

Filed on behalf of Resmed Corp.

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UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

RESMED CORP.
Petitioner

v.

FRACTUS, S.A.,
Patent Owner.

Case No. IPR2026-00341
U.S. Patent No. 8,362,960

**DECLARATION OF DR. MANOS M. TENTZERIS
IN SUPPORT OF PETITION FOR *INTER PARTES* REVIEW OF
U.S. PATENT NO. 8,362,960**

Declaration of Dr. Manos M. Tentzeris in Support of
Petition for *Inter Partes* Review USP No. 8,362,960

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1.	Claim 7	99

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- a) The handheld device according to claim 1, wherein the second antenna is arranged to operate in at least one frequency band used for a wireless service in accordance with Bluetooth™, IEEE802.11a, IEEE802.11b, IEEE802.11g, WLAN, WiFi, UWB, ZigBee, GPS, Galileo, SDARs, XDARS, WiMAX, DAB, FM, DVB-H, or DMB.....99

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I, Manos M. Tentzeris, declare as follows:

I. INTRODUCTION

1. I have been retained by Petitioner ResMed Corp. (“Petitioner” or “ResMed”) to serve as an independent expert consultant in the Inter Partes review proceedings regarding U.S. Patent No. 8,362,960 (“the ’960 patent”) (Ex. 1001). I have been asked to consider the validity of claims 1, 2, 3, 4, 5, 6, 7, 19, and 20 of the ’960 patent (the “challenged claims”). My opinions are set forth below.

2. I am being compensated at my normal rate for all services rendered. My compensation is not dependent, in any way, on the nature of my findings, the content of my testimony, or the outcome of this proceeding or any other proceeding.

3. I have no other interest in this proceeding.

4. My analysis of the materials produced in this proceeding is ongoing and I will continue to review any new material that is provided. This declaration is indicative of only those opinions that I have formed to date. I reserve the right to amend, revise, and/or supplement my opinions stated herein based on any new information that may become available to me or my continuing analysis of the materials already provided.

II. QUALIFICATIONS

5. My qualifications for forming the opinions in this report are summarized here and explained in more detail in my Curriculum Vitae (“CV”), which is submitted as Exhibit 1004.

6. I am currently Ed and Pat Joy Chair Professor with the School of Electrical and Computer Engineering at Georgia Institute of Technology (“Georgia Tech”). I have over 30 years of industry and academic experience, including in the area of antennas, fractal RF structures, and circuit design for these systems. I supervise Doctoral students, as well as visiting students, post-doctoral fellows, and other researchers.

7. I received my Bachelor of Science degree in Electrical Engineering from the National Technical University of Athens in Greece in 1992. I received my Master’s degree and Ph.D. from the University of Michigan at Ann Arbor in 1994 and 1998, respectively. A complete list of my academic positions, activities, and publications is set out in my CV, attached.

8. Between 1991 and 1992, I was a research assistant in the Microwave Lab at the National Technical University of Athens, Greece. From 1992 to 1998, I was a research assistant in the Radiation Laboratory at the University of Michigan, Ann Arbor. I became an assistant professor at the School of Electrical and Computer Engineering at Georgia Tech in 1998, before being promoted to Associate Professor

in the same School in 2004. I then served as Associate Professor until my promotion to Professor in 2016, a title I have held since then. Also in 2016, I was appointed as the Ken Byers Professor in Flexible Electronics.

9. As a professor of Electrical and Computer Engineering, I have taught courses relating to antenna and electromagnetic technologies. A complete list of my teaching positions, honors, and classes taught is set out in my CV. As professor, I have collaborated with over 130 Undergraduate, Masters and Doctoral students, as well as visiting students, post-doctoral fellows and other researchers.

10. Throughout my career, I have received a variety of awards. I am a Fellow of IEEE, a member of the MTT-15 Committee, an Associate Member of European Microwave Association (EuMA), a Fellow of the Electromagnetics Academy, and a member of Commission D, URSI and of the Technical Chamber of Greece. In recognition of my world-leading achievements in the area of antennas and miniaturized/fractal RF structures, I served as an IEEE C-RFID (Committee on RFID technologies) Distinguished Lecturer from 2016–2022 and I served as an IEEE MTT Distinguished Microwave Lecturer (DML) from 2010–2012. I have won awards for my contributions in developing various technologies, including numerous multiband antenna topologies operating at different frequencies and integrated RF modules up to sub-THz frequencies. My achievements include the following:

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- IEEE fellow — a distinction reserved for select IEEE members whose extraordinary accomplishments in any of the IEEE fields of interest are deemed fitting of this prestigious grade elevation. IEEE, About the IEEE Fellow Program, <http://www.ieee.org/membership/fellows/>.
- 2025 IEEE Journal of Microwaves Best Paper Award
- 2024 Georgia Tech Outstanding Achievement in Research Innovation Award
- 2024 IEEE International Microwave Symposium (IMS) Best Student Paper Award
- 2022 Georgia Tech Outstanding Doctoral Thesis Advisor Award
- 2021 IEEE Antennas and Propagation Symposium (APS) Best Student Paper Award (co-authored)
- 2019 Humboldt Research Prize
- 2019 IEEE Antennas and Propagation (APS) Conference Co-Chair
- 2018 Intel IEEE ECTC 2018 Best Student Paper Award
- 2015–present IEEE CRFID Distinguished Lecturer
- 2010–2012 IEEE MTT-S Distinguished Microwave Lecturer
- 2017 Georgia Tech Outstanding Achievement in Research Program Development Award

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- 2017 Archimedes IP Salon Gold Medal
- 2016 Bell Labs Prize Third Award
- 2015 IET Microwaves, Antennas and Propagation Premium Award
- 2014 Georgia Tech ECE Distinguished Faculty Achievement Award
- 2014 IEEE RFID-TA Best Student Paper Award
- 2013 IET Microwaves, Antennas and Propagation Premium Award
- 2012 Finland Distinguished Professor (Fi.Di.Pro.) Award
- 2012 Architecture Award of Excellence, Architecture World Summit
- 2010 IEEE Antennas and Propagation Society Piergiorgio L. E. Uslenghi Letters Prize Paper Award
- 2010 Georgia Tech Senior Faculty Outstanding Undergraduate Research Mentor Award
- 2009 IEEE Transactions on Components and Packaging Technologies Best Paper Award
- 2009 IEEE Antennas and Propagation Symposium (APS) Second Best Student Paper Award
- 2009 E.T.S. Walton Award from Science Foundation Ireland
- 2007 IEEE Antennas and Propagation Symposium (APS) Best Student Paper Award

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- 2007 IEEE International Microwave Symposium (IMS) Third Best Student Paper Award
- 2007 IEEE International Symposium on Antennas and Propagation (ISAP) Poster Presentation Award

11. In Google scholar, there are over 34,290 citations to my work and my work has an h-index of 91. An h-index represents the number of papers with the same number of citations, meaning I have over 91 papers with 91 citations.

12. I have authored or contributed to over 30 books and 920 refereed journal and conference papers; spoken in over 150 presentations, many of which relate to antennas, antenna arrays, RFID systems, multiband antenna design, and other modes of wireless communication and electronics design. A complete list of my publications and conference presentations is included in my curriculum vitae.

13. I am a named inventor on 28 patents in the US and in Europe. In particular, I am a named inventor on patents relating to antenna design, RF systems, and means of reducing signal interference in RF applications. A complete list of my patents and published applications is included in my curriculum vitae.

14. In addition to gaining expertise via my academic training, professional experiences, and research accomplishments described above, I have kept abreast of various sub-disciplines within the antennas space, by reading technical literature, attending and presenting at conferences, and attending and presenting at symposia.

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I have served as an editor for various journals and participated in the peer review process for various technical journals and conferences, and have reviewed manuscripts submitted by other scholars relating to antenna topologies. I have contributed further to the profession by chairing conference committees and planning conferences and panels. Furthermore, I have collaborated with or have communicated with many of the scholars and engineers in the field of antenna systems, including multiband antenna configurations for handheld and mobile devices.

15. I am not an attorney and offer no legal opinions, but in the course of my work, I have had experience studying and analyzing patents and patent claims from the perspective of a person of ordinary skill in the art.

III. MATERIALS CONSIDERED AND SUMMARY OF OPINIONS

16. All of the opinions contained in this declaration are based on the documents I have reviewed and my professional judgment, as well as my education, experience, and professional knowledge. I am not an attorney and I am not offering any legal opinions in this declaration.

17. In forming my opinions expressed in this Declaration, I reviewed the following materials (and any other materials that I reference in this Declaration):

Ex. 1001	U.S. Patent No. 8,362,960
Ex. 1002	Prosecution History of U.S. Patent No. 8,362,960

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Ex. 1005	U.S. Patent Pub. No. 2003/0193437 to Kangasvieri et al. (“Kangasvieri ”)
Ex. 1006	U.S. Patent No. 6,195,048 to Chiba et al. (“Chiba”)
Ex. 1007	U.S. Patent No. 6,909,402 to Vance (“Vance”)
Ex. 1008	Karaboikis et al., “Compact Dual-Printed Inverted-F Antenna Diversity Systems for Portable Wireless Devices,” IEEE Antennas and Wireless Propagation Letters, Vol. 3 (2004)
Ex. 1009	Inoue et al., “Pattern Calibration Free Antenna By Suppressing Mutual Coupling Between Elements,” Proceedings of ISAP’04, Sendai, Japan, 1A2-4 (2004)
Ex. 1010	U.S. Patent No. 6,606,071 to Cheng et al.
Ex. 1011	U.S. Patent No. 6,424,300 to Stanford et al.
Ex. 1012	U.S. Patent No. 6,204,819 to Hayes et al.
Ex. 1013	U.S. Patent No. 6,518,929 to Gilmore
Ex. 1014	Canadian Patent No. CA 2312542 C to Gagnon
Ex. 1015	U.S. Patent No. 6,639,560 to Kadambi et al.
Ex. 1016	U.S. Patent No. 7,109,923 to Ollikainen et al.
Ex. 1017	P. Ciaisi et al., “Design of an Internal Quad-Band Antenna for Mobile Phones,” IEEE Microwave and Wireless Components Letters, Vol. 14, No. 2 (Apr. 2004), pp. 148–150
Ex. 1018	“IBM Unveils First Biometric ThinkPad, Offering Security at Your Fingertips,” Phys.org (Oct. 4, 2004)
Ex. 1019	Dialogue Flybook User’s Manual, Revision 1.02, Part No. DTC-FA33I-01-02 (2003)
Ex. 1020	K.-L. Wong et al., “Isolation between GSM/DCS and WLAN Antennas in a PDA Phone,” Microwave and Optical Technology Letters, Vol. 45, No. 4 (2005), pp. 347–352
Ex. 1021	U.S. Patent Application Publication No. 2006/0082503 to Gaucher et al.
Ex. 1022	U.S. Patent Application Publication No. 2004/0113848 to Gaucher et al.

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Ex. 1025	Georgakopoulos et al., “Coupling Modeling and Reduction Techniques of Cavity-Backed Slot Antennas: FDTD Versus Measurements,” IEEE Transactions on Electromagnetic Compatibility, Vol. 43, No. 3, Aug. 2001, pp. 261–272
Ex. 1026	Sievenpiper et al., “High-Impedance Electromagnetic Surfaces with a Forbidden Frequency Band” 47 IEEE Transactions on Microwave Theory and Techniques 2059–2074 (Nov. 30, 1999)
Ex. 1027	U.S. Patent No. 6,961,545 to Tehrani et al.
Ex. 1030	Yang et al., “Microstrip Antennas Integrated With Electromagnetic Band-Gap (EBG) Structures: A Low Mutual Coupling Design for Array Applications,” 51 IEEE Trans. Antennas & Propagation 2936 (2003).
Ex. 1031	Constantine A. Balanis, Antenna Theory: Analysis and Design 144–50 (3d ed. 2005) (excerpt

18. In support of my opinions, I have taken into account how a person of ordinary skill in the art (as defined below in Section IV) would have understood the claims and the specification of the '960 patent at the time of the alleged invention. My opinions take into account how a person of ordinary skill in the art would have understood the '960 patent, the prior art to the patent, and the state of the art at the time of the alleged invention.

19. As I discuss in detail below, it is my opinion that certain references disclose or suggest all the limitations recited in claims 1, 2, 3, 4, 5, 6, 7, 19, and 20 of the '960 patent. My opinions are additionally guided by my appreciation and understanding of how a person of ordinary skill in the art would have understood the claims of the '960 patent at the time of the alleged invention.

IV. PERSON OF ORDINARY SKILL IN THE ART

21. I have been asked to consider the time of the alleged invention for the '960 patent to be the mid-2005 time frame, including and up to July 21, 2005, which is the filing date of an application associated with the '960 patent. (Ex. 1001, Cover.) I may refer to this time frame in this declaration as the time of the alleged invention, the relevant time, or the time of the '960 patent.

22. Based on my knowledge and experience, I understand what a person of ordinary skill in the art would have known at the time of the alleged invention of the '960 patent. In my opinion, based on my review of the '960 patent, such a person would have had an undergraduate degree in electrical engineering or a related field, and at least two years of experience in antenna design or related technologies. (*See, e.g.,* Ex. 1001, 1:34–8:25 (discussing the background of the '960 patent), 8:29–14:25 (discussing the summary of the disclosure).) Alternatively, more education can supplement practical experience and vice versa.

23. My analysis of the '960 patent and my opinions in this declaration are from the perspective of one of ordinary skill in the art, as I have defined it above, at the time of the alleged invention for that patent

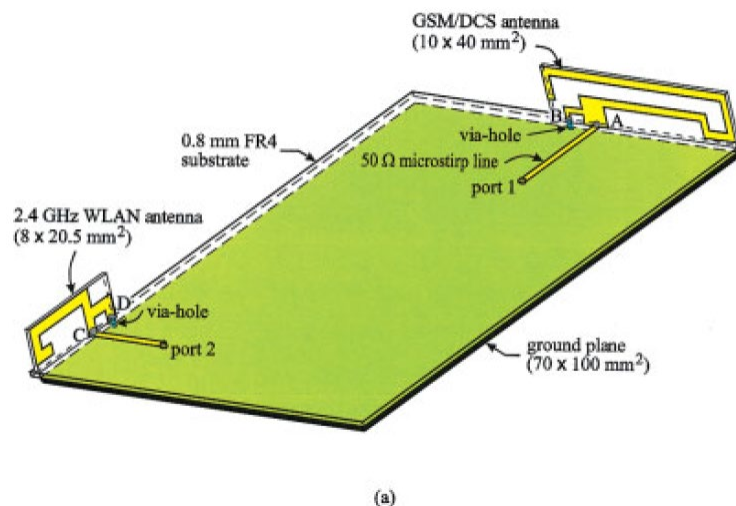
V. TECHNICAL BACKGROUND

24. In this section, I discuss the state of the art relevant to the subject matter of the '960 patent as would have been known, understood, and appreciated by a

person of ordinary skill in the art prior to and at the time of the alleged invention for the '960 patent (e.g., mid-2005 time frame, including and up to July 21, 2005, as I mentioned above in Section IV). I rely on and incorporate the understandings below regarding such known features and technologies to support my opinions regarding the knowledge of a person of ordinary skill in the art at the relevant timeframe and the motivations relating to how the prior art discloses and/or suggests the limitations of claims 1, 2, 3, 4, 5, 6, 7, 19, and 20 of the '960 patent. In my opinion, the understandings regarding the technologies, processes, and features as I discussed in this section (Section V) would have been in the mind of a person of ordinary skill in the art when contemplating the disclosures and/or suggestions in the prior art that I address below in Section IX and when considering combining features from that prior art in the manner that I explain below in that section.

25. At the time of the alleged invention, a person of ordinary skill in the art would have understood that portable wireless devices routinely employed one or more antennas mounted on or adjacent to a conductive ground plane—typically a printed circuit board (“PCB”) or printed wire board (“PWB”). Ex. 1020 (Wong) at Abstract, Figure 1(a). Such antennas were configured to transmit and receive electromagnetic waves within designated frequency bands corresponding to established communications standards, including cellular (e.g., GSM, CDMA, WCDMA), wireless local-area network (WLAN or Wi-Fi), Bluetooth, and GPS.

Ex. 1020 (Wong) at Abstract; *see also* Ex. 1018 (ThinkPad) at 3-4 (describing multiple options for wireless connectivity including 802.11b, 802.11b/g, 802.11a/b/g and Bluetooth); Ex. 1019 (Flybook) at 30 (describing multiple options for wireless connectivity including 802.11b, Bluetooth, and GPRS). For example, Figure 1(a), reproduced below, shows an exemplary configuration of an internal GSM/DCS and WLAN antennas for a PDA phone for cellular/WLAN dual-network operations.



Ex. 1020 (Wong) at Figure 1(a).

Figure 1(a) shows the promising internal GSM/DCS and WLAN antennas for a PDA phone. Both antennas are printed on 0.8-mm-thick FR4 substrate and are in the form of a PIFA with a folded radiating arm in order to achieve a compact structure [3]. The GSM/DCS antenna occupies a small area of 10 X 40 mm² and is fixed at the top edge of a system circuit board having a

ground plane of 100-mm length and 70-mm width in this study, which is a reasonable size for practical PDA phones. Also note that the GSM/DCS antenna is mounted perpendicularly to the system circuit board [4–6] and has a height of 10 mm only, which is less than the thickness of most PDA phones, thus making it possible to conceal the antenna within the casing of the PDA phone as an internal antenna. Given the design dimensions shown in Figure 1(b), the GSM/DCS antenna can generate two separate resonant modes at about 900 and 1800 MHz to cover the GSM (890–960 MHz) and DCS (1710–1880 MHz) bands.

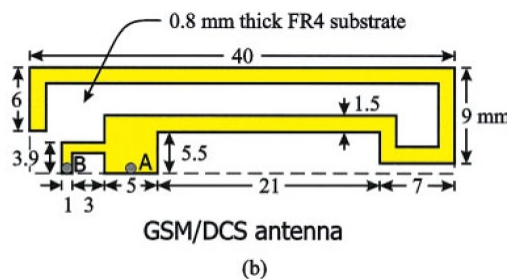
Ex. 1020 (Wong) at 348.

26. A person of ordinary skill in the art would have understood how to configure antennas to transmit and receive signals, and to operate across one or more frequency bands, either through structural tuning of a single radiating element or by using multiple discrete radiating elements. Compact inverted-F antennas (“IFA”) and planar inverted-F antennas (“PIFA”) were particularly well-suited to these requirements because of their low profile, tunability, and ease of integration with a ground plane.

In this paper, we present a study on the isolation of two promising internal antennas (one GSM/DCS antenna and one 2.4-GHz WLAN antenna) for a PDA phone for cellular/WLAN dual-network operations. **Both the GSM/DCS and WLAN antennas are printed PIFAs with compact sizes (see Fig. 1)**

and can be concealed within the casing of a PDA phone for operation as internal antennas. In this study, as in most conventional mobilephone- antenna designs [2], the GSM/DCS antenna is arranged to be fixed at the top edge of the system circuit board. The WLAN antenna is then mounted at various possible locations along the boundary of the system ground plane. At each possible location, the isolation between the GSM/DCS and WLAN antennas is measured and analyzed. The simulation results obtained using Ansoft high-frequency structure simulator (HFSS) simulation software are also presented for comparison. The optimized isolation between the two antennas is discussed.

Ex. 1020 (Wong) at 347–348 (emphasis added), Fig. 1(a). Multi-frequency antenna designs achieved multi-band operation by incorporating multiple radiating portions or branches, each tuned to a different frequency band, enabling simultaneous or selective operation across bands:



Ex. 1020 (Wong) at Figure 1(b), 348 (“the GSM/DCS antenna can generate two separate resonant modes at about 900 and 1800 MHz to cover the GSM (890–960 MHz) and DCS (1710–1880 MHz) bands.”); *see also* Ex. 1021 (Gaucher I) at

Abstract (describing a compact internal quad-band antenna for portable wireless devices that uses an F-shaped metal element and two L-shaped metal elements on a printed circuit board to provide WWAN coverage across the 800, 900, 1800, and 1900 MHz cellular bands, with the laptop display frame or metal supports serving as part of the antenna ground plane), ¶¶ 5 (“a compact sized integrated quadband antenna for portable devices used in wireless applications is provided to provide wireless wide area network quadband coverage for world wide applications.”), 28–30, FIG. 4; Ex. 1022 (Gaucher II) at Abstract, ¶¶ 1, 13, 39–41, 48, FIGS. 4, 5; Ex. 1017 (Ciais) at Abstract, Fig. 1.

27. The drive toward smaller and more feature-rich handsets created a well-recognized demand for compact internal antennas capable of covering multiple frequency bands simultaneously. For example, U.S. Patent No. 6,204,819 (Ex. 1012) described this context directly:

Radiotelephones generally refer to communications terminals which provide a wireless communications link to one or more other communications terminals. . . . **[R]adiotelephones and other wireless communications devices are undergoing miniaturization.** Indeed, many contemporary radiotelephones are less than 11 centimeters in length. As a result, there is increasing interest in small antennas that can be utilized as internally-mounted antennas for radiotelephones. . . . **In addition, it is becoming desirable for radiotelephones to be**

able to operate within multiple frequency bands in order to utilize more than one communications system. . . . In addition, radiotelephones may also incorporate Global Positioning System (GPS) technology and Bluetooth wireless technology. . . . Accordingly, radiotelephones incorporating these technologies may require additional antennas tuned for the particular frequencies of GPS and Bluetooth. . . . [I]t may be unrealistic to incorporate multiple antennas within a radiotelephone for aesthetic reasons as well as for space-constraint reasons. . . . **[S]ome way of isolating multiple antennas operating simultaneously in close proximity within a radiotelephone may also be necessary.** As such, a need exists for small, internal radiotelephone antennas that can operate within multiple frequency bands.

Ex. 1012 (Hayes) at 1:10–2:16 (emphasis added). This passage above captures the core engineering tension that defined the field at the time of the alleged invention: handsets were shrinking while the demand for simultaneous multi-band coverage, spanning cellular, GPS, and Bluetooth, was growing. Additionally, Wong (Ex. 1020) explains:

Integration of cellular and WLAN communication networks can provide users with ubiquitous or seamless data services [1]. For such an integrated cellular/WLAN network application, many dual- mode or dual-network wireless devices (such as PDA phones) are expected to emerge in the market in the near future.

For this application, it is required that a PDA phone be equipped with two antennas, for example, one GSM/DCS (890–960 MHz/1710–1880 MHz) antenna for cellular operation and one WLAN antenna for 2.4-GHz (2400–2484 MHz) WLAN operation [2]. However, due to the limited space available inside a PDA phone, special care is required for achieving optimized isolation between the two antennas in order to avoid performance degradation.

Ex. 1020 (Wong) at 347.

28. It was also well known that wireless devices frequently employed multiple antennas to improve overall performance through diversity techniques. Diversity systems, including spatial diversity and MIMO (multiple-input multiple-output) configurations, place two or more antenna elements on a common device so that each element receives or transmits signals with low correlation relative to the others, enabling the receiver to combine or select among signals to improve link reliability and mitigate multipath fading. The benefit of antenna diversity had long been understood. For example, U.S. Patent No. 6,518,929 explained:

One approach used to improve reception is called antenna diversity. Using antenna diversity, a receiver receives and combines input from two antennas. The antennas are “diverse” in that they are separated by a certain distance and/or have different polarizations so that the noise received at one antenna is substantially uncorrelated to the noise received at the other

antenna. A signal from a transmitter, however, is often substantially correlated at both antennas. By combining the inputs from the two antennas, the substantially correlated signals add and the substantially uncorrelated noise partially adds and partially subtracts. Consequently, the combined signal can nearly double while the combined noise will generally only increase by about half. Doubling the Signal while only increasing the noise by half can Substantially improve reception.

Ex. 1013 (U.S. Patent No. 6,518,929) at 1:49–63. Applying these diversity techniques to compact handheld devices, however, posed a well-recognized engineering challenge: “[k]nown antenna diversity approaches . . . have not been applied to small wireless communications technologies currently available and being developed. The small form factors that make many of these technologies attractive simply cannot accommodate known antenna diversity approaches.” *Id.* at 2:1–6.

29. A person of ordinary skill in the art would further have understood that the ground plane serves as the conductive reference surface that supports antenna operation and shapes radiation characteristics. Ex. 1020 (Wong) at 349, Figure 6. Ground planes inherently carry surface currents, electrical currents that flow along the conductive surface as a natural consequence of electromagnetic operation. *Id.* These surface currents propagate across the ground plane from one antenna’s grounding region to another, creating unwanted electromagnetic coupling between nearby antenna feed points. *Id.* This phenomenon, known as mutual coupling, was

well understood and extensively studied prior to the relevant date. Mutual coupling arises from shared surface currents, electromagnetic interaction between radiating elements, and the proximity of antenna feed points. *Id.* Wong (Ex. 1020) illustrates this phenomenon in Figure 6 (a) and (b) below:

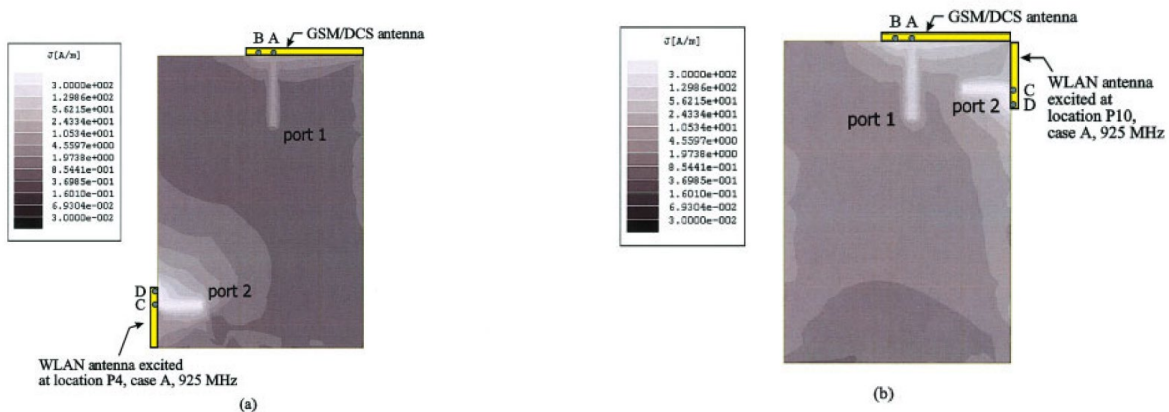


Figure 6 Simulated surface-current distributions in the system ground plane for case A; the WLAN antenna is excited at 925 MHz with the GSM/DCS antenna terminated to a 50Ω load: (a) at location P4; (b) at location P10. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

Ex. 1020 (Wong) at Fig. 6 (rearranged). Strong mutual coupling causes signal interference and degrades system performance in multi-antenna configurations. *Id.* This problem was especially pronounced in compact wireless devices where antenna spacing is inherently limited by the device's physical dimensions.

30. To address mutual coupling, the prior art also disclosed multiple well-known techniques for reducing inter-antenna current flow on a shared ground plane. These techniques fall into three principal categories, each exploiting a different

electromagnetic principle. *See, e.g.,* Ex. 1026 (Sievenpiper) at Abstract (“Specifically, coupling reduction is attempted using lossy material superstrates or ground plane discontinuities, such as slits.”); Ex. 1008 (Karaboikis) at 12-13 (describing $\lambda/4$ slots and a corrugated ground plane to reduce mutual coupling between antenna ports); Ex. 1025 (Georgakopoulos) at 2059–2060 (Section I.B) (describing high-impedance surfaces to alter its radio-frequency electromagnetic properties), Ex. 1025(Georgakopoulos) at Abstract, 264–269 (describing multiple antenna coupling-reduction techniques, including antenna orientation changes and ground-plane discontinuities such as slits, while noting design tradeoffs between coupling reduction and antenna gain); Ex. 1011 (Sanford) at 5:40–61.

31. First, engineers commonly introduced parasitic conductive elements or strips between antenna elements to alter current distribution and suppress coupling. Such structures act as resonant or blocking elements that reduce current flow between antennas and improve isolation. Ex. 1030 (Yang) at Abstract, 2945 (describing use of a mushroom-like electromagnetic band-gap (“EBG”) structure inserted between microstrip antenna elements to suppress surface waves and reduce mutual coupling without substantially increasing antenna size or sacrificing bandwidth); Ex. 1026 (Sievenpiper) at Abstract (describing high-impedance electromagnetic surfaces that suppress AC surface-current propagation and surface waves within selected frequency bands for use in low-profile antenna applications).

These conductive isolation structures were understood as alternatives to slot-based approaches because they could achieve comparable isolation performance without physically severing the ground plane.

32. Second, modifying the ground plane itself, by introducing slits or slots of controlled geometry, was a well-established technique for disrupting surface current paths and reducing coupling between antenna feed regions. A slot of effective length equal to one quarter-wavelength ($\lambda/4$) of the operating frequency presents a high-impedance boundary in the ground plane at that frequency, blocking coupled surface currents. Ex. 1008 (Karaboikis) at 12-13 (describing $\lambda/4$ slots and a corrugated ground plane to reduce mutual coupling between antenna ports).

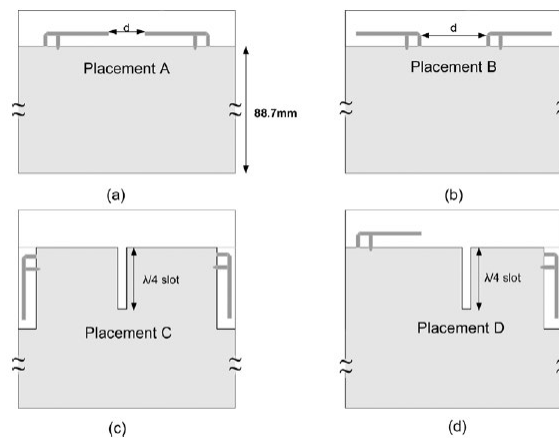


Fig. 7. The geometry of the four different antenna placements.

Ex. 1008 (Karaboikis) at Fig. 7. The mechanism underlying slot-based isolation, a 180-degree phase shift between conducted and radiated power that causes destructive cancellation at the receive antenna, was well understood by persons of ordinary skill in the art prior to the alleged invention. *E.g., id.* at 12 (describing the

use of the $\lambda/4$ slot can reduce mutual coupling to a sufficiently low level, allowing the dual-antenna system to function as a duplexer); Ex. 1005 (Karaboikis) ¶ 4.

33. Third, engineered high-impedance surfaces could create regions that inhibit the propagation of surface currents across the ground plane within specific frequency bands. Ex. 1025 (Georgakopoulos) at 2059–2060 (Section I.B). These structures, implemented through periodic conductive geometries or equivalent inductive/capacitive arrangements, function as electromagnetic filters that block surface current flow and reduce inter-antenna coupling. The relationship between soft surfaces (slot-type structures) and hard surfaces (conductive strip-type structures) as complementary tools for controlling surface wave propagation was well known in the art, with selection between them driven by PCB layout constraints and manufacturing considerations.

34. Multi-band PIFA designs covering cellular, GPS, and Bluetooth frequencies were likewise well established before the alleged invention. U.S. Patent No. 6,606,071 (Ex. 1010) illustrated the known technique of using multiple radiating conductors of different lengths to achieve resonance at distinct bands, with each branch dimensioned to approximately $\lambda/4$ at its target frequency. Ex. 1010 at 1:19-54. More advanced tri-band designs were also known. U.S. Patent No. 6,639,560 (Ex. 1015) described the challenge and solution directly:

The instant invention proposes a new technique for designing a single feed tri-band (dual cellular and non-cellular) PIFA which overcomes the enormity of the bandwidth requirement for its upper resonant band covering both upper cellular and non-cellular frequencies. The serious problem of the mutual coupling encountered in the dual feed multi-band PIFA is a non-entity in the proposed design scheme of this invention. . . . This invention proposes the placement of a shorted parasitic element internal to the dual cellular band PIFA structure to realize a third and an exclusive non-cellular resonant frequency band of the PIFA.”

Ex. 1015 (U.S. Patent No. 6,639,560) at 2:26–41. This passage confirms that the challenge of designing a compact, single-feed PIFA covering both cellular and non-cellular bands (including GPS and Bluetooth) was well recognized, and that a solution using internal parasitic elements was known to persons of ordinary skill in the art before the alleged invention.

35. Diversity antenna systems using PIFAs in compact handsets were also well known. U.S. Patent No. 7,109,923 (Ex. 1016) demonstrated that polarization diversity using PIFAs was viable in handsets because large antenna separations are not required, and showed that two co-located PIFA elements could achieve good diversity gain (5–9 dB) in a personal mobile communication terminal. Ex. 1016 at 1:48–59. The same reference acknowledged that size constraints posed a continuing

design challenge, driving interest in more compact diversity antenna arrangements.

Id. at 1:60–2:7.

36. In summary, prior to the alleged invention, a person of ordinary skill in the art would have understood that: (1) wireless devices commonly employed one or more antennas on a shared PCB ground plane, configured to transmit and receive signals in one or more frequency bands; (2) multiple antennas improve performance through diversity techniques, but their co-location on a common ground plane introduces mutual coupling as a well-known and extensively studied problem; (3) three categories of well-established solutions existed to reduce inter-antenna coupling, parasitic conductive elements or strips, slots or slits in the ground plane, and high-impedance surface structures; and (4) multi-band configurations covering cellular, GPS, and Bluetooth bands were routine and widely implemented in compact handheld form factors. A person of ordinary skill in the art would have been fully aware of each of these design principles and would have readily applied and combined them when addressing the engineering challenges presented by a given multi-band, multi-antenna handheld device. I rely on these understandings in my analysis of the prior art references and the challenged claims in Section IX below.

VI. THE '960 PATENT

37. The '960 Patent, titled “Handheld Device with Two Antennas, and Method of Covering with Two Antennas in a Handheld Device,” issued on January

29, 2013. Ex. 1001, cover page. I understand that the '960 patent issued from a continuation application of U.S. Patent Application No. 11/988,888, filed on September 30, 2008, which is a national-stage filing of International Patent Application No. PCT/EP2006/007050, filed on July 18, 2006. The PCT application claims priority to European Patent Application No. EP 05106694.2, filed on July 21, 2005. I have used July 21, 2005 as the date of the alleged invention of the Challenged Claims for purposes of my analysis and opinions.

38. The '960 patent “relates to a handset and generally to any handheld device, which includes an antenna for receiving and transmitting electromagnetic wave signals.” *Id.* at 1:26–28. The patent acknowledges that such handheld devices were well known in the art and depicts a known prior art handset in Figure 2. The prior art handset includes “a first antenna (201), placed on the top part of the first PCB (200), that operates at the frequency bands for mobile communications, and a second antenna (202) placed on the bottom right corner of the PCB (200) that operates at the frequency bands of the wireless connectivity services.” *Id.* at 3:22–27.

39. The '960 patent distinguishes its claimed invention from the prior art by requiring that the first antenna be configured to transmit and receive electromagnetic wave signals “in at least three frequency bands used for mobile

communication services.” *Id.* at cl. 1. The ’960 patent also discloses embodiments featuring a slot antenna as the second antenna. *Id.* at 14:52–59.

40. The ’960 patent further teaches that the first and second antennas are arranged such that (1) the first antenna extends parallel to a first side of a substantially rectangular ground plane, (2) the second antenna extends parallel to a second side of the substantially rectangular ground plane, (3) the first and second sides are substantially orthogonal, and (4) the first antenna is arranged near a short side of the ground plane. *Id.* at cl. 1.

41. Claims 1, 2, 3, 4, 5, 6, 7, 19, and 20 of the ’960 patent recite limitations relating to the features discussed above. As detailed below in Section IX, however, it is my opinion that all such features of the Challenged Claims were well-known in the art at the relevant time.

A. The challenged claims of the ’960 patent

42. I understand that claims 1, 2, 3, 4, 5, 6, 7, 19, and 20 of the ’960 patent are being challenged. These claims are reproduced below:

Claim 1

A handheld device comprising:

[a] a substantially rectangular ground plane;

[b] a first antenna configured to transmit and receive electromagnetic wave signals in at least three frequency bands used for mobile communication services;

[c] a second antenna configured to operate in at least one frequency band;

[d] the first antenna extends in a direction substantially parallel to a first side of the substantially rectangular ground plane;

[e] the second antenna extends in a direction substantially parallel to a second side of the substantially rectangular ground plane;

[f] the first antenna is arranged near a short side of the substantially rectangular ground plane; and

[g] the first side and the second side are substantially orthogonal.

Claim 2

The handheld device according to claim 1, wherein said handheld device further comprises at least one slot in the substantially rectangular ground plane, wherein said at least one slot is arranged for providing enhanced isolation between a feeding point of said first antenna and a feeding point of said second antenna by providing a high impedance path in said substantially rectangular ground plane between said feeding points in at least one frequency band corresponding to an operating band of one of said first and second antennas.

Claim 3

The handheld device according to claim 2, wherein said at least one slot in the substantially rectangular ground plane has an open end in correspondence with a perimeter of said substantially rectangular ground plane.

Claim 4

The handheld device according to claim 2, wherein said at least one slot has a length of approximately $(2N-1)*A/4$, wherein A is a wavelength corresponding to a frequency within said operating band, and N is an integer, $N>1$.

Claim 5

The handheld device according to claim 1, further comprising at least one conductive strip connected to the substantially rectangular ground plane, wherein said at least one conductive strip is arranged so as to provide a high impedance path in said substantially rectangular ground plane between a feeding point of said first antenna and a feeding point of said second antenna in at least one frequency band corresponding to an operating band of one of said first and second antennas.

Claim 6

6. The handheld device according to claim 5, wherein said at least one conductive strip has a length from its connection to the substantially rectangular ground plane, of approximately $(2N-1)*A/4$, wherein A is a wavelength corresponding to a frequency within said operating band, and N is an integer, $N>1$.

Claim 7

The handheld device according to claim 1, wherein the second antenna is arranged to operate in at least one frequency band used for a wireless service in accordance with Bluetooth™, IEEE802.11a, IEEE802.11b, IEEE802.11g, WLAN, WiFi, UWB, ZigBee, GPS, Galileo, SDARs, XDARS, WiMAX, DAB, FM, DVB-H, or DMB.

Claim 19

The handheld device according to claim 1, wherein the second antenna is arranged to operate in at least one frequency band used for a mobile communication service.

Claim 20

The handheld device according to claim 1, wherein the second antenna is selected from the group consisting of monopole antenna, PIFA, IFA, or patch antenna.

VII. CLAIM CONSTRUCTION

43. I have been asked to give the terms in the challenged claims their plain and ordinary meanings, as would have been understood by a person of ordinary skill in the art, at the time of the alleged invention, taking into consideration the language of the claims, the specification, and the prosecution history (Ex. 1004) of the '960 patent. I have applied these understandings of the claim terms in my analysis and in forming my opinions where appropriate in this Declaration.

44. I believe no express construction of any claim terms is necessary to assess whether the prior art reads on the challenged claims. The terms of the challenged claims are given their plain and ordinary meaning as a person of ordinary skill in the art would have understood them at the time of the alleged invention.

VIII. OVERVIEW OF THE PRIOR ART¹

45. Each of the below cited references relates generally to the field of antenna systems for mobile handheld devices, including multi-band antenna configurations for increased operating versatility. A person of ordinary skill in the art would have been aware of all of these references and recognized the common attributes among them, especially because each relates to improvements over traditional antenna systems that lacked the coverage across multiple frequency bands provided by the multiband antenna systems I discuss below.

A. Overview of Kangasvieri (Ex. 1005)

46. Kangasvieri (Ex. 1005) is directed to antenna structures and methods for improving isolation between antennas in compact, multi-band mobile terminals. Ex. 1005 ¶¶ 1, 3, 4, 66, 69. Kangasvieri addresses the technical problem of limited duplex separation between the transmit and receive frequency bands, which has conventionally necessitated bulky, lossy duplex filters. *Id.* ¶ 2. To overcome this issue, Kangasvieri teaches modifying the device's ground plane by "providing a cut

¹ These summaries of the prior art references in Section VIII are applicable to my analysis below in Section IX. Accordingly, I incorporate these summaries, which reflect how a person of ordinary skill in the art would have understood the references, into my analysis below where appropriate (*see, e.g.*, Section IX below).

in the ground plane for causing the conducted power in the ground plane to undergo a 180-degree phase shift with respect to the radiated power in air.” *Id.* ¶ 4, FIGS. 1,

47. Kangasvieri further teaches multiple antenna configurations, including embodiments in which a slot antenna is used and “the signal fed to the slot antenna undergoes a substantially 180-degree phase shift before it is coupled to the ground plane.” *Id.* ¶ 4, FIGS. 5a, 5b.

B. Overview of Chiba (Ex. 1006)

48. Chiba (Ex. 1006) is directed to a multifrequency inverted-F antenna for use as an internal antenna in compact radio communication devices, such as portable telephones. Ex. 1006 at 1:4-11; *see also id.* at Abstract. Specifically, a multifrequency inverted F-type antenna where “radio waves of multiple frequency bands can be received without increase in size to enable transmission and reception across multiple frequency bands without increasing antenna size or installation volume.” *Id.* at 2:33–36.

C. Overview of Vance (Ex. 1007)

49. Vance discloses multi-band planar inverted-F antennas (“PIFAs”) designed to support multiple resonant frequency bands in compact wireless handsets to serve cellular, GPS, and high band applications. Ex. 1007 at Abstract (reproduced below), 1:55–66 (reproduced below), 5:12-34, 5:40-55(reproduced below).

Antennas and wireless terminals that incorporating the antennas include conductive elements that have a looped track element that can resonate at high and low bands to provide **a multi-band PIFA**.

Id. at Abstract.

Furthermore, it may be desirable for a wireless terminal to operate within multiple frequency bands in order to utilize more than one communications system.

For example, Global System for Mobile communication (GSM) is a digital mobile telephone system that typically operates at a low frequency band, such as between 880 MHz and 960 MHz. Digital Communications System (DCS) is a digital mobile telephone system that typically operates at high frequency bands, such as between 1710 MHz and 1880 MHz. In addition, global positioning systems (GPS) or Bluetooth systems use frequencies of 1.575 or 2.4-2.48 GHz. The frequency bands allocated for mobile terminals in North America include 824-894 MHz for Advanced Mobile Phone Service (AMPS) and 1850-1990 MHz for Personal Communication Services (PCS). Other frequency bands are used in other jurisdictions. Accordingly, internal antennas are being provided for operation within multiple frequency bands.

Id. at 1:25-43 (emphasis added).

Embodiments of the present invention provide antennas for communications devices and wireless terminals. The antennas include a looped conductive planar element that may be particularly suitable for a planar inverted-F antenna (PIFA) element.

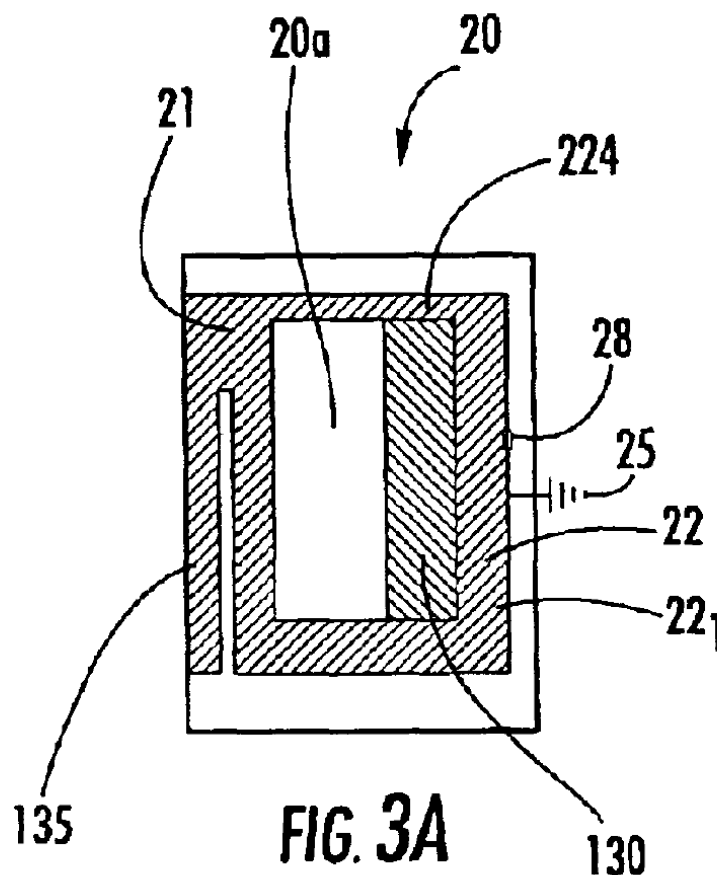
In certain embodiments, **planar inverted-F antennas are configured to operate at a plurality of resonant frequency bandwidths of operation** (typically between about 2-4) and include: (a) a signal feed; (b) a ground feed; and (c) a looped conductive element in communication with the signal and ground feed.

Id. at 1:56-66 (emphasis added).

In certain embodiments, the antenna may be configured to provide resonance for a global positioning system (GPS) as the terminal into which this antenna is to be built, can include a GPS receiver. GPS operates at approximately 1,575 MHz. GPS is well known to those skilled in the art. GPS is a space-based triangulation system using satellites and computers to measure positions anywhere on the earth. Compared to other land-based systems, GPS is less limited in its coverage, typically provides continuous twenty-four hour coverage regardless of weather conditions, and is highly accurate. In the current implementation, a constellation of twenty-four satellites that orbit the earth continually emit the GPS radio frequency. **The additional resonance of the antenna as described above permits the antenna to be used to receive these GPS signals.**

Id. at 5:40-55 (emphasis added).

50. FIG. 3A (reproduced below) depicts a planar inverted-F antenna that is configured to operate at three distinct resonance bands. *Id.* at 3:27-30 (“FIG. 3A is a top view of a planar inverted-F antenna according to additional embodiments of the present invention.”), 9:20-42 (excerpt below).



Id. at FIG. 3A. The planar inverted-F antenna 20, depicted above in FIG. 3A, comprises a looped track/conductive element 22, a feed 28, and a ground 25. *Id.* at 9:21-42. The planar inverted-F antenna 20, depicted above in FIG. 3A, achieves three concurrent resonance bands through a single integrated conductive structure:

(1) low band A ($\approx 824\text{--}894$ MHz) produced by the $\lambda/4$ resonance of the looped track;
(2) high band B (≈ 1575 MHz, GPS) produced by the secondary branch 135 formed from the slotted left side of the looped track; and (3) high band B' ($\approx 2.1\text{--}2.4$ GHz) produced by higher-order resonance of the looped track itself, broadened by the extra-width element 130. *Id.*; *see also id.* at 2:49–60 (reproduced below), FIG. 3B (reproduced below).

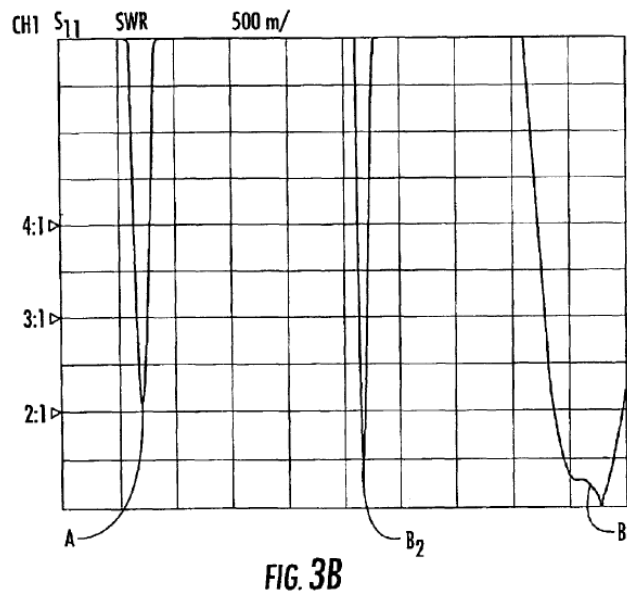
FIG. 3A is another embodiment of an antenna 20 with a looped track 22. In this embodiment, the antenna 20 is configured to generate three resonance bands, a low band “A” at between about 824-894 MHz, and two high bands B₁, B₂. The high bands can be tuned so that one is at 1575 MHz and one at 2.1-2.4 GHz (the higher band being B₁ and primarily attributed to the looped track 22). The antenna 20 includes a secondary band branch 135 (which creates band B₂ at the GPS resonance (1575 MHz) and can widen the high-band resonance). The high band range can be broadened by thickening (increasing the area or the width of the conductive trace) maximal current regions of the radiating element 22. The secondary branch 135 can be formed by slotting or splitting the left side (leg 22 3) of the looped element 22 and can provide additional bandwidth, as well as an additional resonant frequency. The additional resonant frequency can be tuned by adjusting the length of the slot used to create the secondary branch 135. As shown, the first side 22 1 has an extra-strip or width of track 130 that, in operation, can

form part of the high band and low band resonators. In certain embodiments, the extra thickness may provide increased bandwidth in high band operation.

Id. at 9:21–43 (emphasis added).

Still other embodiments are directed to methods for exciting a planar inverted F antenna having low and high band operational modes. The method includes: (a) providing a conductive element with a looped track element, the looped track element configured to form about a $\frac{1}{4}$ wave resonator at a low frequency band and about a $\frac{1}{2}$ wave resonator at a high frequency band; (b) generating a current null along at least one portion of the looped track at a selected low band operation; and (c) generating a current null at two spaced apart portions (typically substantially opposing sides) of the looped track at a selected high band operation.

Id. at 2:49–60.



Id. at FIG. 3B; *see also id.* at 30–32 (“FIG. 3B is a VSWR graph of the antenna shown in FIG. 3A positioned at about 3 mm from the ground plane.”), 9:44–52.

51. FIG. 3C (below) confirms the GPS-band performance, depicting an exemplary radiation pattern measured at approximately 1580 MHz, with peak gain values of -1.23 , -2.3 , and -0.85 dbi in the front, side, and azimuth directions, respectively. *Id.* at 9:51–58.

ANTENNA RADIATION PATTERN (3 mm HEIGHT)
1580 Mhz (GPS):

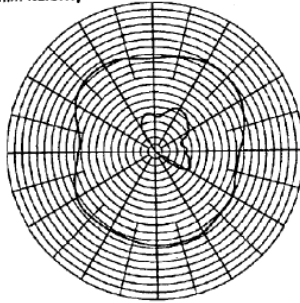


FIG. 3C

2.1 GHZ

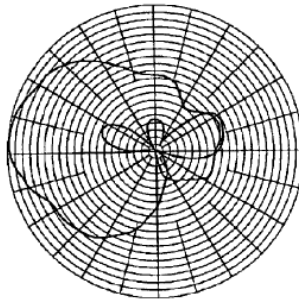


FIG. 3D

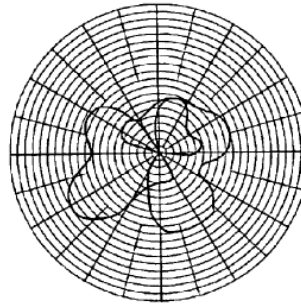


FIG. 3E

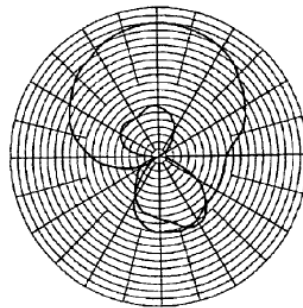


FIG. 3F

Id. at FIGS. 3C–3F; *see also id.* at 3:33–35 (“FIG. 3C is a polar coordinate graph of a front elevation radiation pattern at 1580 MHz (GPS) of the antenna shown in FIG. 3A measured at about a 3 mm antenna height.”), 3:36–40 (“FIGS. 3D–3F are polar coordinate graphs of a front elevation, side elevation, and azimuth directions, respectively, of the radiation pattern

at 2.1 GHz of the antenna shown in FIG. 3A measured at about a 3 mm antenna height.”), 9:54-63.

D. Overview of Inoue (Ex. 1009)

52. Inoue (Ex. 1009) teaches suppression of mutual coupling between adjacent antenna elements using a conductive structure connected to the ground plane rather than a slot formed in the ground plane as discussed by Kangasvieri (Ex. 1005):

This paper investigates a liner array antenna suppressed mutual coupling and variation between elements. If the mutual coupling is suppressed, the distortion of the element pattern and the effect of arrangement error of elements could be suppressed, and good performance could be realized without calibration of antenna. The array antenna system is evaluated with DOA estimation of ESPRIT method [4] in this paper. In section 2, the relation between coupling matrix of an array antenna and DOA estimation error is evaluated in computer simulation, and clarify the range of mutual coupling to minimize the estimation error. In section 3, **microstrip patch array antenna with boxy metallic wall is designed and estimation error in ESPRIT is examined in a measurement of DOA estimation in anechoic chamber using the array antenna.**

Ex. 1009 at Abstract; *see also id.* at 17–18 (§ 1 Introduction).

53. Specifically, Inoue investigates a linear array antenna designed to improve direction-of-arrival (“DOA”) estimation by reducing mutual coupling between elements and discloses a microstrip patch array antenna employing a “boxy metallic wall” around each microstrip patch. *Id.* at 17-18. Inoue expressly states that “mutual coupling of this antenna is suppressed by the boxy metallic wall around the microstrip patch,” and further explains that “[t]he wall is connected to the ground plane of the microstrip antenna.” *Id.* at 18. Figure 5 below illustrates the boxy metallic wall around the patch antenna:

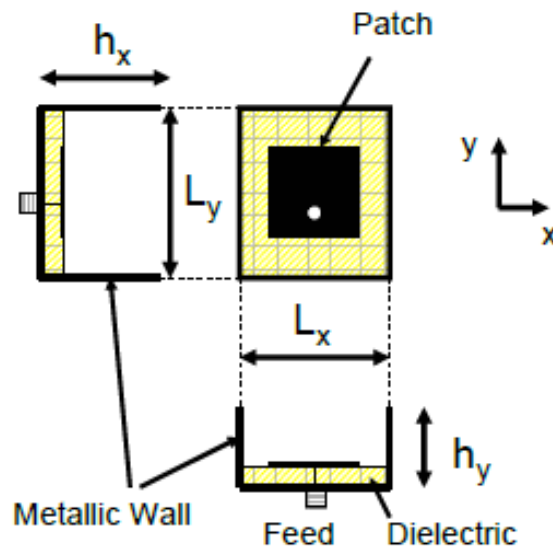


Fig. 5: Boxy metallic wall microstrip antenna.

Id. at Fig. 5. Inoue explains:

Fig. 5 shows the configuration of an element of the array antenna. Mutual coupling of this antenna is suppressed by the boxy metallic wall around the microstrip patch. The wall is connected to the ground plane of the microstrip antenna.

Id. at 18 (excerpted). Figure 6 below illustrates four patch array antenna elements that are arrayed by half wave length interval on the ground plane:

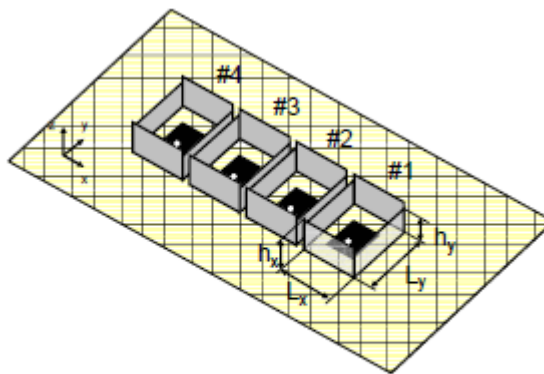


Fig.6: 4 elements liner array antenna with half wavelength interval.

Id. at Fig. 6. Inoue teaches that the dimensions of the metallic wall are selected relative to wavelength to optimize isolation performance:

The size of the wall L_x , L_y , h_x and h_y was optimized with computer simulation to achieve -30dB of mutual coupling between neighboring elements. The optimized parameter is $L_x=0.4\lambda$, $L_y=0.5\lambda$, $h_x=0.25\lambda$ and $h_y=0.2\lambda$ to obtain -33dB of maximum of mutual coupling in experiment at 5GHz.

Id. at 18 (excerpted).

**IX. THE PRIOR ART DISCLOSES ALL OF THE FEATURES OF
CLAIMS 1–7 AND 19–20 OF THE '960 PATENT**

54. As established below, it is my opinion that all features of the Challenged Claims were well known in the prior art.

A. Kangasvieri and Chiba disclose and suggest the features of claims 1–4 and 19–20

55. In my opinion, Kangasvieri and Chiba disclose and/or suggest all of the claim elements of claims 1–4 and 19–20. Below, I address each claim element of the claims.

1. Claim 1

a) A handheld device comprising:

56. I have been asked to assume the preamble of claim 1 is limiting. Under that assumption, it is my opinion that Kangasvieri discloses the preamble of claim 1 and the limitations therein.

57. For example, Kangasvieri (Ex. 1005) discloses a mobile terminal, such as a multi-band phone 200 as shown in Figure 4 below. Ex. 1005 ¶¶ 1 (“The present invention relates generally to an antenna structure and, more particularly, to an antenna structure for use in a *mobile terminal*.”), 35, 60 (“FIG. 4 is a schematic representation of a mobile phone having an improved antenna structure, according to the present invention.”), 69 (“FIG. 4 is a schematic representation of a multi-band mobile phone 200, according to the present invention.”). A person of ordinary skill

in the art would have thus understood that Kangasvieri's mobile terminal is a handheld device as claimed.

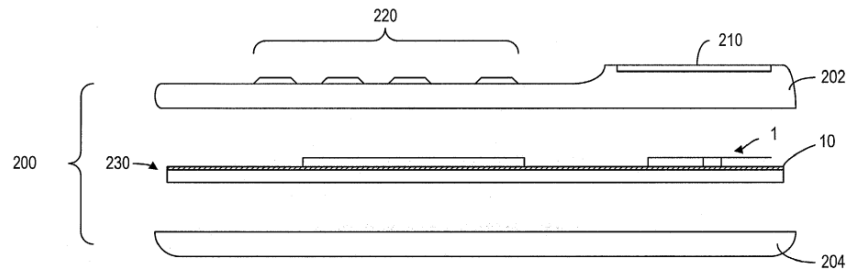


FIG. 4

Ex. 1005, FIG. 4. A person of ordinary skill in the art would have thus understood that Kangasvieri's mobile terminal, such as a multi-band phone 200 as shown in Figure 4, is a handheld device, as claimed.

58. Thus, in my opinion, Kangasvieri discloses "[a] handheld device," as claimed. *See* below at Sections IX.A.1.b-h.

b) a substantially rectangular ground plane;

59. Kangasvieri discloses this limitation. For the same reasons I discussed above for claim limitation 1.a, Kangasvieri discloses a mobile terminal, such as a multi-band phone 200 as shown in Figure 4. As I discuss below, Kangasvieri further discloses the multi-band phone 200 includes a printed wire board (PWB) with a substantially rectangular ground plane.

60. For example, Kangasvieri discloses that a ground plane 10, highlighted in yellow in Figure 4 below, on the upper side of a printed wire board 230. Ex. 1005 ¶ 69 (reproduced below).

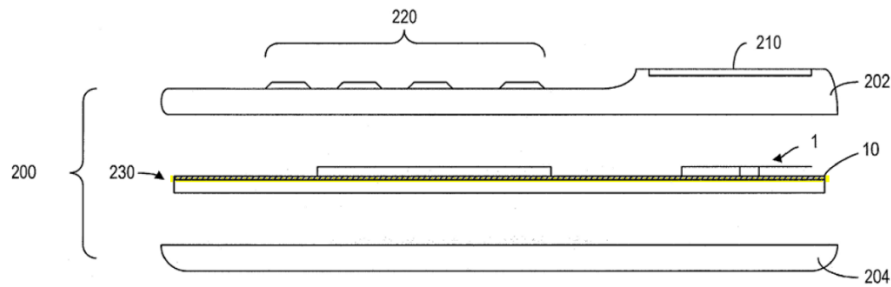


FIG. 4

Id., FIG. 4 (Annotated).

FIG. 4 is a schematic representation of a multi-band mobile phone 200, according to the present invention. **As shown, the mobile phone has an upper body 202 and a lower body 204 to accommodate a PWB (printed wire board) 230.** As in most mobile phones, the upper body has a keypad 220 and a display 210. According to the present invention, the PWB 230 has an antenna system 1 disposed thereon. **As shown in FIG. 4, the ground plane 10 of the antenna system is on the upper side of the PWB 230.** Typically, there would be more than one ground plane in a mobile phone PWB. In that case, all the ground planes in the PWB must be cut to provide the slot 20, as shown in FIGS. 1-3 d. However, the ground plane 10, according to the present invention, is the ground plane that is used to short-circuit the relevant antennas.

Id. ¶ 69 (emphasis added).

61. As shown in Figure 2, below, the ground plane 10, when viewed without regard to slot 20, is bounded by four outer edges forming corners labeled A, B, C, and D.

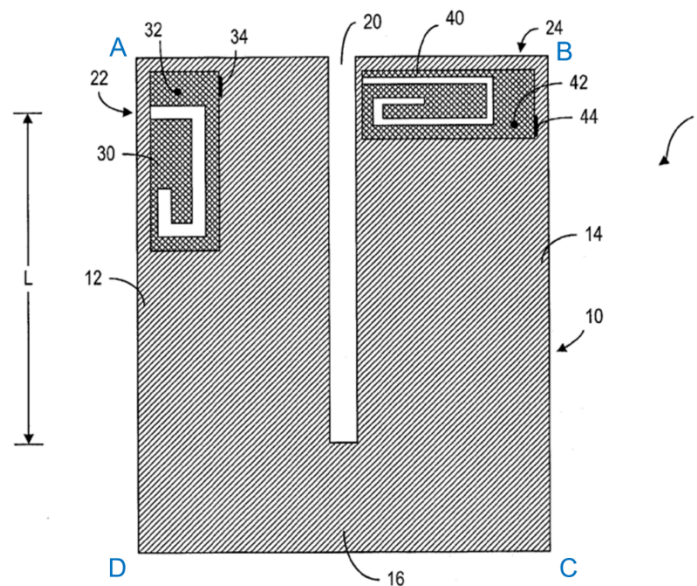


FIG. 2

Id., FIG. 2 (annotated). FIG. 2 is a schematic representation showing the top view of the antenna structure of FIG. 1. *Id.* ¶ 55.

62. These corners A, B, C, and D of the ground plane, as illustrated in Figure 2 above, define an outer perimeter consisting of four generally straight sides arranged in opposing pairs, with adjacent sides meeting at approximately right angles. A person of ordinary skill in the art would have understood that this outer boundary defines a substantially rectangular geometry, notwithstanding the presence

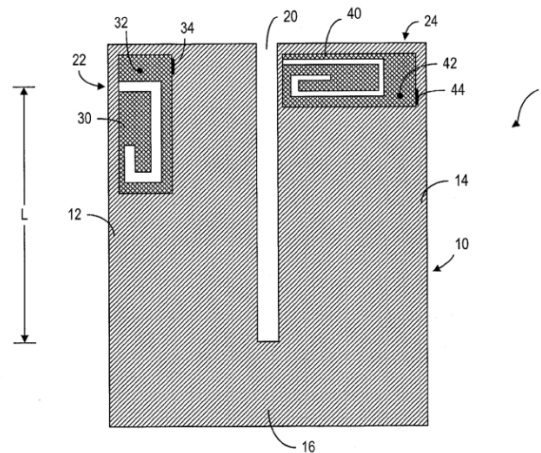
of the slot 20, which is an internal feature that does not alter the overall external shape of the ground plane. Accordingly, such a skilled person would have understood that the ground plane 10 in Figure 2 constitutes a “substantially rectangular” structure.

63. Thus, in my opinion, Kangasvieri discloses “a substantially rectangular ground plane,” as claimed

c) a first antenna configured to transmit and receive electromagnetic wave signals in at least three frequency bands used for mobile communication services;

64. The Kangasvieri-Chiba combination teaches and/or suggests this limitation.

65. For the same reasons I discussed above for claim limitation 1.a, Kangasvieri discloses a mobile terminal, such as a multi-band phone 200 as shown in Figure 4. *See* my discussion above at Section IX.A.1.a. Kangasvieri further discloses “the PWB 230 has an antenna system 1 disposed thereon,” where “the ground plane 10 of the antenna system is on the upper side of the PWB 230.” Ex. 1005 ¶ 69, FIG. 4. Kangasvieri, for example, teaches that the antenna system, with reference to Figure 2 below, includes “a first antenna 22 and a second antenna 24.” *Id.* ¶ 65.



Id., FIG. 2.

66. Kangasvieri explains that the antennas 22 and 24 as represented in Figure 2 above are each a planar inverted-F antenna (“PIFA”). *Id.* ¶ 71; *see also id.* ¶¶ 4, 63. Additionally, Kangasvieri discloses that antennas 22 and 24 operate in frequency bands used for mobile communication services: “For example, in PCS band, the transmit frequency band is in the range of 1850-1910 MHz, and the receive frequency band is in the range of 1930-1990 MHz. Systems such as CDMA IS-95, GSM-1900 and WCDMA-1900 are operated in this particular frequency band.” *Id.* ¶ 65.

67. Kangasvieri further teaches a multiple frequency band antenna system that is configured to transmit and receive electromagnetic wave signals. For example, Kangasvieri teaches that “[a]dvantageously, the first antenna (80) is a *multiple-band antenna operating in at least a first frequency band and a second*

frequency band different from the first frequency band.” Ex. 1005 ¶ 48 (emphasis added); *see also id.* ¶ 69 (“FIG. 4 is a schematic representation of a multi-band mobile phone 200, according to the present invention.”), cl. 17 (“the first antenna (80) is a multiple-band antenna operating in at least a first frequency band and a second frequency band different from the first frequency band”). Additionally, Kangasvieri teaches that “[i]n a multi-band mobile terminal, it is possible to use one PIFA and one *dual-band* slot antenna.” *Id.* ¶ 72 (emphasis added).

68. Kangasvieri, however, does not explicitly disclose “a first antenna configured to transmit and receive electromagnetic wave signals *in at least three frequency bands used for mobile communication services*.” As I discuss below, however, a person of ordinary skill in the art would have been motivated to implement Kangasvieri’s mobile device with a first antenna configured to transmit and receive electromagnetic wave signals *in at least three frequency bands used for mobile communication services* based on the teachings and suggestions of Chiba and the knowledge of such a skilled person.

(1) Chiba’s teachings (Ex. 1006)

69. Chiba (Ex. 1006) teaches an antenna configured to transmit and receive electromagnetic wave signals in at least three frequency bands used for mobile communication services.

70. For example, Chiba teaches a multifrequency inverted F-type antenna “used as an internal antenna of small, thin radio communication terminals such as, chiefly, portable telephones, and more particularly, it relates to a multifrequency inverted F-type antenna capable of receiving radio waves in multiple frequency bands without increasing its size.” Ex. 1006 at 1:4–10; *see also id.* at Abstract (“A multifrequency inverted F-type antenna which can receive [multifrequency] band radio waves without the enlargement of its shape.”). Figure 14 below illustrates the multifrequency inverted F-type antenna that is “capable of receiving radio waves of three different frequency bands, namely, a first frequency band determined by the shape of the first emission conductor 142-1, a second frequency band determined by the shape of the second emission conductor 142-2, and a third frequency band determined by the shape of the third emission conductor 142-3.” *Id.* at 9:41–58.

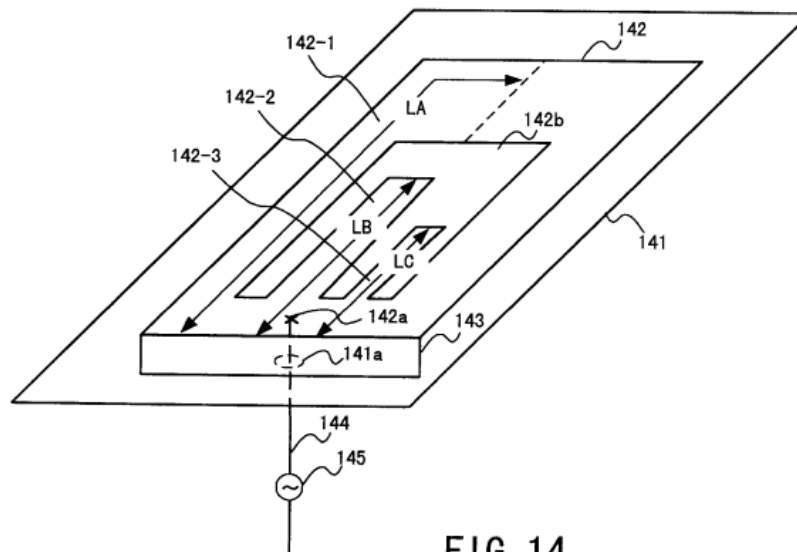


FIG. 14

Id. at FIG. 14.

71. Chiba further explains that “multifrequency inverted F-type antenna
120 according to the second embodiment is capable of receiving radio waves in the
three frequency bands, namely, first frequency band, second frequency band and
third frequency band, without increasing either the installation area or installation
volume.” *Id.* at 10:1–6.

72. A person of ordinary skill in the art would have understood that the multifrequency inverted F-type antenna, as illustrated in Figure 14, above is a PIFA. For example, Figure 14 depicts a planar radiating conductor 142 arranged substantially parallel to a ground conductor 141, with the planar radiating conductor 142 spaced above the ground plane by a short-circuit plate 143. *Id.* at FIG. 14; *see*

also id. at 9:40–58. Such a skilled person would have recognized that such a configuration, namely, a flat planar radiating conductor positioned parallel to a ground plane along with a grounding short-circuit plate at one edge and excitation placed at an intermediate point is a structural architecture for a PIFA. Accordingly, based on the geometry shown in Figure 14 and the accompanying description in the specification, a person of ordinary skill in the art would have recognized antenna 120 as a multifrequency implementation of the well-known PIFA architecture.

73. Such a skilled person, furthermore, would have understood that Chiba’s multifrequency inverted F-type antenna 120 is capable of both transmitting and receiving radio-frequency signals in three frequency bands. Although portions of Chiba occasionally emphasize “receiving,” the specification makes clear that the antenna is intended for use in portable telephones and radio communication terminals, which are inherently two-way communication devices. *Id.* at 1:4–10; *see also id.* at Abstract. Indeed, Chiba states in reference to other related embodiment of the multifrequency inverted F-type antenna that the antenna supports “sending and receiving,” such as sending and receiving GSM and PHS. *Id.* at 6:51–62 (“The multifrequency inverted F-type antenna 30 shown in FIG. 3 may be assumed to be the internal antenna of a portable telephone constituting a dual-mode terminal capable of *sending and receiving* under the two systems”) (emphasis added); *see also id.* at 14:29–34 (Chiba further describes matching the antenna to a

“sending/receiving circuit.”).² These disclosures confirm that antenna 120 in Figure 14 is designed for both send and receive operations for mobile communication services rather than receive-only functionality.

74. Moreover, under the well-established principle of antenna reciprocity, an antenna structure that resonates and receives at a given frequency will likewise transmit at the same frequency when coupled to an appropriate transmitter. Ex. 1014 (Gagnon) at 10:18–21 (“it will be appreciated that antenna reciprocity applies, meaning that the receiver and the transmitter are interchangeable”); Ex. 1027 (Tehrani) at 15:48–59 (“In addition, once a transmit antenna is found that can successfully transmit a packet to a receive antenna, antenna reciprocity usually holds. That is, a packet that is transmitted from the receive antenna can usually be received well by the antenna that had been used to transmit the previous packet.”); Ex. 1031 (Balanis) at 144, 147)³. Additionally, Figure 14, above, shows multiple

² A person of ordinary skill in the art would have understood that the structural configuration shown in Figure 3, which is a planar radiating conductor disposed above a ground plane, is the same PIFA architecture illustrated in Figure 14. The multifrequency inverted F-type antenna 120 of Figure 14 simply adds additional resonant paths to enable operation in additional frequency bands. *Compare* Ex. 1006 FIG. 3 *with* FIG. 14. Accordingly, such a skilled person would have understood that the multifrequency inverted F-type antenna of Figure 14, like the dual-band antenna of Figure 3, is capable of both transmitting and receiving signals in its respective frequency bands.

³ I refer to Exhibits 1014, 1027, 1031 here and elsewhere to demonstrate the knowledge of one of ordinary skill in the art at the time.

radiating elements configured to resonate at distinct frequency bands, and a person of ordinary skill in the art would therefore have understood that antenna 120 is capable of both sending and receiving radio waves in at least three frequency bands.

75. Thus, in my opinion, Chiba teaches an antenna “configured to transmit and receive electromagnetic wave signals in at least three frequency bands used for mobile communication services,” along with the advantages of using such an antenna. Ex. 1006 at 10:1–6. And as I discuss below, it would have been motivated to replace the first antenna with Chiba’s antenna in Kangasvieri’s mobile terminal. *See my discussion below at Section IX.A.1.c.2.*

(2) Reasons to Combine Features of Kangasvieri and Chiba

76. It is my opinion that based on the disclosures and suggestions in Kangasvieri and Chiba, and the knowledge of a person of ordinary skill in the art at the time, such a skilled person would have had reasons to consider and have been motivated to configure and implement the mobile terminal in Kangasvieri (as I discussed above for claim limitation 1.a) so that its first antenna is a multifrequency inverted F-type antenna capable of sending and receiving radio waves in the *three frequency bands* used for mobile communication services as claimed. Furthermore, such an implementation would have been a straightforward combination of well-

known technologies using known methods in the field of antenna system design, and such combination would have had foreseeable results.

77. A person of ordinary skill in the art would have recognized that Chiba and Kangasvieri disclose features in a similar technological field. *See also* my discussions above in Section V.A–G (overview of antenna systems), VIII.A (overview of Kangasvieri), and VIII.B (overview of Chiba). For example, as I discussed above, both Kangasvieri and Chiba related to improving mobile terminals through enhanced antenna structures, including antennas configured to operate in multiple frequency bands. Ex. 1005 ¶¶ 69, 72; Ex. 1006 at 10:1–6. Accordingly, such a skilled person would have had reason to consider the teachings of Chiba when implementing Kangasvieri’s mobile terminal, given that Chiba discloses the benefits of employing a PIFA capable of operation in three or more frequency bands within a mobile communication system of the type disclosed in Kangasvieri.

78. A person of ordinary skill in the art would have recognized that incorporating Chiba’s teachings regarding a PIFA configured to operate in three or more frequency bands into Kangasvieri’s mobile terminal would have enabled the combined mobile terminal to operate across additional frequency bands without significantly increasing the antenna footprint on the ground plane. For the same reasons I discussed above, Chiba expressly teaches that its multifrequency inverted-F antenna achieves multi-band performance while maintaining compact dimensions.

Ex. 1006 at 10:1–6. Given Kangasvieri’s mobile terminal architecture and the known industry demand for supporting multiple communication standards within limited space constraints, a person of ordinary skill in the art would have appreciated the benefit of implementing Chiba’s multi-band PIFA to enhance frequency capability while preserving form factor. *See* my discussion above at Section IX.A.1.c.1.

79. That is, given Kangasvieri’s mobile terminal supporting multiple frequency bands, as I have discussed above with reference to Figure 4 of Kangasvieri, a person of ordinary skill in the art would have appreciated that the advantages associated with implementing a PIFA configured to operate in three frequency bands, as taught by Chiba, would likewise apply to Kangasvieri’s mobile terminal. A person of ordinary skill in the art would have been further driven by the industry demand at the time of the invention for smaller, more feature-rich handsets incorporating compact internal antennas capable of simultaneously covering multiple frequency bands. Ex. 1012 (Hayes) at 1:10–2:16 (“In addition, it is becoming desirable for radiotelephones to be able to operate within multiple frequency bands in order to utilize more than one communications system.”).⁴

⁴ I refer to Exhibit 1012 here and elsewhere to demonstrate the knowledge of one of ordinary skill in the art at the time.

80. Furthermore, replacing Kangasvieri's PIFA with Chiba's multifrequency PIFA would have been a straightforward and predictable modification to the mobile terminal. Indeed, both references utilize planar inverted-F antennas having the same fundamental architecture, e.g., a planar radiating element disposed above a ground plane. Ex. 1005 ¶ 71; Ex. 1006 at 10:1–6. Additionally, Chiba expressly teaches that its multifrequency PIFA achieves operation in three frequency bands without increasing the antenna's footprint or volume relative to conventional single-band PIFAs. Ex. 1006 at 10:1–6. Thus, replacing Kangasvieri's PIFA with Chiba's similarly sized multifrequency PIFA would not have required a substantial structural redesign of the mobile terminal or expansion of the ground plane. Put simply, this modification would predictably increase the number of supported frequency bands while maintaining the same or similar compact form factor.

81. Furthermore, implementing an antenna configured to operate in three or more frequency bands in the combined system would have been a straightforward application of established antenna design principles for mobile terminals to achieve the foreseeable result of a mobile terminal capable of operating across additional communication bands while maintaining the compact form factor required in handheld devices. A person of ordinary skill in the art, exercising ordinary skill, would have readily configured Kangasvieri's terminal to incorporate such a

multifrequency PIFA consistent with routine design considerations and established antenna principles. Thus, such a skilled person would have had a reasonable expectation of success in the above modification.

82. Thus, in my opinion, the combination of Kangasvieri and Chiba teaches and/or suggests “a first antenna configured to transmit and receive electromagnetic wave signals in at least three frequency bands used for mobile communication services,” as claimed.

d) a second antenna configured to operate in at least one frequency band;

83. The Kangasvieri-Chiba combination teaches and/or suggests this limitation.

84. For example, as I discussed above, Kangasvieri teaches a mobile terminal including both a first and second antenna. *See* my discussion above at Section IX.A.1.c. In particular, Kangasvieri teaches a “second antenna 24,” shown in Figure 2 below, that operates in at least one frequency band. Ex. 1005 ¶ 65.

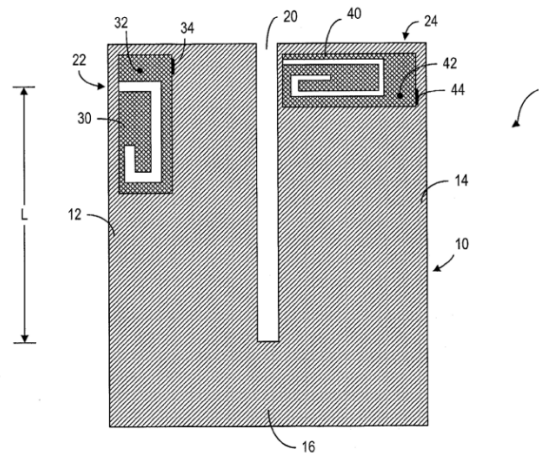


FIG. 2

Ex. 1005, FIG. 2.

85. Kangasvieri further explains that in a multi-band mobile terminal, the first antenna may cover the PCS band and another lower frequency band (e.g., GSM 850), while the second antenna is used to cover the PCS Band. *Id.* ¶ 72. Thus, Kangasvieri teaches a second antenna configured to operate in at least one frequency band, as required by the claim.

86. It is my opinion that combining Chiba with Kangasvieri's mobile terminal would not eliminate or materially alter Kangasvieri's second antenna. As discussed above, Chiba is relied upon only for its teaching of replacing Kangasvieri's first antenna with a multi-frequency PIFA capable of operating in three or more frequency bands. *See* my discussion above at Section IX.A.1.c. The second antenna disclosed in Kangasvieri would remain present in the combined mobile terminal and would continue to operate in at least one frequency band, consistent with Kangasvieri's disclosure. A person of ordinary skill in the art,

therefore, would have understood that substituting Chiba's multi-frequency PIFA for Kangasvieri's first antenna would not affect the structure, placement, orientation, or operation of Kangasvieri's second antenna.

87. Thus, in my opinion, the combination of Kangasvieri and Chiba teaches and/or suggests "a second antenna configured to operate in at least one frequency band," as claimed.

e) the first antenna extends in a direction substantially parallel to a first side of the substantially rectangular ground plane;

88. The Kangasvieri-Chiba combination teaches and/or suggests this limitation. For example, as I discussed above, the mobile terminal includes a first and second antenna arranged on ground plane 10. *See* my discussion above at Section IX.A.1.c.

89. Figure 2 of Kangasvieri, annotated, illustrates a printed circuit board including a ground plane 10 having a substantially rectangular shape, defined by corners A, B, C, and D as annotated. Ex. 1005, FIG. 2. For clarity, side AD (shown in blue) is identified as the claimed "first side" of the substantially rectangular ground plane, where side AD extends vertically between corners A and D.

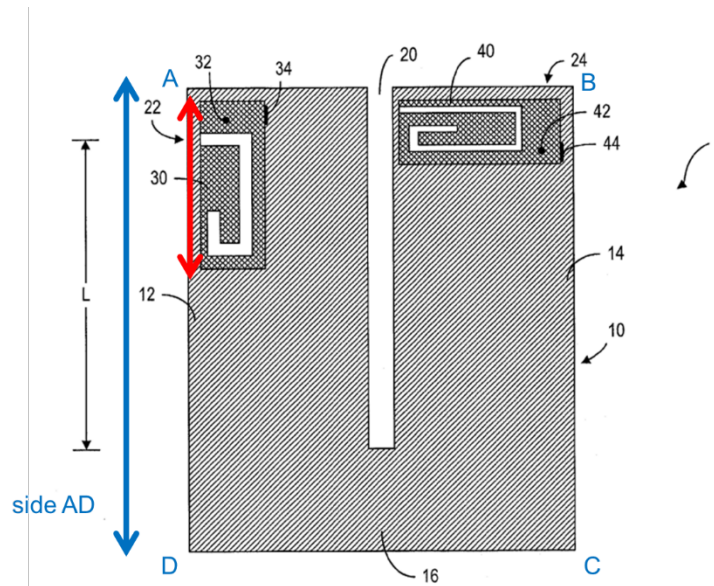


FIG. 2

Id., FIG. 2 (annotated).

90. Additionally, the first antenna 30, as shown in Figure 2, is disposed adjacent to the upper left region of the ground plane 10. Specifically, as shown by the red arrow overlay, the first antenna extends primarily vertically, parallel to side AD of the rectangular ground plane 10.

91. It is my opinion that combining Chiba with Kangasvieri's mobile terminal would not materially alter either the location or the orientation of Kangasvieri's first antenna relative to the substantially rectangular ground plane. As discussed above, a person of ordinary skill in the art would have recognized that Chiba's multi-frequency PIFA retains substantially the same footprint as Kangasvieri's first antenna and, accordingly, would have implemented Chiba's multi-frequency PIFA in substantially the same location and orientation on the

ground plane as Kangasvieri's original first PIFA antenna. Thus, in my opinion, the replaced first antenna would continue to extend in a direction substantially parallel to the first side of the substantially rectangular ground plane, as demonstrated and disclosed in Kangasvieri.

92. Thus, in my opinion, the combination of Kangasvieri and Chiba teaches and/or suggests "the first antenna extends in a direction substantially parallel to a first side of the substantially rectangular ground plane," as claimed.

f) the second antenna extends in a direction substantially parallel to a second side of the substantially rectangular ground plane;

93. The Kangasvieri-Chiba combination teaches and/or suggests this limitation. For example, as I discussed above, the mobile terminal includes a first and second antenna arranged on ground plane 10. *See* my discussion above at Section IX.A.1.c.

94. Figure 2 of Kangasvieri, annotated, illustrates a printed circuit board including a ground plane 10 having a substantially rectangular shape, defined by corners A, B, C, and D as annotated. Ex. 1005, FIG. 2. For clarity, side AB (shown in green) is identified as the claimed "second side" of the substantially rectangular ground plane, where side AB extends horizontally between corners A and B.

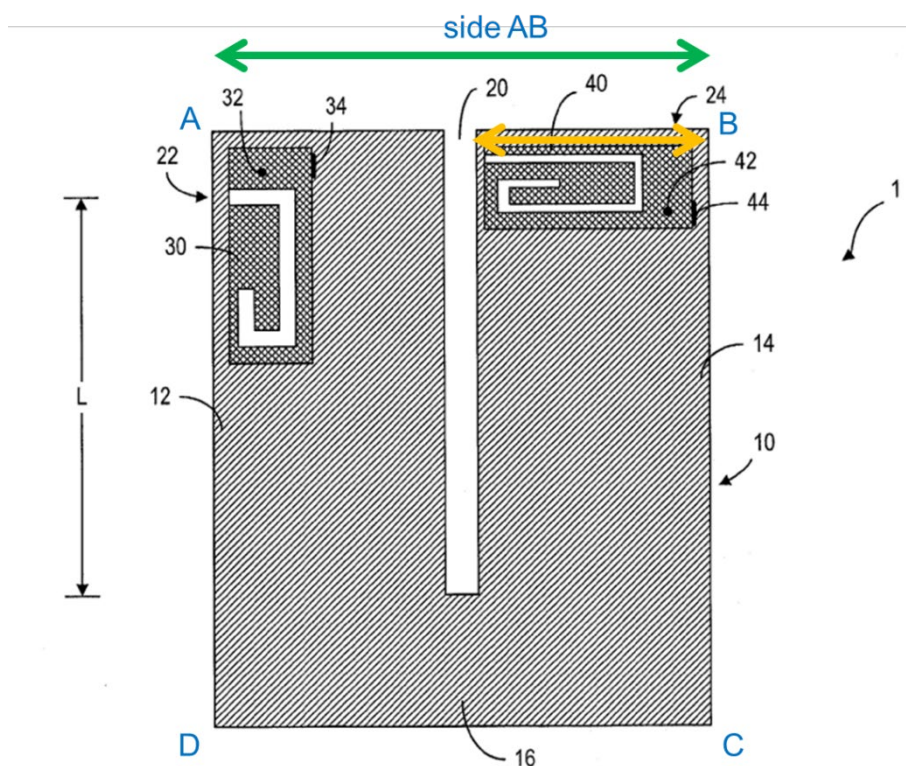


FIG. 2

Id., FIG. 2 (annotated).

95. Additionally, the second antenna 40, as shown in Figure 2, is disposed near the upper region of the ground plane and extends primarily horizontally (shown in orange), running laterally across the top portion of the ground plane 10. As depicted in the annotated figure, the longitudinal extension direction of the second antenna aligns with this horizontal orientation. Accordingly, the second antenna extends in a direction substantially parallel to side AB of the substantially rectangular ground plane.

96. It is my opinion that combining Chiba with Kangasvieri's mobile terminal would not materially alter either the location or the orientation of

Kangasvieri's second antenna relative to the substantially rectangular ground plane. As discussed above, a person of ordinary skill in the art would have recognized that Chiba's multi-frequency PIFA retains substantially the same footprint as the first PIFA antenna in Kangasvieri's mobile terminal and, accordingly, would have implemented Chiba's multi-frequency PIFA in substantially the same location and orientation on the ground plane as Kangasvieri's original first PIFA antenna. Thus, in my opinion, the second antenna would continue to extend in a direction substantially parallel to the second side of the substantially rectangular ground plane, as demonstrated and disclosed in Kangasvieri.

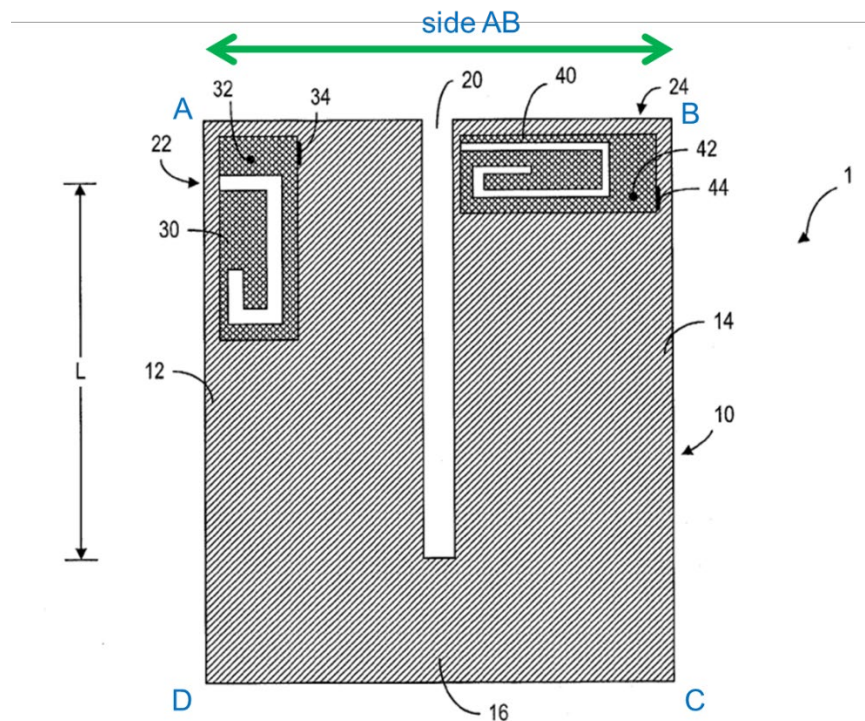
97. Thus, in my opinion, the combination of Kangasvieri and Chiba teaches and/or suggests "the second antenna extends in a direction substantially parallel to a second side of the substantially rectangular ground plane," as claimed.

g) the first antenna is arranged near a short side of the substantially rectangular ground plane; and

98. The Kangasvieri-Chiba combination teaches and/or suggests this limitation. For example, as discussed above, the mobile terminal includes a first and second antenna arranged on ground plane 10. See my discussion above at Section IX.A.1.c.

99. Figure 2 of Kangasvieri, annotated, illustrates a printed circuit board including a ground plane 10 having a substantially rectangular shape, defined by

corners A, B, C, and D as annotated. Ex. 1005, FIG. 2. In this configuration, the vertical sides (AD and BC) are longer than the horizontal sides (AB and CD) as shown in Figure 2. Accordingly, sides AB (shown in green) and CD constitute the “short sides” of the rectangular ground plane 10.



Ex. 1005, FIG. 2 (annotated).

100. As depicted in the annotated Figure 2, the first antenna 30 is positioned adjacent to the upper left region of the ground plane; said differently, the first antenna is disposed proximate to side AB, which is a short side of the rectangular ground plane 10, and occupies the corner region near point A. Accordingly, a person

of ordinary skill in the art would have recognized that the first antenna's placement is "near" the short side AB of the rectangular ground plane.

101. It is my opinion that combining Chiba with Kangasvieri's mobile terminal would not materially alter either the location or the orientation of Kangasvieri's first antenna relative to the substantially rectangular ground plane. As discussed above, a person of ordinary skill in the art would have recognized that Chiba's multi-frequency PIFA retains substantially the same footprint as Kangasvieri's first antenna and, accordingly, would have implemented Chiba's multi-frequency PIFA in substantially the same location and orientation on the ground plane as Kangasvieri's original first PIFA antenna. Thus, in my opinion, the replaced first antenna would continue to extend in a direction substantially parallel to the first side of the substantially rectangular ground plane, as demonstrated and disclosed in Kangasvieri.

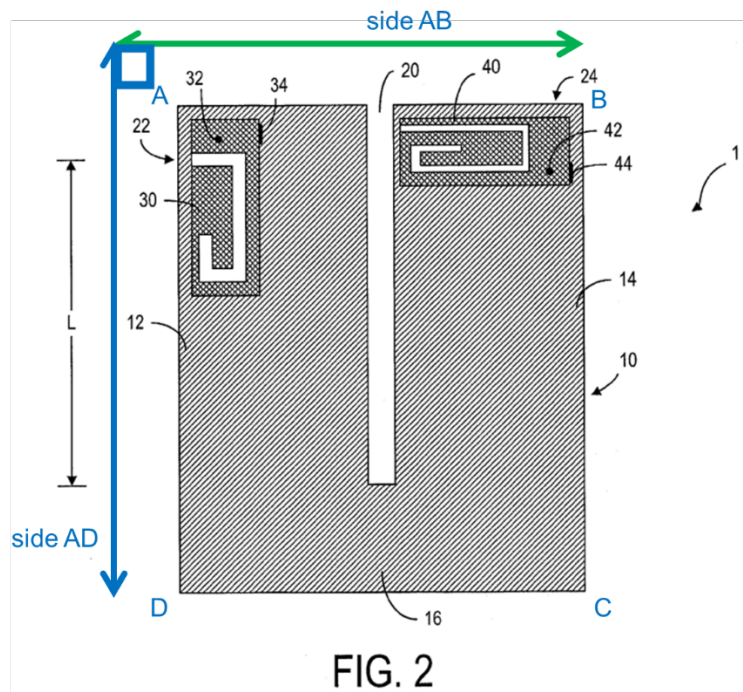
102. Thus, in my opinion, the combination of Kangasvieri and Chiba teaches and/or suggests "the first antenna is arranged near a short side of the substantially rectangular ground plane," as claimed.

h) the first side and the second side are substantially orthogonal.

103. The Kangasvieri-Chiba combination teaches and/or suggests this limitation. For example, as I discussed above, the mobile terminal includes a first

and second antenna arranged on ground plane 10. *See* my discussion above at Section IX.A.1.c.

104. Figure 2 of Kangasvieri, annotated, illustrates a printed circuit board including a ground plane 10 having a substantially rectangular shape, defined by corners A, B, C, and D as annotated. Ex. 1005, FIG. 2. Side AD (shown in blue) extends vertically between corners A and D. Side AB (shown in green) extends horizontally between corners A and B.



Ex. 1005, FIG. 2 (annotated).

105. Because side AD is vertical and side AB is horizontal, the two sides intersect at corner A and form a right angle of 90 degrees.⁵ That is, a person of ordinary skill in the art would have recognized that sides AD and AB are perpendicular to one another and therefore substantially orthogonal.

106. For the same reasons discussed above, it is my opinion that combining Chiba with Kangasvieri's mobile terminal would not materially alter either the location or the orientation of Kangasvieri's first antenna relative to the substantially rectangular ground plane. Chiba's multi-frequency PIFA retains substantially the same footprint as Kangasvieri's first antenna and would be implemented in substantially the same location and orientation on the ground plane as Kangasvieri's original first PIFA antenna. Accordingly, the replaced first antenna would continue to extend in a direction substantially parallel to the first side of the substantially rectangular ground plane, consistent with Kangasvieri's disclosure. Because the first side and the second side correspond to adjacent sides of Kangasvieri's substantially rectangular ground plane, a person of ordinary skill in the art would have understood those sides to be substantially orthogonal.

⁵ The specification of the '960 patent explains that "substantially orthogonal" encompasses angles within a range of approximately 60° to 120°. Ex. 1001 at 17:8-11.

107. Accordingly, in my opinion, the combination of Kangasvieri and Chiba teaches and/or suggests “the first side and the second side are substantially orthogonal,” as claimed.

2. Claim 2

a) **The handheld device according to claim 1, wherein said handheld device further comprises at least one slot in the substantially rectangular ground plane, wherein said at least one slot is arranged for providing enhanced isolation between a feeding point of said first antenna and a feeding point of said second antenna by providing a high impedance path in said substantially rectangular ground plane between said feeding points in at least one frequency band corresponding to an operating band of one of said first and second antennas.**

108. The Kangasvieri-Chiba combination teaches and/or suggests claim 2. For the same reasons I discussed above for claim 1, the combination relies on Kangasvieri for the mobile terminal layout, including the substantially rectangular ground plane and the slot formed therein, and relies on Chiba only to substitute Kangasvieri’s first antenna with a multifrequency PIFA structure. *See* my discussion above at Section IX.A.1.a–h. As I discuss below, Kangasvieri further teaches this limitation.

109. First, Kangasvieri teaches a slot 20 formed in the substantially rectangular ground plane 10 of the mobile terminal. Ex. 1005 ¶¶ 10 (“The antenna structure is characterized by a slot (20) provided between the first section (12) and the second section (14) of the ground plane (10)”), 65, FIG. 2.

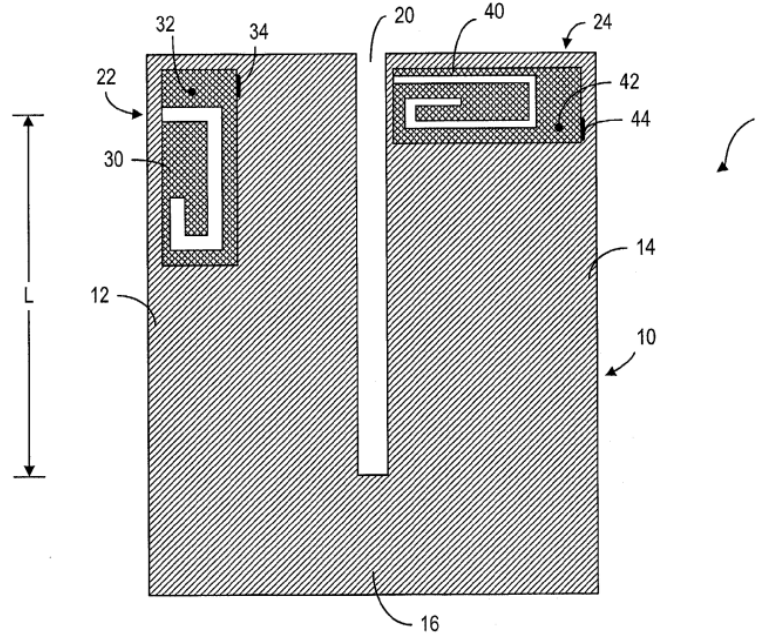


FIG. 2

Ex. 1005 FIG. 2. The slot 20 is visible in Figure 2 above, as well as Figure 1, as a physical gap running across the rectangular ground plane 10 “such that the ground plane 10 is separated into a first section 12 and a second section 14, galvanically connected via a connecting section 16.” *Id.* ¶ 65; *see also id.*, FIG. 1. Accordingly, in my opinion, Kangasvieri teaches “wherein said handheld device further comprises at least one slot in the substantially rectangular ground plane.”

110. Second, Kangasvieri teaches that the slot’s purpose is to improve isolation between the antennas, and by extension isolation between their feed points. Kangasvieri teaches that the first antenna 22 has a feed line 32 and the second antenna 24 has a feed line 42. *Id.* ¶ 65. With reference to Figure 2 above, the first antenna 22 and feed line 32 are located on the first section 12 of the ground plane,

and the second antenna 24 and the feed line 42 are located on the second section 14 of the ground plane. *Id.*, FIG. 2. Kangasvieri further provides that slot 20 formed in the ground plane 10 improves the isolation between the first antenna 22 and the second antenna 24. *Id.* ¶ 65; *see also id.* ¶ 64.

111. Kangasvieri explains that this isolation is tied to the slot's effect on current flowing between the two antenna feed regions as "the conducted power in the receive antenna via the ground plane 10 is phase-shifted by 180 degrees as compared to the power radiated in air from the transmit antenna." *Id.* ¶ 65 (excerpted below).

The first antenna 22 comprises a radiating element 30, a feed line 32, and a grounding strip 34 connecting the radiating element 30 to the ground plane 10 for grounding. The second antenna 24 comprises a radiating element 40, a feed line 42 and a grounding strip 44 connecting the radiating element 40 to the ground plane 10 for grounding. **In order to improve the isolation between the first antenna 22 and the second antenna 24, a slot 20 is provided in the ground plane 10 such that the ground plane 10 is separated into a first section 12 and a second section 14, galvanically connected via a connecting section 16.** The slot 20 has an effective length L, which is substantially equal to one quarter-wavelength of the center frequency of the radiating elements 30, 40 as shown in FIG. 2. **As such, the conducted power in the receive antenna via the ground plane 10 is**

phase-shifted by 180 degrees as compared to the power radiated in air from the transmit antenna. Consequently, the radiated power and the conducted power compensate each other, and the isolation between the first antenna 22 and the second antenna 24 is improved. It should be noted that the effective length L can be realized by the connecting section 16, as shown in FIG. 2, or by a switch 62, as shown in FIG. 3C.

Id. (emphasis added). Because the feed line of each antenna is connected to distinct sections of the ground plane (section 12 for antenna 22 and feed line 32, section 14 for antenna 24 and feed line 42), a person of ordinary skill in the art would have understood that the slot 20 physically and electrically separates the two feeding regions. *Id.* ¶ 65; *see also id.* ¶¶ 45 (“the radiating element (78, 88, 90) has a slot (76, 86) provided thereon for *effectively separating* the feed line (72, 82) and the grounding strip (74, 84) of the first antenna (70, 80) by a distance substantially equal to one half wavelength of a resonant frequency of the radiating element (78, 88, 90) of the first antenna.”), 51 (“providing a slot (76, 86) on the radiating element (78, 88, 90) for *effectively separating* the feed line (72, 82) and the grounding strip (74, 84) of the first antenna (70, 80) by a distance substantially equal to one half wavelength of a resonant frequency of the radiating element (78, 88, 90) of the first antenna.”).

112. Accordingly, in my opinion, Kangasvieri teaches “wherein said at least one slot is arranged for providing enhanced isolation between a feeding point of said first antenna and a feeding point of said second antenna.”

113. Third, a person of ordinary skill in the art would have recognized that the effect of the slot is to provide a high-impedance path in the ground plane between the two feeding points at a frequency band corresponding to an operating band of the antennas. For example, Kangasvieri discloses that “a primary object of the present invention to improve the isolation between antennas **operating in substantially the same frequency band** and disposed over a common ground plane for grounding.” Ex. 1005 ¶ 64 (emphasis added). Kangasvieri explains that “[t]o achieve this object, the present invention **uses a cut in the common ground plane to change the phase of the conducted power in the ground plane.**”⁶ Ex. 1005 ¶ 64 (emphasis added).

⁶ Kangasvieri uses the term “cut” and “slot” interchangeably to describe a discontinuity formed in the ground plane to improve antenna isolation. *See* Ex. 1005 at Abstract (“a cut is provided between the first and second sections of the ground plane”), ¶¶ 4 (“The object can be achieved by providing a cut in the ground plane for causing the conducted power in the ground plane to undergo a 180-degree phase shift with respect to the radiated power in air.”), 10 (“a slot (20) provided between the first section (12) and the second section (14) of the ground plane (10) for improving isolation between the receive antenna and the transmit antenna, wherein the slot has an effect length (L) substantially equal to a quarter wavelength of the frequency band”), 64 (“cut in the common ground plane”), 65 (“a slot 20 is provided in the ground plane 10 such that the ground plane 10 is separated into a first section 12 and a second section 14,”).

114. Kangasvieri teaches that “[t]he object can be achieved by **providing a cut in the ground plane for causing the conducted power in the ground plane to undergo a 180-degree phase shift** with respect to the radiated power in air.” Ex. 1005 ¶ 4 (emphasis added). A person of ordinary skill in the art would have understood that dimensions of the slot, where the length corresponds to a quarter-wave, provide the isolation between the feed points that cause the conducted power in the ground plane to undergo a 180-degree phase shift with respect to the radiated power in air. For instance, “[t]he **length of the cut is substantially equal to one quarter-wavelength of the operating frequency band** of transmit/receive antenna pair **so as to provide isolation between the transmit antenna and the receive antenna.**” Ex. 1005 at Abstract. Such a skilled person would have understood that the quarter-wave slot presents high impedance, ideally approaching an open-circuit or infinite impedance condition, at its resonant frequency as the round-trip current path has a total electrical length of approximately one-half wavelength ($\lambda/2$), which produces a *180-degree phase shift*.⁷ E.g., Ex. 1005 ¶¶ 10 (“The slot has an effective

⁷ A POSITA would understand that the round-trip surface-current path around the slot is $(2 \times \lambda/4) + \Delta \approx \lambda/2$, where Δ represents the additional path length associated with traversing the slot width. Because the slot width is small relative to the slot length,

length (L) substantially equal to a quarter wavelength of the frequency band.”), 65; *see also id.* cl. 1. Accordingly, a person of ordinary skill in the art would have understood that Kangasvieri’s quarter-wavelength slot structure functions as an effective high-impedance isolation element within the ground plane.

115. Accordingly, in my opinion, Kangasvieri teaches “wherein said handheld device further comprises at least one slot in the substantially rectangular ground plane, wherein said at least one slot is arranged for providing enhanced isolation between a feeding point of said first antenna and a feeding point of said second antenna by providing a high impedance path in said substantially rectangular ground plane between said feeding points in at least one frequency band corresponding to an operating band of one of said first and second antennas.”

116. It is my opinion that replacing Kangasvieri’s first antenna with Chiba’s multi-frequency PIFA would not materially alter the ground plane structure, the slot geometry, or the relative placement of the antenna feed points. A person of ordinary skill in the art would have implemented Chiba’s multi-frequency PIFA within substantially the same antenna position as Kangasvieri’s original first antenna in

the resulting electrical path length is approximately one-half wavelength, corresponding to an approximately 180-degree phase shift at the operating frequency.

order to preserve the disclosed device architecture and antenna layout. Accordingly, slot 20 would remain positioned in the substantially rectangular ground plane between the antenna feed regions, continuing to provide isolation between the antennas as taught by Kangasvieri.

117. Thus, in my opinion, the Kangasvieri-Chiba combination discloses and/or suggests “wherein said handheld device further comprises at least one slot in the substantially rectangular ground plane, wherein said at least one slot is arranged for providing enhanced isolation between a feeding point of said first antenna and a feeding point of said second antenna by providing a high impedance path in said substantially rectangular ground plane between said feeding points in at least one frequency band corresponding to an operating band of one of said first and second antennas.”

3. Claim 3

a) The handheld device according to claim 2, wherein said at least one slot in the substantially rectangular ground plane has an open end in correspondence with a perimeter of said substantially rectangular ground plane.

118. The Kangasvieri-Chiba combination teaches and/or suggests this limitation. For the same reasons I discussed above, Kangasvieri discloses a slot 20 formed in the ground plane 10. *See* my discussion above at Section IX.A.2; Ex.

1005, FIG. 2. The isometric and top views (Figures 1 and 2) depict the slot extending to the edge of the ground plane, thereby forming an open-ended slot at the perimeter.

119. Kangasvieri further describes the slot as a “cut in the ground plane,” indicating a physical incision in the conductive ground structure. Ex. 1005 ¶ 4 (“The object can be achieved by providing a cut in the ground plane for causing the conducted power in the ground plane to undergo a 180-degree phase shift with respect to the radiated power in air.”); *see also* Abstract (“In an antenna structure having a transmit antenna disposed over a first section of a ground plane and a receive antenna disposed over a second section of the ground plane, a cut is provided between the first and second sections of the ground plane.”), FIG. 2. A person of ordinary skill in the art would have understood that such a “cut” originates from and extends to the edge of the ground plane, as depicted in Figure 2, rather than forming a fully enclosed internal slot.

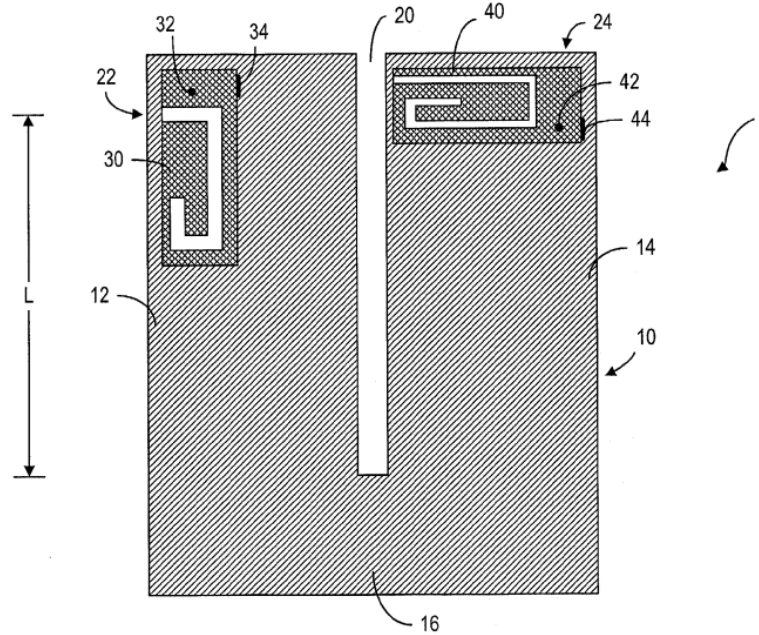


FIG. 2

Ex. 1005 at FIG. 2.

120. Moreover, Kangasvieri explains that the slot 20 divides the ground plane 10 into a first section 12 and a second section 14, which remain galvanically connected only through a connecting section 16. Ex. 1005 ¶¶ 65, 66, FIGS. 1, 2. Accordingly, a person of ordinary skill in the art would have understood that Kangasvieri's slot necessarily has an open end at the perimeter of the substantially rectangular ground plane as for the ground plane to be separated into two distinct sections connected solely by a connecting section 16, the slot must extend from the perimeter inward.

121. It is my opinion that replacing Kangasvieri's first antenna with Chiba's multi-frequency PIFA would not materially alter the ground plane structure, the slot

geometry, or the relative placement of the antenna feed points. A person of ordinary skill in the art would have implemented Chiba's multi-frequency PIFA in substantially the same antenna position as Kangasvieri's original first antenna in order to preserve the disclosed device architecture and antenna layout. Accordingly, slot 20 would remain positioned in the substantially rectangular ground plane between the antenna feed regions, continuing to provide isolation between the antennas as taught by Kangasvieri.

122. Thus, in my opinion, the Kangasvieri–Chiba combination teaches and/or suggests “[t]he handheld device according to claim 2, wherein said at least one slot in the substantially rectangular ground plane has an open end in correspondence with a perimeter of said substantially rectangular ground plane.”

4. Claim 4

a) The handheld device according to claim 2, wherein said at least one slot has a length of approximately $(2N-1)*A/4$, wherein A is a wavelength corresponding to a frequency within said operating band, and N is an integer, $N>1$.

123. The Kangasvieri-Chiba combination teaches and/or suggests the features of claim 4. For the same reasons I discussed above for claim 2, the Kangasvieri-Chiba combination has a slot having an effective length of approximately one-quarter wavelength ($\lambda/4$) at the operating frequency of the antenna system. *See* my discussion above at Section IX.A.2; *see also* Ex. 1005 ¶¶

10, 65, FIGS. 1–2. However, as I discuss below, the extension to having a slot with a length of approximately $(2N-1)*A/4$, where $N>1$ would have been apparent based on Kangasvieri’s disclosures and the knowledge in the art.

124. Kangasvieri, in view of common sense, teaches or suggests this limitation. For instance, Kangasvieri, based on common knowledge, teaches a slot length “of approximately $(2N-1)*A/4$, wherein A is a wavelength corresponding to a frequency within said operating band.” Here, A is used to denote wavelength (λ), and thus the formula represents the set of all odd-integer multiples of a quarter wavelength ($\lambda/4$): $\lambda/4$, $3\lambda/4$, $5\lambda/4$, and so on. Each such length is functionally equivalent to $\lambda/4$ from the perspective of the underlying phase-cancellation mechanism that produces the claimed “enhanced isolation.”

125. A person of ordinary skill in the art would have thus recognized that each odd multiple of $\lambda/4$ produces a round-trip path along the slot edges of an odd multiple of $\lambda/2$, which in every case yields a net phase shift of an odd multiple of 180 degrees, that is, substantially 180-degree phase inversion. The fundamental isolation mechanism is therefore preserved regardless of which odd multiple is selected.

126. Put simply, the same cancellation effect of the slot occurs when $2L$ equals any odd half-wavelength, that is, when $L = (2N-1)*\lambda/4$ for any positive integer N . In each case, the round-trip path produces a phase difference congruent

to 180 degrees modulo 360 degrees, ensuring that the conducted and radiated energy remain in destructive phase alignment. A person of ordinary skill in the art would have readily understood that increasing N merely extends the effective slot path length by integer multiples without altering the fundamental cancellation mechanism.

127. Here, Kangasvieri expressly teaches that electrical path length relative to wavelength controls antenna resonance, impedance characteristics, and the degree of phase shift experienced by conducted currents. Ex. 1005 ¶¶ 10, 65, FIGS. 1–2. That relationship is precisely what gives rise to the isolation behavior. Accordingly, selecting an effective slot length corresponding to an odd integer multiple of $\lambda/4$ to achieve the known 180-degree phase cancellation effect would have been a mere design choice when designing the antenna system given the dimensions of the ground plane and antennas, along with the wavelength (λ), which corresponds to a frequency within the operating band of the two antennas.

128. Put simply, a person of ordinary skill in the art would have recognized that the choice among odd multiples of $\lambda/4$ is dictated by ordinary engineering considerations such as available board geometry, slot routing constraints, feed-point placement, impedance tuning, and the desired degree of coupling reduction, rather than inventive insight. Where the physical layout of the handset or the placement of adjacent antenna elements made a simple $\lambda/4$ slot less practical, a designer would

naturally select a longer effective slot length such as $3\lambda/4$ or $5\lambda/4$ while preserving the same quarter-wave phase cancellation mechanism. Because each odd multiple produces the same fundamental phase inversion and isolation effect, the result would have been predictable and expected.

129. For example, in higher-frequency antenna designs, where wavelengths are shorter and coupling effects between closely spaced antenna elements become more sensitive to small dimensional changes, a designer would have appreciated the importance of precisely controlling the effective electrical length of the slot. In such circumstances, the designer may select an odd multiple such as $3\lambda/4$ or $5\lambda/4$ because the physical routing of the slot, spacing between antennas, feed-point placement, and the desired isolation performance may make a physical length corresponding to a higher odd multiple more practical while preserving the same quarter-wave phase cancellation mechanism. Likewise, where the slot must be routed around other components or adapted to the physical geometry of the handset, a higher odd multiple permits the same isolation performance in a more practical layout. These are routine design trade-offs well within the ordinary skill in the art, because each value of N produces the same fundamental phase inversion and mutual-coupling reduction as the $\lambda/4$ case expressly taught by Kangasvieri, yielding a predictable and expected result.

130. It is my opinion that replacing Kangasvieri's first antenna with Chiba's multi-frequency PIFA would not modify or materially alter the function of slot 20 in Kangasvieri. Specifically, substituting Chiba's multi-frequency PIFA for Kangasvieri's first antenna would not materially alter the ground plane structure, the slot geometry, the slot's isolation function, or the relative placement of the antenna feed points. A person of ordinary skill in the art would have implemented Chiba's multi-frequency PIFA in substantially the same antenna position as Kangasvieri's original first antenna in order to preserve the disclosed device architecture and antenna layout. Accordingly, slot 20 would remain positioned in the substantially rectangular ground plane between the antenna feed regions, continuing to provide isolation between the antennas as taught by Kangasvieri.

131. Thus, in my opinion, the Kangasvieri–Chiba combination teaches and/or suggests “[t]he handheld device according to claim 2, wherein said at least one slot has a length of approximately $(2N-1)*A/4$, wherein A is a wavelength corresponding to a frequency within said operating band, and N is an integer, $N>1$.”

5. Claim 19

a) The handheld device according to claim 1, wherein the second antenna is arranged to operate in at least one frequency band used for a mobile communication service.

132. The Kangasvieri-Chiba combination teaches and/or suggests claim 19. For the same reasons I discussed above for claim 1, Kangasvieri expressly teaches

that the second antenna operates in a frequency band used for mobile communication services. *See* my discussion above at Section IX.A.1.a–h. Specifically, Kangasvieri teaches that the second antenna may be used to cover the PCS band and further discusses operation in bands such as GSM 850. Ex. 1005 ¶¶ 65, 72. These bands are standard mobile communication service bands used in cellular networks.

133. Thus, Kangasvieri teaches “wherein the second antenna is arranged to operate in at least one frequency band used for a mobile communication service”.

134. It is my opinion that replacing Kangasvieri’s first antenna with Chiba’s multi-frequency PIFA would not modify or materially alter the operation of Kangasvieri’s second antenna. As I have explained above, Chiba is relied upon only for the structure and multi-band capability of the first antenna. The second antenna would remain as disclosed in Kangasvieri in the combined mobile terminal and would continue to operate in at least one mobile communication service band, consistent with Kangasvieri’s disclosure.

135. Accordingly, in my opinion, the Kangasvieri-Chiba combination teaches and/or suggests “[t]he handheld device according to claim 1, wherein the second antenna is arranged to operate in at least one frequency band used for a mobile communication service.”

6. Claim 20

a) The handheld device according to claim 1, wherein the second antenna is selected from the group consisting of monopole antenna, PIFA, IFA, or patch antenna.

136. The Kangasvieri-Chiba combination teaches and/or suggests claim 20. For the same reasons I discussed above for claim 1, Kangasvieri expressly teaches a second antenna. *See* my discussion above at Section IX.A.1.d. Kangasvieri further teaches that the second antenna is implemented as a planar inverted-F antenna (PIFA) structure. Ex. 1005 ¶¶ 63, 72, FIG. 2.

137. For the same reasons I discussed above for Claim 19, the combination with Chiba affects only the first antenna and does not alter the type of Kangasvieri's second antenna. *See* my discussion above at Section IX.A.4.

138. Accordingly, in my opinion, the Kangasvieri-Chiba combination discloses and/or suggests [t]he handheld device according to claim 1, wherein the second antenna is selected from the group consisting of monopole antenna, PIFA, IFA, or patch antenna”.

B. Kangasvieri, Chiba, and Inoue disclose and suggest the features of claims 5 and 6.

1. Claim 5

a) The handheld device according to claim 1, further comprising at least one conductive strip connected to the substantially rectangular ground plane, wherein said at least one conductive strip is arranged so as to provide a high impedance path in said substantially rectangular ground plane between a feeding point of said first antenna and a feeding point of said second antenna in at least one frequency band corresponding to an operating band of one of said first and second antennas.

139. The Kangasvieri-Chiba combination, in further view of Inoue teaches and/or suggests the features of claim 5. For the same reasons I discussed above for claim 1, the Kangasvieri-Chiba combination discloses a mobile terminal comprising a first antenna operating in at least three frequency bands used for mobile communication services, and a second antenna operating in at least one frequency band. *See* my discussion above at Section IX.A.1.a–h; *see also* Ex. 1005 ¶¶ 65, 69, 72, FIGS. 1–2.

140. For the same reasons I discussed above for claim 2, Kangasvieri teaches the concept of modifying the ground plane of a mobile terminal to control surface current propagation and improve isolation between the two antennas. *See* my discussion above at Section IX.A.2. Kangasvieri achieves this isolation by introducing a slot 20 in the substantially rectangular ground plane, which provides enhanced isolation between a feeding point of first antenna and a feeding point of

said second antenna by producing a 180-degree phase shift at the second feed point. Ex. 1005 ¶¶ 4, 10, 45, 64, 65, FIGS. 1, 2. That is, Kangasvieri's slot provides a high impedance path in the substantially rectangular ground plane between the feeding points in at least one frequency band corresponding to an operating band of one of the first and second antennas. *Id.* Kangasvieri, however, does not expressly teach using a conductive strip connected to the ground plane as the structure providing the high-impedance path between feed points.

141. A person of ordinary skill in the art would have been motivated to implement the isolation function taught by Kangasvieri using a conductive strip based on the teachings of Inoue.

(1) Inoue's teachings (Ex. 1009)

142. Inoue teaches a similar isolation objective using a conductive structure connected to the ground plane rather than a slot, explaining that mutual coupling between adjacent antenna elements is suppressed by a "boxy metallic wall" surrounding the microstrip patch:

This paper investigates a liner array antenna suppressed mutual coupling and variation between elements. If the mutual coupling is suppressed, the distortion of the element pattern and the effect of arrangement error of elements could be suppressed, and good performance could be realized without calibration of antenna. The array antenna system is evaluated

with DOA estimation of ESPRIT method [4] in this paper. In section 2, the relation between coupling matrix of an array antenna and DOA estimation error is evaluated in computer simulation, and clarify the range of mutual coupling to minimize the estimation error. In section 3, **microstrip patch array antenna with boxy metallic wall is designed and estimation error in ESPRIT is examined in a measurement of DOA estimation in anechoic chamber using the array antenna.**

Ex. 1009 at 17; *see also id.* at 17–18 (§ 1 Introduction).

143. Specifically, Inoue discloses that “mutual coupling of this antenna is suppressed by the boxy metallic wall around the microstrip patch,” and further explains that “[t]he wall is connected to the ground plane of the microstrip antenna.”

Ex. 1009 at 18. The boxy metallic wall around the microstrip patch antenna is illustrated in Figure 5 below:

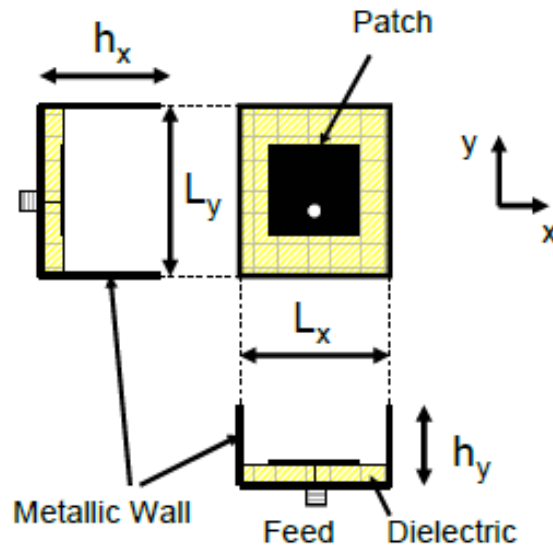


Fig.5: Boxy metallic wall microstrip antenna.

Id. at Fig. 5. Thus, Inoue teaches a conductive structure connected to the ground plane that suppresses mutual coupling between neighboring antenna elements by reducing unwanted interaction across the shared conductive surface. *Id.*

144. A person of ordinary skill in the art would have understood that Inoue's metallic wall performs the same fundamental function as Kangasvieri's slot, namely, creating a high-impedance isolation region between adjacent antenna feed points to suppress coupling and improve independent antenna operation. For instance, Inoue teaches that the dimensions of the metallic wall are selected relative to wavelength to optimize isolation performance:

The size of the wall L_x , L_y , h_x and h_y was optimized with computer simulation to achieve -30dB of mutual coupling between neighboring elements. **The optimized parameter is**

**$L_x=0.4\lambda$, $L_y=0.5\lambda$, $h_x=0.25\lambda$ and $h_y=0.2\lambda$ to obtain -33dB of
maximum of mutual coupling in experiment at 5GHz.**

Id. at 18 (excerpted) (emphasis added).

145. Although Inoue illustrates a boxy metallic wall surrounding the microstrip patch antenna, a person of ordinary skill in the art would have understood that the relevant teaching is the use of a conductive structure connected to the ground plane to suppress mutual coupling by creating a high-impedance boundary. The isolation effect arises from the conductive wall's ability to alter surface-current propagation across the shared conductive plane, not from the fact that the wall completely surrounds the antenna element.

146. Such a skill artisan would have further understood that Inoue's "boxy metallic wall" corresponds to the recited "conductive strip" because the relevant characteristic is whether the structure is a conductive element connected to the ground plane and arranged to provide a high-impedance isolation path between antenna feed points, not whether the reference labels it as a "strip" or a "wall." Inoue's metallic wall is an elongated conductive member having physical dimensions, including width, height, and depth, is physically connected to the ground plane, and functions by altering current flow across the shared conductive surface to reduce coupling between adjacent antenna elements (including antenna feed regions). Ex. 1009 at 18. A person of ordinary skill in the art, therefore, would

have recognized that Inoue's metallic wall is simply an implementation of the claimed conductive strip.

(2) Reasons to Combine Features of Kangasvieri, Chiba and Inoue

147. A person of ordinary skill in the art would have been motivated, in light of Inoue, to configure the mobile terminal of the combined Kangasvieri-Chiba mobile terminal so that the isolation structure between the first and second antenna feed points comprises at least one conductive wall connected to the substantially rectangular ground plane. Such a modification would have been a straightforward combination of known antenna-isolation techniques using known methods to yield predictable results. For instance, Kangasvieri and Inoue are directed to the same technological field: reducing coupling between antenna elements in compact wireless antenna arrangements disposed over a common ground plane. *Compare* Ex. 1005 ¶¶ 4, 65, FIGS. 5a, 5b. *with* Ex. 1009 at 17–18, FIGS. 5, 6. Because Inoue addresses the similar isolation problem and as discussed above, Inoue teaches that mutual coupling between adjacent antenna elements can be suppressed using a conductive metallic wall connected to the ground plane (Ex. 1009 at 18), a person of ordinary skill in the art implementing the combined Kangasvieri-Chiba mobile terminal would have had direct reason to consider Inoue's teachings.

148. A person of ordinary skill in the art would have understood that, in adapting Inoue's teaching to the Kangasvieri-Chiba mobile terminal, a single conductive wall positioned between the adjacent antenna feed points on the common ground plane could provide a similar isolation function as Kangasvieri's slot or cut; namely, reducing coupling by creating a high-impedance boundary that suppresses unwanted current propagation between the antennas. Indeed, because both structures operate on similar electromagnetic principles and address the same multiple-antenna isolation problem, replacing Kangasvieri's slot having an effective length of approximately one-quarter wavelength ($\lambda/4$) with a conductive wall of comparable electrical length—such as the conductive metallic wall disclosed in Inoue, where the wall dimensions (e.g., $L_x = 0.4\lambda$ and $L_y = 0.5\lambda$) are specifically optimized to suppress mutual coupling—would have been a straightforward and predictable design choice.

149. Such a substitution would have required little to no redesign of the overall mobile-terminal architecture or expansion of the ground plane, while also preserving ground-plane continuity and avoiding the need to cut or interrupt the ground plane, an important practical consideration as device size and available PCB area decrease. Accordingly, a person of ordinary skill in the art would have had practical motivation to select a conductive strip over a slot in specific design contexts. As discussed with respect to Kangasvieri, a slot physically separates the

ground plane into two regions connected only by a bridge, which may compromise the mechanical integrity of the PCB. A conductive wall connected to the ground plane avoids this structural discontinuity while achieving a similar isolation effect. Thus, such a skilled person would have recognized the conductive wall as an alternative to the slot, and the choice between them would have been a straightforward design decision based on PCB layout constraints, manufacturing preferences, and desired ground plane continuity.

150. Indeed, as discussed above in the Background Section, the field of antenna design recognizes both “hard surfaces” (conductive strip-type structures) and “soft surfaces” (slot-type structures) as standard implementation choices for controlling surface wave propagation and electromagnetic coupling on ground planes. *See* my discussion above at Section V; Ex. 1026 (Sievenpiper) at Abstract (“Specifically, coupling reduction is attempted using lossy material superstrates or ground plane discontinuities, such as slits.”); Ex. 1008 (Karaboikis) at 12-13 (describing $\lambda/4$ slots and a corrugated ground plane to reduce mutual coupling between antenna ports); Ex. 1025 (Georgakopoulos) at 2059–2060 (Section I.B) (describing high-impedance surfaces to alter its radio-frequency electromagnetic properties).⁸ These constructs were well-known by at least 1999–2005 as

⁸ I refer to Exhibits 1008, 1025, 1026 here and elsewhere to demonstrate the knowledge of one of ordinary skill in the art at the time.

complementary engineering tools for RF isolation. Accordingly, a person of ordinary skill in the art selecting between them would have done so based on standard design trade-offs, not inventive insight.

151. A person of ordinary skill in the art exercising ordinary skill would have had a reasonable expectation of success in making that modification. That is, in my opinion, incorporating the teachings of Inoue into the Kangasvieri-Chiba mobile terminal would have led a person of ordinary skill in the art to replace Kangasvieri's slot 20 with an alternative high-impedance structure, e.g., the conductive wall disclosed in Inoue, to achieve a similar isolation function. As discussed above, both Kangasvieri's slot and Inoue's conductive wall suppress mutual coupling between closely spaced antenna elements by presenting a high-impedance boundary that disrupts surface current propagation. A person of ordinary skill in the art would have recognized these structures as functionally similar implementations of a known isolation technique and would have understood that substituting one for the other would yield a predictable result. This substitution would not materially alter the overall antenna layout, ground plane configuration, or the relative placement of the antenna feed regions, but instead represents a routine design choice among known alternatives for achieving antenna isolation.

152. Thus, in my opinion, the combination of Kangasvieri, Chiba, and Inoue teaches and/or suggests "[t]he handheld device according to claim 1, further

comprising at least one conductive strip connected to the substantially rectangular ground plane, wherein said at least one conductive strip is arranged so as to provide a high impedance path in said substantially rectangular ground plane between a feeding point of said first antenna and a feeding point of said second antenna in at least one frequency band corresponding to an operating band of one of said first and second antennas.”

2. Claim 6

a) The handheld device according to claim 5, wherein said at least one conductive strip has a length from its connection to the substantially rectangular ground plane, of approximately $(2N-1)*A/4$, wherein A is a wavelength corresponding to a frequency within said operating band, and N is an integer, $N>1$.

153. The combined Kangasvieri-Chiba-Inoue mobile terminal teaches and/or suggests the features of claim 6. For the same reasons I discussed above for claim 5, the combined Kangasvieri-Chiba-Inoue mobile terminal has a conductive metallic wall (“conductive strip”) having an effective length of approximately one-quarter wavelength ($\lambda/4$) at the operating frequency of the antenna system. *See* my discussion above at Section IX.B.1. Additionally, similar to my discussions for claim 4 above, it is my opinion that the extension to having a conductive metallic wall with a length of approximately $(2N-1)*A/4$, where $N>1$ would have been apparent to one of skill in the art.

154. As I discussed above for claim 4, Kangasvieri teaches that the isolation slot 20 is dimensioned such that the length of the cut is substantially equal to one quarter-wavelength of the operating frequency band to provide isolation between the transmit and receive antennas. Ex. 1005, Abstract; *see also* Ex. 1005 ¶¶ 4, 10, 45, 64–65; *see* my discussion above at IX.A.4. Thus, as I have explained above, Kangasvieri expressly teaches the underlying quarter-wavelength impedance principle used to create a high-impedance path between adjacent feed points. *See* my discussion above at IX.A.4.

155. Inoue further reinforces that conductive isolation structures connected to the ground plane are intentionally dimensioned relative to wavelength to optimize mutual coupling suppression. In particular, Inoue states that

The size of the wall L_x , L_y , h_x and h_y was optimized with computer simulation to achieve -30dB of mutual coupling between neighboring elements. The optimized parameter is $L_x=0.4\lambda$, $L_y=0.5\lambda$, $h_x=0.25\lambda$ and $h_y=0.2\lambda$ to obtain -33dB of maximum of mutual coupling in experiment at 5GHz.

Id. at 18 (excerpted). Inoue, thus, confirms that conductive isolation structures were routinely dimensioned based on wavelength-dependent RF behavior to achieve the desired impedance and isolation performance.

156. Accordingly based on these teachings in Inoue and Kangasvieri and the knowledge in the art, a person of ordinary skill in the art would have understood that

once motivated to use a conductive isolation structure such as Inoue's metallic wall in place of Kangasvieri's slot, the length of that conductive structure would likewise be selected according to the same known quarter-wave design principles. Specifically, a conductive wall, or equivalent conductive isolation structure having a length of approximately an odd multiple of a quarter wavelength, $L \approx (2N-1) \cdot \lambda/4$, produces a high-impedance transformation at the target operating frequency, as this is based on a similar RF principle reflected in Kangasvieri's quarter-wave slot disclosure. *E.g.*, Ex. 1005 ¶ 65.

157. Accordingly, a person of ordinary skill in the art would have recognized that selecting an electrical length corresponding to an odd multiple of $\lambda/4$ (e.g., $\lambda/4$, $3\lambda/4$, $5\lambda/4$) can achieve the same fundamental phase inversion associated with isolation structures such as a conductive wall or slot. While higher-order multiples may introduce additional resonant behavior, the underlying mechanism, producing a phase shift that suppresses surface currents and reduces mutual coupling, remains the same. A skilled artisan would have selected among these lengths based on routine design considerations, including available board space, antenna spacing, fabrication constraints, and the desired operating frequency.

158. For example, in higher-frequency antenna designs, where wavelengths are shorter and coupling between closely spaced elements is more sensitive to small dimensional variations, a designer may adjust the effective electrical length

(including through higher odd multiples) to achieve the desired isolation while accommodating layout constraints. Thus, these references, together with the knowledge in the art, establish that the electrical length of the isolation structure, selected relative to the wavelength, governs its phase response and coupling reduction performance. Put simply, a person of ordinary skill in the art could select an appropriate electrical length from among odd multiples of $\lambda/4$ to achieve the desired isolation between antennas at a given operating frequency, yielding a predictable result.

159. Thus, in my opinion, the combination of Kangasvieri, Chiba, and Inoue teaches or suggests “[t]he handheld device according to claim 5, wherein said at least one conductive strip has a length from its connection to the substantially rectangular ground plane, of approximately $(2N-1)*A/4$, wherein A is a wavelength corresponding to a frequency within said operating band, and N is an integer, $N>1$.”

C. Kangasvieri, Chiba, and Vance disclose and suggest the features of claim 7.

1. Claim 7

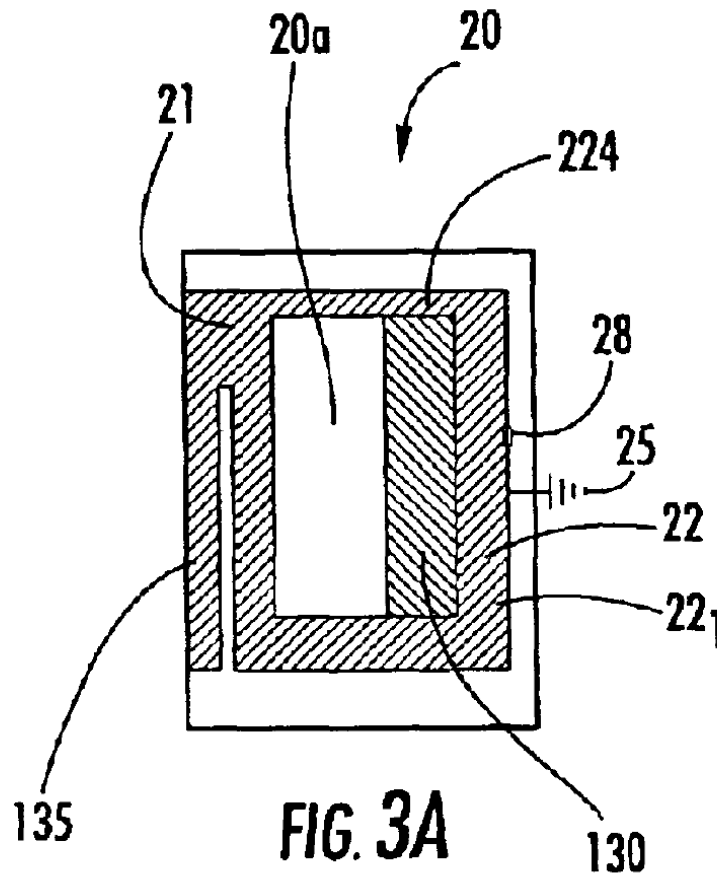
a) The handheld device according to claim 1, wherein the second antenna is arranged to operate in at least one frequency band used for a wireless service in accordance with Bluetooth™, IEEE802.11a, IEEE802.11b, IEEE802.11g, WLAN, WiFi, UWB, ZigBee, GPS, Galileo, SDARs, XDARS, WiMAX, DAB, FM, DVB-H, or DMB.

160. The combination of Kangasvieri, Chiba, and Vance teaches and/or suggests the features of claim 7. For the same reasons I discussed above for claim 1, the Kangasvieri-Chiba combination discloses a mobile terminal comprising a first antenna operating in at least three frequency bands used for mobile communication services, and a second antenna operating in at least one frequency band. *See* my discussion above at Section IX.A.1.a–h; *see also* Ex. 1005 ¶¶ 65, 69, 72, FIGS. 1–2. Kangasvieri teaches a second antenna configured for operation in a cellular communications band, such as GSM. Ex. 1005 ¶ 65. However, the Kangasvieri-Chiba combination does not expressly teach that the second antenna is arranged to operate in at least one frequency band used for a wireless service in accordance with Bluetooth™, IEEE802.11a, IEEE802.11b, IEEE802.11g, WLAN, WiFi, UWB, ZigBee, GPS, Galileo, SDARs, XDARS, WiMAX, DAB, FM, DVB-H, or DMB. As I discuss below, Vance supplies this teaching.

Vance's teachings (Ex. 1007)

161. Vance (Ex. 1007) teaches a known multi-band planar inverted-F antenna (“PIFA”) structure specifically designed for compact wireless terminals. Ex. 1007 at 5:13–34 (“The inverted-F conductive element can be configured to operate at a plurality, typically at least first and second, of resonant frequency bands and, in certain particular embodiments, can also be configured to operate at a third or more resonant frequency bands.”); *see also id.* at 2:51–66 (“planar inverted-F antennas are configured to operate at a plurality of resonant frequency bandwidths of operation (typically between about 2-4).”). Vance explains that the PIFA antenna is capable of operating in multiple distinct frequency bands, including a conventional cellular band such as GSM and an additional band used for another wireless service, such as GPS. *Id.* at 5:13–34, 5:40-55 (“the antenna may be configured to provide resonance for a global positioning System (GPS) as the terminal into which this antenna is to be built, can include a GPS receiver. GPS operates at approximately 1,575 MHz. . . . The additional resonance of **the antenna as described above permits the antenna to be used to receive these GPS signals.**”) (emphasis added).

162. For example, Figure 3A (below) illustrates an “antenna 20 [that] is configured to generate three resonance bands, . . . [and] includes a secondary band branch 135 (which creates band B at the GPS resonance (1575 MHz) and can widen the high-band resonance).” *Id.* at 9:20–42.



Id. at FIG. 3A. Accordingly, a person of ordinary skill in the art would have understood that Vance teaches a single PIFA antenna element configured for multi-band operation, including cellular communications and additional connectivity functions, such as GPS.

163. Thus, for the reasons above, in my opinion, Vance teaches an antenna capable of operating in at least one mobile communication band and also “arranged to operate in at least one frequency band used for a wireless service in accordance with Bluetooth™, IEEE802.11a, IEEE802.11b, IEEE802.11g, WLAN, WiFi, UWB, ZigBee, GPS, Galileo, SDARs, XDARS, WiMAX, DAB, FM, DVB-H, or DMB.”.

(3) Rationale to combine

164. A person of ordinary skill in the art would have been motivated to modify the Kangasvieri–Chiba mobile terminal by implementing Vance’s known multi-band PIFA antenna structure as the second antenna.

165. First, all three references are directed to the same field of technology: compact internal antennas for portable wireless communication devices. *E.g.*, Ex. 1005 ¶¶ 1, 35, 60, 69; Ex. 1006 at 1:4–10; Ex. 1007 at 5:13–34. Each reference addresses the common engineering problem of providing reliable wireless communications within the limited physical space of a handheld terminal.

166. Second, Vance’s multi-band PIFA structure would have provided a known and predictable improvement to the combined Kangasvieri-Chiba mobile terminal by enabling the second antenna to operate not only in the cellular band already contemplated by Kangasvieri, but also in an additional service band, such as GPS or other connectivity frequencies. Ex. 1007 at 5:13–34, 5:40-55. A person of ordinary skill in the art would have been further motivated by the industry demand at the time of the invention for smaller, more feature-rich handsets incorporating compact internal antennas capable of simultaneously covering multiple frequency bands, including cellular communications, GPS, and Bluetooth connectivity. Ex. 1012 (Hayes) at 1:10–2:16 (“In addition, it is becoming desirable for radiotelephones to be able to operate within multiple frequency bands in order to

utilize more than one communications system. ... In addition, radiotelephones may also incorporate Global Positioning System (GPS) technology and Bluetooth wireless technology.”).⁹

167. A person of ordinary skill in the art would have recognized that implementing Vance’s multi-band PIFA in place of the second PIFA antenna in the combined Kangasvieri-Chiba mobile terminal would have been a straightforward use of a known antenna configuration to achieve its known advantage, multi-band operation in a compact handset form factor.

168. Because Vance’s antenna was expressly designed for handheld wireless terminals and for operation across multiple frequency bands, a person of ordinary skill in the art would have had a reasonable expectation of success in using Vance’s structure within the combined Kangasvieri-Chiba mobile terminal.

169. Thus, in my opinion, a person of ordinary skill in the art would have been motivated to configure the second antenna of the combined Kangasvieri-Chiba mobile terminal as a multi-band PIFA antenna operating in both the GSM band and an additional wireless-service band, as recited in claim 7.

⁹ I refer to Exhibit 1012 here and elsewhere to demonstrate the knowledge of one of ordinary skill in the art at the time.

X. CONCLUSION

170. I declare that all statements made herein of my knowledge are true, and that all statements made on information and belief are believed to be true, and that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code.

Dated: May 12, 2026

By: 

Manos M. Tentzeris, Ph.D.