made with discrete electronic components due to the electromagnetic interferences generated by this part; it is thus not integrated with the rest of the implant circuit, which would otherwise allow a reduction of the dimensions and the power consumption of the implant. Since an implantable system with discrete components has a high power rating, its power supply by an inductive link is thus hardly practicable. A few designs group the electronics and the electrodes on the same silicon slice. This method facilitates achievement of a vector of a few electrodes, but its application to a large number of electrodes in an array format remains to be proven. The efficiency of an inductive coupling to supply the implantable part of the system is very low because the majority of the currently used techniques are based on ASK modulation. This low efficiency prevents the integration of all the desired functions in the same implant when discrete component designs are used.

The implants used for electric stimulation purposes are thus far unable to monitor changes on the electrode-tissue interface. Such a monitoring function is however highly desired to monitor and follow the evolution of the milieu in

contact with the implanted system. The majority of the existing systems are unable to process a large number of inputs and outputs (many tens and hundreds); they are mostly designed for a few stimulation channels only, e.g. for a 10 x 10 array of electrodes. Furthermore, the assembly of implant electronics with an electrode array having a large number of electrodes in a surface having reduced dimensions has so far not received much attention in the art, as for some other aspects related to implants and implant systems.

10 SUMMARY

An object of the present invention is to provide a body electronic implant which may be used as a stimulating implant on the visual cortex to provide artificial vision to a blind person, or for other applications such as a monitoring device for implantable biomedical measurements, and especially for measuring parameters around an electrode-neuronal tissues interface.

Another object of the present invention is to provide a body implant which is sufficiently miniaturized and has an
20 integration level adapted for full and direct fitting into the cerebral cortex, at the back of the head of a user, yet which is highly configurable, functionally flexible and has a low power consumption.

Another object of the present invention is to provide a body implant assembly combining a full custom mixed-signal chip and a large number of electrodes fitting on a surface having reduced dimensions.

Another object of the present invention is to provide a body implant capable of storing preset stimulation parameters
30 actively useable with real-time incoming specific stimulation parameters to form the stimulation signals, thereby relieving external unit-implant real-time communications.

Another object of the present invention is to provide a body implant capable of monitoring changes on the electrode-tissue interface through voltage, current and impedance measurements, and capable of reporting these changes to the external unit for diagnosis and adjustment purposes.

Another object of the present invention is to provide an implant system based on the above implant, and which can process real scene images for improved stimulation over an electrode array having a limited resolution.

10 According to the present invention, there is provided a body implant assembly comprising:

 an electrode array having multiple adjacent electrodes directed towards respective stimulation sites;

 an antenna;

 a full custom mixed-signal chip including a transceiver circuit coupled to the antenna, an AC to DC voltage transformation circuit coupled to the transceiver circuit and powering the full custom mixed-signal chip from energy contained in a control signal received by the transceiver
20 circuit, a controller connected to the transceiver circuit and processing operation data contained in the control signal received by the transceiver circuit, and a stimuli generator circuit connected to the controller and generating stimulation signals in accordance with the operation data;

 an electrode selection circuit connected to the stimuli generator circuit and having selectable outputs for transmission of the stimulation signals to selected ones of the electrodes in accordance with the operation data; and

 a substrate support having a first side receiving the
30 full custom mixed-signal chip, the antenna and the electrode selection circuit, and a second, opposite side receiving the electrode array, the first side having contacts lying around the full custom mixed-signal chip and connected to the outputs of the electrode selection circuit respectively, the

second side having an array of adjacent contacts aligned with and connected to the electrodes respectively, the contacts on the first and second sides being interconnected respectively together by an interconnection circuit across the substrate support.

According to the present invention, there is also provided a body implant comprising:

an electrode array having multiple adjacent electrodes directed towards respective stimulation sites;

10 an antenna;

a transceiver circuit coupled to the antenna;

an AC to DC voltage transformation circuit coupled to the transceiver circuit and providing implant power supply from energy contained in an implant control signal received by the transceiver circuit;

a controller connected to the transceiver circuit and processing operation data contained in the implant control signal received by the transceiver circuit;

20 a stimuli generator circuit connected to the controller and generating stimulation signals in accordance with the operation data; and

an electrode selection circuit connected between the stimuli generation circuit and the electrode array, the electrode selection circuit having selectable outputs for transmission of the stimulation signals to selected ones of the electrodes in accordance with the operation data;

30 the controller having a decoder circuit decoding the operation data contained in the implant control signal, a configuration controller storing common and specific stimulation parameters specified in the operation data and respectively addressed to all of the stimulation sites and specific ones of the stimulation sites, and a stimulation command controller transmitting stimulation control signals

to the stimuli generator circuit in accordance with the common and specific stimulation parameters.

According to the present invention, there is also provided a body implant comprising:

an electrode array having multiple adjacent electrodes directed towards respective stimulation sites;

an antenna;

a transceiver circuit coupled to the antenna;

10 an AC to DC voltage transformation circuit coupled to the transceiver circuit and providing implant power supply from energy contained in an implant control signal received by the transceiver circuit;

a controller connected to the transceiver circuit and processing operation data contained in the implant control signal received by the transceiver circuit;

a stimuli generator circuit connected to the controller and generating stimulation signals in accordance with the operation data;

20 an electrode selection circuit connected between the stimuli generation circuit and the electrode array, the electrode selection circuit having selectable outputs for transmission of the stimulation signals to selected ones of the electrodes in accordance with the operation data; and

a monitoring unit coupled between the controller and the electrode selection circuit, and controllably taking signal measurements at selected ones of the stimulation sites in response to monitoring control signals and producing test result signals indicative of the signal measurements;

30 the controller having a decoder circuit decoding the operation data contained in the implant control signal, a monitoring command generator decoding diagnosis instructions contained in the operation data and transmitting the monitoring control signals to the monitoring unit in accordance with the diagnosis instructions, and a diagnosis

controller receiving and processing the test result signals from the monitoring unit.

According to the present invention, there is also provided a body implant comprising:

an electrode array having multiple adjacent electrodes directed towards respective measurement sites;

an antenna;

a transceiver circuit coupled to the antenna;

an AC to DC voltage transformation circuit coupled to
10 the transceiver circuit and providing implant power supply from energy contained in an implant control signal received by the transceiver circuit;

a controller connected to the transceiver circuit and processing operation data contained in the implant control signal received by the transceiver circuit;

an electrode selection circuit connected to the electrode array, the electrode selection circuit having selectable outputs for communication with selected ones of the electrodes and the respective measurement sites; and

20 a monitoring unit coupled between the controller and the electrode selection circuit, and controllably taking signal measurements at the selected ones of the measurement sites in response to monitoring control signals and producing test result signals indicative of the signal measurements;

the controller having a decoder circuit decoding the operation data contained in the implant control signal, a monitoring command generator decoding diagnosis instructions contained in the operation data and transmitting the monitoring control signals to the monitoring unit in
30 accordance with the diagnosis instructions, and a diagnosis controller receiving and processing the test result signals from the monitoring unit.

According to the present invention, there is also provided a body implant comprising:

an electrode array having multiple adjacent electrodes directed towards respective stimulation sites;

an antenna;

a transceiver circuit coupled to the antenna;

an AC to DC voltage transformation circuit coupled to the transceiver circuit and providing implant power supply from energy contained in an implant control signal received by the transceiver circuit;

10 a controller connected to the transceiver circuit and processing operation data contained in the implant control signal received by the transceiver circuit;

a stimuli generator circuit connected to the controller and generating stimulation signals in accordance with the operation data; and

an electrode selection circuit connected between the stimuli generation circuit and the electrode array, the electrode selection circuit having selectable outputs grouped into channels for transmission of the stimulation signals to selected ones of the electrodes in accordance with the
20 operation data;

the electrode selection circuit including, for each channel, a demultiplexer circuit connected to and operating switch arrangements in accordance with site and polarity control signals, the switch arrangements being subjected to the stimulation signals and connected respectively to the outputs assigned to the channel;

the stimuli generator circuit including, for each channel, a signal generator controlled by a channel controller assisted by a timer connected to a register
30 circuit receiving stimulation control signals, the signal generator producing the stimulation signals in accordance with the stimulation control signals, the register circuit and the channel controller producing the site and polarity

control signals in accordance with the stimulation control signals; and

the controller having a decoder circuit decoding the operation data contained in the implant control signal, a configuration controller storing stimulation parameters specified in the operation data, and a stimulation command controller transmitting the stimulation control signals to the stimuli generator circuit in accordance with the stimulation parameters.

10 According to the present invention, there is also provided an artificial vision system for stimulating a visual cortex of a blind person, comprising:

a body implant including an electrode array having multiple adjacent electrodes applicable against the visual cortex of the blind person, and a micro-stimulator means mounted on a back side of the electrode array, for selectively generating stimulation signals on the electrodes producing phosphenes on the visual cortex representing an artificial image in response to airwave-received implant control signals; and

20 an external unit including an image sensor adapted to take a real scene image, an image processor and command generator means connected to the image sensor for processing image data signals produced by the image sensor in accordance with predetermined processing operations and generating implant compatible stimulation commands causing the body implant to produce the artificial image on the visual cortex corresponding to the real scene image, and a transceiver circuit connected to the image processor and command generator means, for producing airwave-transmitted implant control signals carrying the stimulation commands, the processing operations including a digitalization of the image data signals to form a digital image, an image reduction of the digital image into a scaled down image having a same

resolution as the electrode array, and an image enhancement of the scaled down image to form an enhanced image corresponding to the artificial image produced by the implant unit and from which the stimulation commands are generated.

BRIEF DESCRIPTION OF THE DRAWINGS

A detailed description of preferred embodiments will be given hereinbelow with reference to the following drawings, in which like numbers refer to like elements:

10 Figures 1, 2 and 3 are, respectively, schematic views of front and rear sides of a substrate support of a body implant assembly and an exploded view thereof with an electrode array according to an embodiment of the present invention;

Figures 4, 5 and 6 are, respectively, schematic views of front and rear sides of a substrate support of a body implant assembly and an exploded view thereof with an electrode array according to another embodiment of the present invention;

Figure 7 is a schematic diagram of a body implant system according to an embodiment of the present invention;

20 Figures 8, 9, 10 and 11 are schematic diagrams of the internal controller, the stimuli generation circuit, the monitoring circuit and the electrode selection circuit of a body implant according to the present invention;

Figure 12 is a schematic diagram illustrating a possible format of a communication protocol for a body implant according to the present invention;

Figure 13 is a schematic diagram illustrating possible definitions of parameters in the registers of an internal controller of a body implant according to the present invention;

30 Figure 14 is a schematic diagram illustrating a stimulation mode command format for a body implant according to the present invention;

Figure 15 is a schematic diagram illustrating a diagnosis mode command format for a body implant according to the present invention;

Figure 16 is a schematic diagram illustrating a power management mode command format for a body implant according to the present invention;

Figure 17 is a schematic diagram illustrating an image processing sequence performed by an image processor for command word generation for implant control according to the present invention;

Figures 18A-B and 19A-B are schematic diagrams illustrating scaled-down and enhanced images generated by an image processor and the corresponding histograms respectively, according to the present invention;

Figure 20 is a schematic diagram illustrating a screen capture of an external unit user interface according to the present invention; and

Figure 21 is a schematic diagram illustrating a body implant artificial vision system worn by a user according to the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to Figure 21, there is shown a body implant system worn by a user 2 according to the present invention, in the context where the user 2 is a blind person and the system is used to provide artificial vision to the user 2. It should be understood that this context exemplifies a typical use of the implant system according to the present invention, and should not be taken in a limitative or restrictive sense, as the implant system may be used in many other contexts, for example for monitoring purposes, and especially for measuring parameters around an electrode-neuronal tissues interface.

The body implant system includes two main parts: an implant 4 positioned on the visual cortex of the user 2, and an external unit 6 that can be inserted in a pocket and which acquires real life scenes, processes the image information and communicates with the implant 4 to provide energy for powering the implant 4 and to control it in order to stimulate the visual cortex of the user 2 through an electrode array used to generate phosphenes in the visual field corresponding to a transposition of the real life scenes. The real life scenes can be acquired through a camera 8 (e.g. a CMOS image sensor) mounted on an earpiece of an eyeglass, while the implant energy and control signals can be transmitted through an inductive link using an antenna 10 positioned behind the head of the user 2.

Referring to Figures 1-6, there are shown two embodiments of the body implant assembly according to the present invention. These embodiments feature integration of most of the electronic components of the implant in a single full custom mixed-signal chip 12, thereby reducing power consumption and size of the circuit. Furthermore, a special interconnection circuit is provided for interconnection of the chip 12 with a high resolution electrode array 14 having multiple adjacent electrodes 16, e.g. a 25 x 26 array = 650 electrodes made of biocompatible materials, having an average height of approx. 1,5 mm, spaced by approx. 400 μm from one another and extending over a very small area, e.g. 1 cm^2 . The resulting implant assembly is thus highly miniaturized compared to prior art implants, and the interconnection circuit provides individual connections to every electrode 16. The electrode array 14 can be made of several smaller electrode arrays assembled together (not shown), instead of a larger single array if desired.

Referring to Figures 1-3, the chip 12 is embedded on a side of a very thin substrate support 14 having contacts 17

lying around the chip 12, at a given distance therefrom. These contacts 17 are respectively connected to the pads 18 of the chip 12 for example by a wire bond 24. The other side of the substrate support 14 is provided with an array of adjacent contacts 20 aligned with and connected to the electrodes 16 respectively. The connection of the contacts 20 with the electrodes 16 can be achieved by cold welding or any other suitable technique. The contacts 17 and 20 on both sides of the substrate support 14 are interconnected
10 respectively together by an interconnection circuit 22 across the substrate support. Depending on the number of links to achieve, the interconnection circuit 22 may be formed of layers made in the substrate support 14 and stacked between the sides thereof. To reduce the space taken by the contacts 17, they may be distributed in an alternate shifted pattern over two or more adjacent sets of rows surrounding the chip 12. The body implant assembly resulting from this embodiment is thus very thin for a reasonable cross section. An antenna
20 34 extends on the substrate support 14 around the chip 12 for communication with the external unit 6. The antenna 34 is connected to pads 18 of the chip 12 assigned for this purpose. A capacitor 36 is coupled to the antenna 34 for proper operation. Other suitable antenna configurations may be used.

Referring to Figures 4-6, the substrate support 14 may be formed of a front relatively flat portion 26 having however a smaller cross section than the substrate support 14 in the former embodiment, and a smaller rear portion 28 projecting behind the front portion and receiving the
30 electrode array 14. As in the former case, the contacts 17 on the foremost face of the front portion 26 are connected respectively to the pads 18 of the chip 12. The contacts 17 however also project through and appear behind the front portion 26. The interconnection circuit in this case has a

series of peripheral contacts 30 surrounding the array of adjacent contacts 20 on the rearmost face of the rear portion 28. The peripheral contacts 30 and the contacts 17 appearing behind the front portion 26 are respectively connected together by a wire bond 32. Circuit layers of suitable designs made in the rear portion 28 and stacked between the rearmost and foremost face thereof interconnect the peripheral contacts 30 with the array of adjacent contacts 20 respectively. The body implant assembly resulting from this
10 embodiment is thus thicker than in the former embodiment, but as a smaller cross-section.

In both of the above embodiments, the body implant assembly can be made from a silicon die containing all the electronic circuitry necessary to receive command words, detect and correct transmission errors, decode the command words and control the stimulation process accordingly.

Referring to Figure 7, the full custom mixed-signal chip 12 preferably integrates a FM bi-directional data transfer & energy receiver 38, a controller 40, a stimuli generator unit
20 44, an optional but generally desirable monitoring unit 46, and depending on the chosen design, an electrode selection circuit 48 or not as it can also be provided as a separate circuit from the chip 12 as depicted by the dotted lines 202, then forming another full custom chip.

The receiver 38 recovers high frequency AC signal from the implant control signal emitted by the external unit 6, and transforms it to a DC voltage. This DC voltage is used to power up the whole implant. The receiver 38 recovers also clock and data from the same implant control signal emitted
30 by the external unit 6, and transmits it to the internal controller 40. The receiver 38 gets feedback data from the internal controller 40 and transmits it to the user through the inductive link depicted by arrows 42. The receiver 38 thus acts as a transceiver. Although the feedback function is

likely to be indispensable in most applications, it can nevertheless be omitted if it is really useless for a specific application.

The controller 40 decodes the commands generated by the external unit 6 in order to produce all control signals to the stimuli generator unit 44 and the monitoring unit 46.

Referring to Figure 8, the controller 40 may be embodied by a circuitry mainly containing 12 units, which are grouped into 3 main sections: a main controller module 50, a
10 stimulation controller module 52, and a diagnosis controller module 54. The main controller module 50 detects data frames and corrects communication errors, if present, in order to build the command words used by the other modules in the controller 40. This can be achieved through a serial/parallel converter & frame detector 56 and an error correction & command word decoder 58.

A power management module 60 (PMM) can be provided to turn other modules, units, or stimulation channels on or off individually to keep power consumption to a minimum at any
20 given time. Only the PMM 60 itself and the two previous modules 56, 58, necessary for command reception, are not susceptible to being turned off. Turning a module off means lowering its power consumption down to zero, but does not imply a real shut down of the unit, keeping programmed parameters valid where volatile memory is used. For sake of clarity, only few of the many control lines to the controller's internal modules are presented in Figure 8.

A configuration controller 62 preferably keeps every communication, stimulation, and diagnosis parameter
30 programmed by the user by means of registers CR0-CR8, and makes them available for other modules or units. A Power-On-Reset function controlled by the main controller 50 can be implemented.

A proper knowledge of the communication protocol for the implant as set forth hereinafter might be important for understanding the following part.

The stimulation controller module 52 has a Random Access Memory 64 (RAM) intended to keep a stimulation channel/site address sequence programmed by the external unit 6 during the configuration process.

10 A stimulation commands generator 66 (SCG) decodes the stimulation instructions and sends the required control signals to the stimuli generator unit 44 (as shown in Figure 7), according to programmed shared stimulation parameters, if applicable.

A clock signal 68 whose frequency depends on a specific programmed parameter SCTB stored in the register CR3 is used for stimulation by the stimuli generator unit 44 and is generated by a stimulation clock module 70.

20 The diagnosis controller module 54 has a monitoring commands generator 72 (MCG) which decodes the diagnosis instructions related to the analog monitoring of the stimulation system and electrode/tissue condition, and sends the required control signals to the monitoring unit 46 (as shown in Figure 7), according to the programmed options/parameters.

A clock signal 74 whose frequency depends on a specific programmed parameter MCTB stored in the register CR5 is used for monitoring purposes by the monitoring unit 46 and is generated by a monitoring clock module 76.

30 A diagnosis controller 78 (DC) transmits test vectors sent by the external unit 6 upon request to any module and units, and receives test results thereof, both from digital tests and from analog monitoring performed by the monitoring commands generator 72. The DC 78 also sends the results back to the external unit 6, via parity insertion & return word encoder and parallel/serial converter modules 80, 82. For

sake of clarity, only a few of the many control lines to the controller's internal modules are presented in this Figure 8.

Referring to Figure 9, the stimuli generator unit 44 may be embodied by a circuitry composed of 25 individual and independent channel stimuli generators 84 (CSG). Each of the CSG 84 has a channel controller 86 (CC), a timer module 88 and a current digital to analog converter 90 (DAC).

Two sets of registers 92, 94 allow to load the next stimulation parameters while the current ones are used, thereby eliminating delays between two successive stimulations. Not shown are the diagnosis signals to/from the controller's diagnosis controller module 78 (see Figure 8) for testability and the power management control signals from the power management module 60.

Referring to Figure 10, the monitoring unit 46 may be embodied by a circuitry having the necessary sources and measurement modules to perform real/time continuous stimulation supervision and detailed voltage/current/complex impedance measurement for detailed diagnosis.

During normal stimulation, continuous monitoring can be performed by constantly comparing the peak voltage V_{pk} across any monitored stimulation site $Prb0$, $Prb1$ to a maximum reference voltage V_{Ref} , through comparator 96. If the monitored voltage exceeds the reference, the channel overflow signal $ChanOF$ is activated and the channel on which the problem arose is stored in a register 98 $DefChan$. The reference signal V_{Ref} is set by the maximum allowed current and impedance between any stimulation site monitored by the DAC 100 and in accordance with the parameter $CalRes$ stored in the register $CR6$ of the configuration controller 62 shown in Figure 8 and sent to the calibration channel decoder 102 shown in Figure 11.

Many options are available for detailed diagnosis. The source may be either internal, then using the DAC 100 for

this purpose, or external and then using any of the channel's DAC 90 shown in Figure 9, as selected by the MonSrc signal produced by the demultiplexer 104 and operating the transistor arrangements 106 shown in Figure 11. A waveform shaper 108 may be used to provide an unaltered square wave or a sine shaped wave for testing purposes. An output stage 110 provides the electrode array 14 with a stimulation current MonStim transmitted to the transistor arrangements 106 and provides the monitoring circuit 46 with an accurate voltage
10 dependent copy of the stimulation current, which may be measured via a current controlled oscillator 112, whose range can be modified according to the input signal level OscRng derived from the parameter OCR stored in the register CR7 of the configuration controller 62 shown in Figure 8. Any sampled voltage across the monitored site can be measured with the same oscillator 112 through a transconductance amplifier 114 with variable gain for various input voltage ranges as set by the signal GmRng. The peak magnitude of the voltage across the monitored site can be measured by means of
20 a peak detector 116. The phase between the stimulation current and the monitored voltage can be measured through a phase detector 118 and a frequency and phase estimator 120 for complex impedance measurements. A monitoring unit controller 166 controls most of the components of the monitoring unit 46 in accordance with the various control signals produced by the monitoring commands generator 72 (see Figure 8). A sample and hold circuit 168 is provided for the transconductance measurement.

Not shown are the diagnosis signals to/from the
30 controller's diagnosis controller 78 (see Figure 8) for testability and the power management control signals from the power management module 60.

It should be noted that in the case where the implant 4 is intended to be used solely for monitoring purposes, then

all the circuits of the implant 4 with functions only related to the generation of stimulation signals can be removed from the implant 4 inasmuch as no stimulation signals are required. Such is the case when the implant 4 is used for example to monitor certain body organs producing measurable electric signals to be monitored. For example, the DACs 90 and 100 (see Figure 10), and the stimulation commands generator 66 (see Figure 8) can be omitted in such a case.

Referring to Figure 11, the electrode selection circuit 48 can be embodied by a multiplexor/demultiplexor circuitry comprising 25 selection channels 122 provided with channel decoders 126 for activating up to 25 sites simultaneously. Each site can be activated in both directions by means of switch arrangements 124, depending on the sign bit (signal Sign #x) for every channel.

A test channel decoder 128 selects which channel has to be monitored. When a specific channel is monitored, the current from the corresponding channel stimuli generator 84 in the stimuli generator unit 44 is deviated to the monitoring unit 46 through the MonSrc line 130 and the stimulation current comes from that latter unit through the MonStim line 132. The channel stimuli generator 84 is notified that its channel is being monitored with the MonChan#x signal transmitted to corresponding the channel controller 86.

The electrode selection circuit 48 may be provided with a calibration channel circuit formed of the channel decoder 102 and a calibration network 134 and used by the analog monitoring unit 46. The calibration channel decoder 102 selects an appropriate known resistive element value. This is also used in the continuous monitoring process, generating the appropriate reference limit voltage VRef.

Sets of analog multiplexers 136 provide the monitoring unit 46 with the voltage across any pair of electrodes through the Prb0 and Prb1 lines 138, 140.

Referring to Figure 12, there is shown a possible format of a communication protocol for the body implant according to the present invention. In the illustrated case, the command words 142 are 26 bits long or less and are composed of three parts, the mode identification bits 144, the instruction 146 and the data 148. Note that each instruction 146 can contain
10 one or several parts, depending on the selected mode.

A session usually starts with a configuration process. Then the stimulation period can start, according to the programmed configuration parameters 148 transmitted by the external unit 6. If a problem arises, the diagnosis mode allows a monitoring of both analog and digital components of the system. Finally, at any time, the power management mode enables the external unit 6 to turn on or off any component for reduced power consumption.

The configuration mode set by the command word <1,0> ==
20 00 allows to define several variable parameters related to stimulation or monitoring.

The first five configuration registers CR0 to CR4 of the configuration controller 62 (see Figure 8) define the communication protocol during stimulation. The next four registers CR5 to CR8 define many diagnosis parameters, the first three being dedicated to the analog monitoring and the last one relating to digital diagnosis of the system.

Referring to Figure 13, the definition of the parameters in the registers CR0-CR8 is as follows. The Partial
30 Stimulation Word Chain Length (PSWCL) parameter defines the number of sequential stimulation words that are sent without interruption. The Amplitude Flag (AF) parameter defines whether the stimulation current amplitude is specific or common for every site. The Amplitude Word Length (AWL)

parameter defines the number of bits specifying the amplitude of the stimulation current. The Pulse Duration Flag (PDF) parameter defines if the stimulation current pulse duration is specific or common for every site. The Pulse Duration Word Length (PDWL) parameter defines the number of bits specifying the pulse duration of the stimulation current. The Interphase Duration Flag (IDF) parameter defines if the delay between the two phases of the stimulation current is specific or common for every site. The Interphase Duration Word Length (IDWL) parameter defines the number of bits specifying the delay between the two phases of the stimulation current. The Common Amplitude (CAMP) parameter defines the amplitude of the stimulation current if this parameter is common for every site. The Common Pulse Duration (CPD) parameter defines the pulse duration of the stimulation current if this parameter is common for every site. The Common Interphase Duration (CID) parameter defines the delay between the two phases of the stimulation current if this parameter is common for every site. The Stimulation Clock Time Base (SCTB) parameter defines the frequency of the stimulation clock 70 shown in Figure 8. The Stimulation Sequence Channel (SSC) and the Stimulation Sequence Site (SSS) parameters are used to fill the Stimulation Sequence RAM 64 shown in Figure 8. The Low Pass Filter Cut-off Frequency (LPFCF) parameter defines the cut-off frequency of the Gm-C low-pass filter 150 shown in Figure 10 in the monitoring unit 46. The Monitoring Clock Time Base (MCTB) parameter defines the frequency of the monitoring clock 76 in the controller 40 (see Figure 8). The Monitoring DAC Amplitude (MDACA) parameter defines the amplitude of the output current of the DAC 90 (Figure 9) for continuous monitoring. The Calibration Resistor (CALRES) parameter defines the reference equivalent resistor in the calibration network 134 for continuous monitoring (see Figure 11). The Transconductance Range (GMR) parameter

defines the gain of the transconductance amplifier 114 (see Figure 10). The Oscillator Current Range (OCR) parameter defines the input current range of the current controlled oscillator 112 (see Figure 10). The Unit/Module Under Test (UMUT) parameter defines the unit or module under test for digital diagnosis. The Scan Chain Length (SCL) parameter defines the number of bits of the scan chain in the unit or module under test. The Stimulation clock Sync (SS) parameter synchronizes the stimulation clock 70 (Figure 8). The
10 Monitoring clock Sync (MS) parameter synchronizes the monitoring clock 76 (Figure 8). The RAM Reset (RR) parameter resets the address pointer of the Stimulation Sequence RAM 64 (Figure 8) to zero. The Continuous Monitoring (CM) parameter turns the continuous monitoring feature of the controller 40 (Figure 7) on/off.

Referring to Figure 14, in the stimulation mode set by the command word <1,0> == 01, the instruction 152 depends directly on the stimulation communication protocol defined in the configuration. The instruction 152 is sent as a chain of
20 a certain number (PSWCL) of stimulation words, each containing 1 to 34 bits, depending on the common parameters. If the chain is longer than 24 bits, it is divided into sequential stimulation instruction words of 24 bits or less for the last word.

Referring to Figure 15, the diagnosis mode set by the command word <1,0> == 10 allows detailed and various analyses of the condition of the system, on both the digital and analog sides. When the first bit of the diagnosis instruction word 154 is set in a low state 156, the following data is
30 used to determine the information required for analog monitoring. The instruction is then composed of: a Monitored Site (MS) parameter, a Monitored Channel (MC) parameter, a Monitoring current Amplitude (MAMP) parameter, and a Monitoring Options (MOPT) parameter. The MOPT parameter