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UTILITY PATENT APPLICATION TRANSMITTAL (Only for new nonprovisional applications under 37 CFR § 1.53(b))	Attorney Docket No.	1744.0140004
	First Inventor or Application Identifier	David F. Sorrells
	Title	Universal Frequency Translation and Applications of Same
	Express Mail Label No.	

APPLICATION ELEMENTS See MPEP chapter 600 concerning utility patent application contents.	ADDRESS TO: Assistant Commissioner for Patents Box Patent Application Washington, DC 20231
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1. ☐ * Fee Transmittal Form (e.g., PTO/SB/17) (Submit an original, and a duplicate for fee processing) 2. ☒ Specification [Total Pages <u>42</u>] (preferred arrangement set forth below) - Descriptive title of the Invention - Cross References to Related Applications - Statement Regarding Fed sponsored R & D - Reference to Microfiche Appendix - Background of the Invention - Brief Summary of the Invention - Brief Description of the Drawings (if filed) - Detailed Description - Claim(s) - Abstract of the Disclosure 3. ☒ Drawing(s) (35 U.S.C. 113) [Total Sheets <u>39</u>] 4. ☒ Oath or Declaration [Total Pages <u>6</u>] a. ☐ Newly executed (original or copy) b. ☒ Copy from a prior application (37 CFR 1.63(d)) (for continuation/divisional with Box 17 completed) [Note Box 5 below] i. ☐ DELETION OF INVENTOR(S) Signed statement attached deleting inventor(s) named in the prior application, see 37 CFR §§ 1.63(d)(2) and 1.33(b). 5. ☒ Incorporation By Reference (useable if Box 4b is checked) The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 4b, is considered as being part of the disclosure of the accompanying application and is hereby incorporated by reference therein.	6. ☐ Microfiche Computer Program (Appendix) 7. Nucleotide and/or Amino Acid Sequence Submission (if applicable, all necessary) a. ☐ Computer Readable Copy b. ☐ Paper Copy (identical to computer copy) c. ☐ Statement verifying identity of above copies
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ACCOMPANYING APPLICATION PARTS
8. ☒ A photocopy of the Assignment
9. ☒ A photocopy of the 37 CFR 3.73(b) Statement
10. ☒ A photocopy of the Power of Attorney from Assignee
11. ☐ English Translation Document (if applicable)
12. ☐ Information Disclosure Statement (IDS)/PTO-1449 ☐ Copies of IDS Citations
13. ☐ Preliminary Amendment
14. ☒ Two Return Receipt Postcards (MPEP 503) (Should be specifically itemized)
15. ☐ *Small Entity Statement(s) (PTO/SB/09-12) ☐ Statement filed in prior application, Status still proper and desired
16. ☐ Certified Copy of Priority Document(s) (if foreign priority is claimed)
17. ☒ Other: 37 C.F.R. § 1.136(a)(3) Authorization

*NOTE FOR ITEMS 1 & 14: IN ORDER TO BE ENTITLED TO PAY SMALL ENTITY FEES, A SMALL ENTITY STATEMENT IS REQUIRED (37 C.F.R. § 1.27), EXCEPT IF ONE FILED IN A PRIOR APPLICATION IS RELIED UPON (37 C.F.R. § 1.28).

17. If a CONTINUING APPLICATION, check appropriate box, and supply the requisite information below and in a preliminary amendment:

☒ Continuation ☐ Divisional ☐ Continuation-in-Part (CIP) of prior application No: 09/176,027

Prior application information: Examiner S. Bhattacharya Group/Art Unit: 2745

18. CORRESPONDENCE ADDRESS

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**REGISTERED PATENT AGENTS

February 25, 2000

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Box Patent Application

Re: U.S. Non-Provisional Utility Patent Application under 37 C.F.R. § 1.53(b)
(Continuation of Appl. No. 09/176,027; Filed: October 21, 1998)
Appl. No. (to be assigned); Filed: (herewith)
For: **Universal Frequency Translation and Applications of Same**
Inventors: Sorrells *et al.*
Our Ref: 1744.0140004

Sir:

The following documents are forwarded herewith for appropriate action by the U.S.
Patent and Trademark Office:

1. PTO Utility Patent Application Transmittal Form (PTO/SB/05) (*in duplicate*);
2. A copy of prior U.S. Utility Patent Application No. 09/176,027 entitled:

Universal Frequency Translation and Applications of Same

and naming as inventors:

David F. Sorrells
Michael J. Bultman
Robert W. Cook
Richard C. Looke
Charley D. Moses, Jr.

Assistant Commissioner for Patents
February 25, 2000
Page 2

the application consisting of:

- a. A specification containing:
 - (i) 40 pages of description prior to the claims;
 - (ii) 1 page of claims (3 claims);
 - (iii) a one (1) page abstract;
 - b. Thirty-nine (39) sheets of drawings: (Figures 1A-1D, 2-5, 6A-6I, 7-14, 15A-15F, 16-19, 20A-20A1, 20B-20F, 21, 22A-22F, 23A-23F, and 24A-24J);
 - c. A photocopy of the original combined Declaration and Power of Attorney, executed by inventors David F. Sorrells, Michael J. Bultman, Robert W. Cook, and Charley D. Moses, Jr., filed in Appl. No. 09/176,027;
 - d. A photocopy of a facsimile transmission of an original combined Declaration and Power of Attorney, executed by inventor Richard C. Looke, filed in Appl. No. 09/176,027;
3. Authorization to Treat a Reply As Incorporating An Extension of Time Under 37 C.F.R. § 1.136(a)(3) (*in duplicate*);
 4. A photocopy of an original Assignment to **ParkerVision, Inc.**, executed by inventors David F. Sorrells, Michael J. Bultman, Robert W. Cook, and Charley D. Moses, Jr., filed in Appl. No. 09/176,027;
 5. A photocopy of a facsimile transmission of an original Assignment to **ParkerVision, Inc.**, executed by inventor Richard C. Looke, filed in Appl. No. 09/176,027;
 6. A photocopy of a facsimile transmission of an original, executed Certificate under 37 C.F.R. § 3.73(b);
 7. A photocopy of a facsimile transmission of an original, executed Power of Attorney from Assignee; and
 8. Two (2) return postcards.

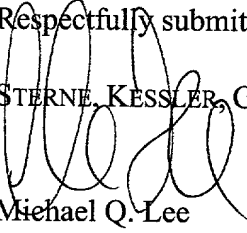
Assistant Commissioner for Patents
February 25, 2000
Page 3

It is respectfully requested that, of the two attached postcards, one be stamped with the filing date of these documents and returned to our courier, and the other, prepaid postcard, be stamped with the filing date and unofficial application number and returned as soon as possible.

This application is being filed under 37 C.F.R. § 1.53(b) without filing fee.

Respectfully submitted,

STERNE, KESSLER, GOLDSTEIN & FOX P.L.L.C.


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Universal Frequency Translation, and Applications of Same

**Inventors: David F. Sorrells
Michael J. Bultman
Robert W. Cook
Richard C. Looke
Charley D. Moses, Jr.**

Cross-Reference to Other Applications

The following applications of common assignee are related to the present application, have the same filing date as the present application, and are herein incorporated by reference in their entireties:

"Method and System for Down-Converting Electromagnetic Signals,"
Attorney Docket No. 1744.0010000.

"Method and System for Frequency Up-Conversion," Attorney Docket No.
1744.0020000.

"Method and System for Ensuring Reception of a Communications Signal,"
Attorney Docket No. 1744.0030000.

"Integrated Frequency Translation And Selectivity," Attorney Docket No.
1744.0130000.

Background of the Invention

Field of the Invention

The present invention is generally related to frequency translation, and applications of same.

Related Art

Various communication components exist for performing frequency down-conversion, frequency up-conversion, and filtering. Also, schemes exist for signal reception in the face of potential jamming signals.

Summary of the Invention

The present invention is related to frequency translation, and applications of same. Such applications include, but are not limited to, frequency down-conversion, frequency up-conversion, enhanced signal reception, unified down-conversion and filtering, and combinations and applications of same.

Further features and advantages of the invention, as well as the structure and operation of various embodiments of the invention, are described in detail below with reference to the accompanying drawings. The drawing in which an element first appears is typically indicated by the leftmost character(s) and/or digit(s) in the corresponding reference number.

Brief Description of the Figures

The present invention will be described with reference to the accompanying drawings, wherein:

FIG. 1A is a block diagram of a universal frequency translation (UFT) module according to an embodiment of the invention;

FIG. 1B is a more detailed diagram of a universal frequency translation (UFT) module according to an embodiment of the invention;

FIG. 1C illustrates a UFT module used in a universal frequency down-conversion (UFD) module according to an embodiment of the invention;

FIG. 1D illustrates a UFT module used in a universal frequency up-conversion (UFU) module according to an embodiment of the invention;

FIG. 2 is a block diagram of a universal frequency translation (UFT) module according to an alternative embodiment of the invention;

FIG. 3 is a block diagram of a universal frequency up-conversion (UFU) module according to an embodiment of the invention;

FIG. 4 is a more detailed diagram of a universal frequency up-conversion (UFU) module according to an embodiment of the invention;

FIG. 5 is a block diagram of a universal frequency up-conversion (UFU) module according to an alternative embodiment of the invention;

FIGS. 6A-6I illustrate example waveforms used to describe the operation of the UFU module;

FIG. 7 illustrates a UFT module used in a receiver according to an embodiment of the invention;

FIG. 8 illustrates a UFT module used in a transmitter according to an embodiment of the invention;

FIG. 9 illustrates an environment comprising a transmitter and a receiver, each of which may be implemented using a UFT module of the invention;

FIG. 10 illustrates a transceiver according to an embodiment of the invention;

FIG. 11 illustrates a transceiver according to an alternative embodiment of the invention;

FIG. 12 illustrates an environment comprising a transmitter and a receiver, each of which may be implemented using enhanced signal reception (ESR) components of the invention;

FIG. 13 illustrates a UFT module used in a unified down-conversion and filtering (UDF) module according to an embodiment of the invention;

FIG. 14 illustrates an example receiver implemented using a UDF module according to an embodiment of the invention;

FIGS. 15A-15F illustrate example applications of the UDF module according to embodiments of the invention;

FIG. 16 illustrates an environment comprising a transmitter and a receiver, each of which may be implemented using enhanced signal reception (ESR) components of the invention, wherein the receiver may be further implemented using one or more UFD modules of the invention;

FIG. 17 illustrates a unified down-converting and filtering (UDF) module according to an embodiment of the invention;

FIG. 18 is a table of example values at nodes in the UDF module of FIG. 17;

FIG. 19 is a detailed diagram of an example UDF module according to an embodiment of the invention;

FIGS. 20A and 20A-1 are example aliasing modules according to embodiments of the invention;

FIGS. 20B-20F are example waveforms used to describe the operation of the aliasing modules of FIGS. 20A and 20A-1;

FIG. 21 illustrates an enhanced signal reception system according to an embodiment of the invention;

FIGS. 22A-22F are example waveforms used to describe the system of FIG. 21;

FIG. 23A illustrates an example transmitter in an enhanced signal reception system according to an embodiment of the invention;

FIGS. 23B and 23C are example waveforms used to further describe the enhanced signal reception system according to an embodiment of the invention;

FIG. 23D illustrates another example transmitter in an enhanced signal reception system according to an embodiment of the invention;

FIGS. 23E and 23F are example waveforms used to further describe the enhanced signal reception system according to an embodiment of the invention;

FIG. 24A illustrates an example receiver in an enhanced signal reception system according to an embodiment of the invention; and

FIGS. 24B-24J are example waveforms used to further describe the enhanced signal reception system according to an embodiment of the invention.

Detailed Description of the Preferred Embodiments

Table of Contents

- (1) Universal Frequency Translation
- (2) Frequency Down-conversion
- (3) Frequency Up-conversion

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SKGF Ref: 1744.0140000

- (4) Enhanced Signal Reception
- (5) Unified Down-conversion and Filtering
- (6) Example Embodiments of the Invention
- (7) Conclusion

(I) Universal Frequency Translation

The present invention is related to frequency translation, and applications of same. Such applications include, but are not limited to, frequency down-conversion, frequency up-conversion, enhanced signal reception, unified down-conversion and filtering, and combinations and applications of same.

FIG. 1A illustrates a universal frequency translation (UFT) module 102 according to embodiments of the invention. (The UFT module is also sometimes called a universal frequency translator, or a universal translator.)

As indicated by the example of FIG. 1A, some embodiments of the UFT module 102 include three ports (nodes), designated in FIG. 1A as Port 1, Port 2, and Port 3. Other UFT embodiments include other than three ports.

Generally, the UFT module 102 (perhaps in combination with other components) operates to generate an output signal from an input signal, where the frequency of the output signal differs from the frequency of the input signal. In other words, the UFT module 102 (and perhaps other components) operates to generate the output signal from the input signal by translating the frequency (and perhaps other characteristics) of the input signal to the frequency (and perhaps other characteristics) of the output signal.

An example embodiment of the UFT module 103 is generally illustrated in FIG. 1B. Generally, the UFT module 103 includes a switch 106 controlled by a control signal 108. The switch 106 is said to be a controlled switch.

As noted above, some UFT embodiments include other than three ports. For example, and without limitation, FIG. 2 illustrates an example UFT module 202. The example UFT module 202 includes a diode 204 having two ports, designated as Port 1 and Port 2/3. This embodiment does not include a third port, as indicated by the dotted line around the "Port 3" label.

The UFT module is a very powerful and flexible device. Its flexibility is illustrated, in part, by the wide range of applications in which it can be used. Its power is illustrated, in part, by the usefulness and performance of such applications.

For example, a UFT module 115 can be used in a universal frequency down-conversion (UFD) module 114, an example of which is shown in FIG. 1C. In this capacity, the UFT module 115 frequency down-converts an input signal to an output signal.

As another example, as shown in FIG. 1D, a UFT module 117 can be used in a universal frequency up-conversion (UFU) module 116. In this capacity, the UFT module 117 frequency up-converts an input signal to an output signal.

These and other applications of the UFT module are described below. Additional applications of the UFT module will be apparent to persons skilled in the relevant art(s) based on the teachings contained herein. In some applications, the UFT module is a required component. In other applications, the UFT module is an optional component.

(2) Frequency Down-conversion

The present invention is directed to systems and methods of universal frequency down-conversion, and applications of same.

In particular, the following discussion describes down-converting using a Universal Frequency Translation Module. The down-conversion of an EM signal by aliasing the EM signal at an aliasing rate is fully described in co-pending U.S. Patent Application entitled "Method and System for Down-converting an Electromagnetic Signal," Application No. (to be assigned) , Attorney Docket Number 1744.0010000, the full disclosure of which is incorporated herein by reference. A relevant portion of the above mentioned patent application is summarized below to describe down-converting an input signal to produce a down-converted signal that exists at a lower frequency or a baseband signal.

FIG. 20A illustrates an aliasing module 2000 for down-conversion using a universal frequency translation (UFT) module 2002 which down-converts an EM input signal 2004. In particular embodiments, aliasing module 2000 includes a switch 2008 and a capacitor 2010. The electronic alignment of the circuit components is flexible. That is, in one implementation, the switch 2008 is in series with input signal 2004 and capacitor 2010 is shunted to ground (although it may be other than ground in configurations such as differential mode). In a second implementation (see FIG. 20A-1), the capacitor 2010 is in series with the input signal 2004 and the switch 2008 is shunted to ground (although it may be other than ground in configurations such as differential mode). Aliasing module 2000 with UFT module 2002 can be easily tailored to down-convert a wide variety of electromagnetic signals using aliasing frequencies that are well below the frequencies of the EM input signal 2004.

In one implementation, aliasing module 2000 down-converts the input signal 2004 to an intermediate frequency (IF) signal. In another implementation, the

aliasing module 2000 down-converts the input signal 2004 to a demodulated baseband signal. In yet another implementation, the input signal 2004 is a frequency modulated (FM) signal, and the aliasing module 2000 down-converts it to a non-FM signal, such as a phase modulated (PM) signal or an amplitude modulated (AM) signal. Each of the above implementations is described below.

In an embodiment, the control signal 2006 includes a train of pulses that repeat at an aliasing rate that is equal to, or less than, twice the frequency of the input signal 2004. In this embodiment, the control signal 2006 is referred to herein as an aliasing signal because it is below the Nyquist rate for the frequency of the input signal 2004. Preferably, the frequency of control signal 2006 is much less than the input signal 2004.

A train of pulses 2018 as shown in FIG. 20D controls the switch 2008 to alias the input signal 2004 with the control signal 2006 to generate a down-converted output signal 2012. More specifically, in an embodiment, switch 2008 closes on a first edge of each pulse 2020 of FIG. 20D and opens on a second edge of each pulse. When the switch 2008 is closed, the input signal 2004 is coupled to the capacitor 2010, and charge is transferred from the input signal to the capacitor 2010. The charge stored during successive pulses forms down-converted output signal 2012.

Exemplary waveforms are shown in FIGS. 20B-20F.

FIG. 20B illustrates an analog amplitude modulated (AM) carrier signal 2014 that is an example of input signal 2004. For illustrative purposes, in FIG. 20C, an analog AM carrier signal portion 2016 illustrates a portion of the analog AM carrier signal 2014 on an expanded time scale. The analog AM carrier signal portion 2016 illustrates the analog AM carrier signal 2014 from time t_0 to time t_1 .

FIG. 20D illustrates an exemplary aliasing signal 2018 that is an example of control signal 2006. Aliasing signal 2018 is on approximately the same time scale

as the analog AM carrier signal portion 2016. In the example shown in FIG. 20D, the aliasing signal 2018 includes a train of pulses 2020 having negligible apertures that tend towards zero (the invention is not limited to this embodiment, as discussed below). The pulse aperture may also be referred to as the pulse width as will be understood by those skilled in the art(s). The pulses 2020 repeat at an aliasing rate, or pulse repetition rate of aliasing signal 2018. The aliasing rate is determined as described below, and further described in co-pending U.S. Patent Application entitled "Method and System for Down-converting an Electromagnetic Signal," Application No. (to be assigned), Attorney Docket Number 1744.0010000.

As noted above, the train of pulses 2020 (i.e., control signal 2006) control the switch 2008 to alias the analog AM carrier signal 2016 (i.e., input signal 2004) at the aliasing rate of the aliasing signal 2018. Specifically, in this embodiment, the switch 2008 closes on a first edge of each pulse and opens on a second edge of each pulse. When the switch 2008 is closed, input signal 2004 is coupled to the capacitor 2010, and charge is transferred from the input signal 2004 to the capacitor 2010. The charge transferred during a pulse is referred to herein as an under-sample. Exemplary under-samples 2022 form down-converted signal portion 2024 (FIG. 20E) that corresponds to the analog AM carrier signal portion 2016 (FIG. 20C) and the train of pulses 2020 (FIG. 20D). The charge stored during successive under-samples of AM carrier signal 2014 form the down-converted signal 2024 (FIG. 20E) that is an example of down-converted output signal 2012 (FIG. 20A). In FIG. 20F, a demodulated baseband signal 2026 represents the demodulated baseband signal 2024 after filtering on a compressed time scale. As illustrated, down-converted signal 2026 has substantially the same "amplitude envelope" as AM carrier signal 2014. Therefore, FIGS. 20B-20F illustrate down-conversion of AM carrier signal 2014.

The waveforms shown in FIGS. 20B-20F are discussed herein for illustrative purposes only, and are not limiting. Additional exemplary time domain and frequency domain drawings, and exemplary methods and systems of the invention relating thereto, are disclosed in co-pending U.S. Patent Application entitled
5 "Method and System for Down-converting an Electromagnetic Signal," Application No. (to be assigned), Attorney Docket Number 1744.0010000.

The aliasing rate of control signal 2006 determines whether the input signal 2004 is down-converted to an IF signal, down-converted to a demodulated baseband signal, or down-converted from an FM signal to a PM or an AM signal. Generally,
10 relationships between the input signal 2004, the aliasing rate of the control signal 2006, and the down-converted output signal 2012 are illustrated below:

$$\begin{aligned} (\text{Freq. of input signal 2004}) &= n \cdot (\text{Freq. of control signal 2006}) \pm \\ &(\text{Freq. of down-converted output signal 2012}) \end{aligned}$$

For the examples contained herein, only the "+" condition will be discussed. The
15 value of n represents a harmonic or sub-harmonic of input signal 2004 (e.g., $n = 0.5, 1, 2, 3, \dots$).

When the aliasing rate of control signal 2006 is off-set from the frequency of input signal 2004, or off-set from a harmonic or sub-harmonic thereof, input signal
20 2004 is down-converted to an IF signal. This is because the under-sampling pulses occur at different phases of subsequent cycles of input signal 2004. As a result, the under-samples form a lower frequency oscillating pattern. If the input signal 2004 includes lower frequency changes, such as amplitude, frequency, phase, etc., or any combination thereof, the charge stored during associated under-samples reflects the
25 lower frequency changes, resulting in similar changes on the down-converted IF

signal. For example, to down-convert a 901 MHz input signal to a 1 MHz IF signal, the frequency of the control signal 2006 would be calculated as follows:

$$\begin{aligned}(\text{Freq}_{\text{input}} - \text{Freq}_{\text{IF}})/n &= \text{Freq}_{\text{control}} \\(901 \text{ MHz} - 1 \text{ MHz})/n &= 900/n\end{aligned}$$

For $n = 0.5, 1, 2, 3, 4$, etc., the frequency of the control signal 2006 would be substantially equal to 1.8 GHz, 900 MHz, 450 MHz, 300 MHz, 225 MHz, etc.

Exemplary time domain and frequency domain drawings, illustrating down-conversion of analog and digital AM, PM and FM signals to IF signals, and exemplary methods and systems thereof, are disclosed in co-pending U.S. Patent Application entitled "Method and System for Down-converting an Electromagnetic Signal," Application No. (to be assigned) , Attorney Docket Number 1744.0010000.

Alternatively, when the aliasing rate of the control signal 2006 is substantially equal to the frequency of the input signal 2004, or substantially equal to a harmonic or sub-harmonic thereof, input signal 2004 is directly down-converted to a demodulated baseband signal. This is because, without modulation, the under-sampling pulses occur at the same point of subsequent cycles of the input signal 2004. As a result, the under-samples form a constant output baseband signal. If the input signal 2004 includes lower frequency changes, such as amplitude, frequency, phase, etc., or any combination thereof, the charge stored during associated under-samples reflects the lower frequency changes, resulting in similar changes on the demodulated baseband signal. For example, to directly down-convert a 900 MHz input signal to a demodulated baseband signal (i.e., zero IF), the frequency of the control signal 2006 would be calculated as follows:

$$\begin{aligned}(\text{Freq}_{\text{input}} - \text{Freq}_{\text{IF}})/n &= \text{Freq}_{\text{control}} \\(900 \text{ MHz} - 0 \text{ MHz})/n &= 900 \text{ MHz}/n\end{aligned}$$

For $n = 0.5, 1, 2, 3, 4$, etc., the frequency of the control signal 2006 should be substantially equal to 1.8 GHz, 900 MHz, 450 MHz, 300 MHz, 225 MHz, etc.

Exemplary time domain and frequency domain drawings, illustrating direct down-conversion of analog and digital AM and PM signals to demodulated baseband signals, and exemplary methods and systems thereof, are disclosed in the co-pending U.S. Patent Application entitled "Method and System for Down-converting an Electromagnetic Signal," Application No. (to be assigned), Attorney Docket Number 1744.0010000.

Alternatively, to down-convert an input FM signal to a non-FM signal, a frequency within the FM bandwidth must be down-converted to baseband (i.e., zero IF). As an example, to down-convert a frequency shift keying (FSK) signal (a sub-set of FM) to a phase shift keying (PSK) signal (a subset of PM), the mid-point between a lower frequency F_1 and an upper frequency F_2 (that is, $[(F_1 + F_2) \div 2]$) of the FSK signal is down-converted to zero IF. For example, to down-convert an FSK signal having F_1 equal to 899 MHz and F_2 equal to 901 MHz, to a PSK signal, the aliasing rate of the control signal 2006 would be calculated as follows:

$$\begin{aligned}\text{Frequency of the input} &= (F_1 + F_2) \div 2 \\&= (899 \text{ MHz} + 901 \text{ MHz}) \div 2 \\&= 900 \text{ MHz}\end{aligned}$$

Frequency of the down-converted signal = 0 (i.e., baseband)

$$\begin{aligned} (\text{Freq}_{\text{input}} - \text{Freq}_{\text{IF}})/n &= \text{Freq}_{\text{control}} \\ (900 \text{ MHz} - 0 \text{ MHz})/n &= 900 \text{ MHz}/n \end{aligned}$$

For $n = 0.5, 1, 2, 3$, etc., the frequency of the control signal 2006 should be substantially equal to 1.8 GHz, 900 MHz, 450 MHz, 300 MHz, 225 MHz, etc. The frequency of the down-converted PSK signal is substantially equal to one half the difference between the lower frequency F_1 and the upper frequency F_2 .

As another example, to down-convert a FSK signal to an amplitude shift keying (ASK) signal (a subset of AM), either the lower frequency F_1 or the upper frequency F_2 of the FSK signal is down-converted to zero IF. For example, to down-convert an FSK signal having F_1 equal to 900 MHz and F_2 equal to 901 MHz, to an ASK signal, the aliasing rate of the control signal 2006 should be substantially equal to:

$$\begin{aligned} (900 \text{ MHz} - 0 \text{ MHz})/n &= 900 \text{ MHz}/n, \text{ or} \\ (901 \text{ MHz} - 0 \text{ MHz})/n &= 901 \text{ MHz}/n. \end{aligned}$$

For the former case of $900 \text{ MHz}/n$, and for $n = 0.5, 1, 2, 3, 4$, etc., the frequency of the control signal 2006 should be substantially equal to 1.8 GHz, 900 MHz, 450 MHz, 300 MHz, 225 MHz, etc. For the latter case of $901 \text{ MHz}/n$, and for $n = 0.5, 1, 2, 3, 4$, etc., the frequency of the control signal 2006 should be substantially equal to 1.802 GHz, 901 MHz, 450.5 MHz, 300.333 MHz, 225.25 MHz, etc. The frequency of the down-converted AM signal is substantially equal to the difference between the lower frequency F_1 and the upper frequency F_2 (i.e., 1 MHz).

Exemplary time domain and frequency domain drawings, illustrating down-conversion of FM signals to non-FM signals, and exemplary methods and systems

thereof, are disclosed in the co-pending U.S. Patent Application entitled "Method and System for Down-converting an Electromagnetic Signal," Application No. (to be assigned), Attorney Docket Number 1744.0010000.

5 In an embodiment, the pulses of the control signal 2006 have negligible apertures that tend towards zero. This makes the UFT module 2002 a high input impedance device. This configuration is useful for situations where minimal disturbance of the input signal may be desired.

10 In another embodiment, the pulses of the control signal 2006 have non-negligible apertures that tend away from zero. This makes the UFT module 2002 a lower input impedance device. This allows the lower input impedance of the UFT module 2002 to be substantially matched with a source impedance of the input signal 2004. This also improves the energy transfer from the input signal 2004 to the down-converted output signal 2012, and hence the efficiency and signal to noise (s/n) ratio of UFT module 2002.

15 Exemplary systems and methods for generating and optimizing the control signal 2006, and for otherwise improving energy transfer and s/n ratio, are disclosed in the co-pending U.S. Patent Application entitled "Method and System for Down-converting an Electromagnetic Signal," Application No. (to be assigned), Attorney Docket Number 1744.0010000.

20 (3) *Frequency Up-conversion*

The present invention is directed to systems and methods of frequency up-conversion, and applications of same.

An example frequency up-conversion system 300 is illustrated in FIG. 3. The frequency up-conversion system 300 is now described.

5 An input signal 302 (designated as "Control Signal" in FIG. 3) is accepted by a switch module 304. For purposes of example only, assume that the input signal 302 is a FM input signal 606, an example of which is shown in FIG. 6C. FM input signal 606 may have been generated by modulating information signal 602 onto oscillating signal 604 (FIGS. 6A and 6B). It should be understood that the invention is not limited to this embodiment. The information signal 602 can be analog, digital, or any combination thereof, and any modulation scheme can be used.

10 The output of switch module 304 is a harmonically rich signal 306, shown for example in FIG. 6D as a harmonically rich signal 608. The harmonically rich signal 608 has a continuous and periodic waveform.

15 FIG. 6E is an expanded view of two sections of harmonically rich signal 608, section 610 and section 612. The harmonically rich signal 608 may be a rectangular wave, such as a square wave or a pulse (although, the invention is not limited to this embodiment). For ease of discussion, the term "rectangular waveform" is used to refer to waveforms that are substantially rectangular. In a similar manner, the term "square wave" refers to those waveforms that are substantially square and it is not the intent of the present invention that a perfect square wave be generated or needed.

20 Harmonically rich signal 608 is comprised of a plurality of sinusoidal waves whose frequencies are integer multiples of the fundamental frequency of the waveform of the harmonically rich signal 608. These sinusoidal waves are referred to as the harmonics of the underlying waveform, and the fundamental frequency is referred to as the first harmonic. FIG. 6F and FIG. 6G show separately the sinusoidal components making up the first, third, and fifth harmonics of section 610 and section 25 612. (Note that in theory there may be an infinite number of harmonics; in this example, because harmonically rich signal 608 is shown as a square wave, there are

only odd harmonics). Three harmonics are shown simultaneously (but not summed) in FIG. 6H.

5 The relative amplitudes of the harmonics are generally a function of the relative widths of the pulses of harmonically rich signal 306 and the period of the fundamental frequency, and can be determined by doing a Fourier analysis of harmonically rich signal 306. According to an embodiment of the invention, the input signal 606 may be shaped to ensure that the amplitude of the desired harmonic is sufficient for its intended use (e.g., transmission).

10 A filter 308 filters out any undesired frequencies (harmonics), and outputs an electromagnetic (EM) signal at the desired harmonic frequency or frequencies as an output signal 310, shown for example as a filtered output signal 614 in FIG. 6I.

15 FIG. 4 illustrates an example universal frequency up-conversion (UFU) module 401. The UFU module 401 includes an example switch module 304, which comprises a bias signal 402, a resistor or impedance 404, a universal frequency translator (UFT) 450, and a ground 408. The UFT 450 includes a switch 406. The input signal 302 (designated as "Control Signal" in FIG. 4) controls the switch 406 in the UFT 450, and causes it to close and open. Harmonically rich signal 306 is generated at a node 405 located between the resistor or impedance 404 and the switch 406.

20 Also in FIG. 4, it can be seen that an example filter 308 is comprised of a capacitor 410 and an inductor 412 shunted to a ground 414. The filter is designed to filter out the undesired harmonics of harmonically rich signal 306.

The invention is not limited to the UFU embodiment shown in FIG. 4.

25 For example, in an alternate embodiment shown in FIG. 5, an unshaped input signal 501 is routed to a pulse shaping module 502. The pulse shaping module 502 modifies the unshaped input signal 501 to generate a (modified) input signal 302

(designated as the "Control Signal" in FIG. 5). The input signal 302 is routed to the switch module 304, which operates in the manner described above. Also, the filter 308 of FIG. 5 operates in the manner described above.

The purpose of the pulse shaping module 502 is to define the pulse width of the input signal 302. Recall that the input signal 302 controls the opening and closing of the switch 406 in switch module 304. During such operation, the pulse width of the input signal 302 establishes the pulse width of the harmonically rich signal 306. As stated above, the relative amplitudes of the harmonics of the harmonically rich signal 306 are a function of at least the pulse width of the harmonically rich signal 306. As such, the pulse width of the input signal 302 contributes to setting the relative amplitudes of the harmonics of harmonically rich signal 306.

Further details of up-conversion as described in this section are presented in pending U.S. application "Method and System for Frequency Up-Conversion," Attorney Docket No. 1744.0020000, incorporated herein by reference in its entirety.

(4) Enhanced Signal Reception

The present invention is directed to systems and methods of enhanced signal reception (ESR), and applications of same.

Referring to FIG. 21, transmitter 2104 accepts a modulating baseband signal 2102 and generates (transmitted) redundant spectrums 2106a-n, which are sent over communications medium 2108. Receiver 2112 recovers a demodulated baseband signal 2114 from (received) redundant spectrums 2110a-n. Demodulated baseband signal 2114 is representative of the modulating baseband signal 2102, where the level

of similarity between the modulating baseband signal 2114 and the modulating baseband signal 2102 is application dependent.

Modulating baseband signal 2102 is preferably any information signal desired for transmission and/or reception. An example modulating baseband signal 2202 is illustrated in FIG. 22A, and has an associated modulating baseband spectrum 2204 and image spectrum 2203 that are illustrated in FIG. 22B. Modulating baseband signal 2202 is illustrated as an analog signal in FIG. 22a, but could also be a digital signal, or combination thereof. Modulating baseband signal 2202 could be a voltage (or current) characterization of any number of real world occurrences, including for example and without limitation, the voltage (or current) representation for a voice signal.

Each transmitted redundant spectrum 2106a-n contains the necessary information to substantially reconstruct the modulating baseband signal 2102. In other words, each redundant spectrum 2106a-n contains the necessary amplitude, phase, and frequency information to reconstruct the modulating baseband signal 2102.

FIG. 22C illustrates example transmitted redundant spectrums 2206b-d. Transmitted redundant spectrums 2206b-d are illustrated to contain three redundant spectrums for illustration purposes only. Any number of redundant spectrums could be generated and transmitted as will be explained in following discussions.

Transmitted redundant spectrums 2206b-d are centered at f_1 , with a frequency spacing f_2 between adjacent spectrums. Frequencies f_1 and f_2 are dynamically adjustable in real-time as will be shown below. FIG. 22D illustrates an alternate embodiment, where redundant spectrums 2208c,d are centered on unmodulated oscillating signal 2209 at f_1 (Hz). Oscillating signal 2209 may be suppressed if desired using, for example, phasing techniques or filtering techniques. Transmitted

redundant spectrums are preferably above baseband frequencies as is represented by break 2205 in the frequency axis of FIGS. 22C and 22D.

Received redundant spectrums 2110a-n are substantially similar to transmitted redundant spectrums 2106a-n, except for the changes introduced by the communications medium 2108. Such changes can include but are not limited to signal attenuation, and signal interference. FIG. 22E illustrates example received redundant spectrums 2210b-d. Received redundant spectrums 2210b-d are substantially similar to transmitted redundant spectrums 2206b-d, except that redundant spectrum 2210c includes an undesired jamming signal spectrum 2211 in order to illustrate some advantages of the present invention. Jamming signal spectrum 2211 is a frequency spectrum associated with a jamming signal. For purposes of this invention, a "jamming signal" refers to any unwanted signal, regardless of origin, that may interfere with the proper reception and reconstruction of an intended signal. Furthermore, the jamming signal is not limited to tones as depicted by spectrum 2211, and can have any spectral shape, as will be understood by those skilled in the art(s).

As stated above, demodulated baseband signal 2114 is extracted from one or more of received redundant spectrums 2210b-d. FIG. 22F illustrates example demodulated baseband signal 2212 that is, in this example, substantially similar to modulating baseband signal 2202 (FIG. 22A); where in practice, the degree of similarity is application dependent.

An advantage of the present invention should now be apparent. The recovery of modulating baseband signal 2202 can be accomplished by receiver 2112 in spite of the fact that high strength jamming signal(s) (e.g. jamming signal spectrum 2211) exist on the communications medium. The intended baseband signal can be recovered because multiple redundant spectrums are transmitted, where each

redundant spectrum carries the necessary information to reconstruct the baseband signal. At the destination, the redundant spectrums are isolated from each other so that the baseband signal can be recovered even if one or more of the redundant spectrums are corrupted by a jamming signal.

5 Transmitter 2104 will now be explored in greater detail. FIG. 23A illustrates transmitter 2301, which is one embodiment of transmitter 2104 that generates redundant spectrums configured similar to redundant spectrums 2206b-d. Transmitter 2301 includes generator 2303, optional spectrum processing module 2304, and optional medium interface module 2320. Generator 2303 includes: first oscillator 10 2302, second oscillator 2309, first stage modulator 2306, and second stage modulator 2310.

Transmitter 2301 operates as follows. First oscillator 2302 and second oscillator 2309 generate a first oscillating signal 2305 and second oscillating signal 2312, respectively. First stage modulator 2306 modulates first oscillating signal 2305 15 with modulating baseband signal 2202, resulting in modulated signal 2308. First stage modulator 2306 may implement any type of modulation including but not limited to: amplitude modulation, frequency modulation, phase modulation, combinations thereof, or any other type of modulation. Second stage modulator 2310 modulates modulated signal 2308 with second oscillating signal 2312, resulting in 20 multiple redundant spectrums 2206a-n shown in FIG. 23B. Second stage modulator 2310 is preferably a phase modulator, or a frequency modulator, although other types of modulation may be implemented including but not limited to amplitude modulation. Each redundant spectrum 2206a-n contains the necessary amplitude, phase, and frequency information to substantially reconstruct the modulating 25 baseband signal 2202.

Redundant spectrums 2206a-n are substantially centered around f_1 , which is the characteristic frequency of first oscillating signal 2305. Also, each redundant spectrum 2206a-n (except for 2206c) is offset from f_1 by approximately a multiple of f_2 (Hz), where f_2 is the frequency of the second oscillating signal 2312. Thus, each redundant spectrum 2206a-n is offset from an adjacent redundant spectrum by f_2 (Hz). This allows the spacing between adjacent redundant spectrums to be adjusted (or tuned) by changing f_2 that is associated with second oscillator 2309. Adjusting the spacing between adjacent redundant spectrums allows for dynamic real-time tuning of the bandwidth occupied by redundant spectrums 2206a-n.

In one embodiment, the number of redundant spectrums 2206a-n generated by transmitter 2301 is arbitrary and may be unlimited as indicated by the "a-n" designation for redundant spectrums 2206a-n. However, a typical communications medium will have a physical and/or administrative limitations (i.e. FCC regulations) that restrict the number of redundant spectrums that can be practically transmitted over the communications medium. Also, there may be other reasons to limit the number of redundant spectrums transmitted. Therefore, preferably, the transmitter 2301 will include an optional spectrum processing module 2304 to process the redundant spectrums 2206a-n prior to transmission over communications medium 2108.

In one embodiment, spectrum processing module 2304 includes a filter with a passband 2207 (FIG. 23C) to select redundant spectrums 2206b-d for transmission. This will substantially limit the frequency bandwidth occupied by the redundant spectrums to the passband 2207. In one embodiment, spectrum processing module 2304 also up converts redundant spectrums and/or amplifies redundant spectrums prior to transmission over the communications medium 2108. Finally, medium interface module 2320 transmits redundant spectrums over the communications

medium 2108. In one embodiment, communications medium 2108 is an over-the-air link and medium interface module 2320 is an antenna. Other embodiments for communications medium 2108 and medium interface module 2320 will be understood based on the teachings contained herein.

5 FIG. 23D illustrates transmitter 2321, which is one embodiment of transmitter 2104 that generates redundant spectrums configured similar to redundant spectrums 2208c-d and unmodulated spectrum 2209. Transmitter 2321 includes generator 2311, spectrum processing module 2304, and (optional) medium interface module 2320. Generator 2311 includes: first oscillator 2302, second oscillator 2309, first stage modulator 2306, and second stage modulator 2310.

10 As shown in FIG. 23D, many of the components in transmitter 2321 are similar to those in transmitter 2301. However, in this embodiment, modulating baseband signal 2202 modulates second oscillating signal 2312. Transmitter 2321 operates as follows. First stage modulator 2306 modulates second oscillating signal 2312 with modulating baseband signal 2202, resulting in modulated signal 2322. As described earlier, first stage modulator 2306 can effect any type of modulation including but not limited to: amplitude modulation frequency modulation, combinations thereof, or any other type of modulation. Second stage modulator 2310 modulates first oscillating signal 2304 with modulated signal 2322, resulting in redundant spectrums 2208a-n, as shown in FIG. 23E. Second stage modulator 2310 is preferably a phase or frequency modulator, although other modulators could used including but not limited to an amplitude modulator.

20 Redundant spectrums 2208a-n are centered on unmodulated spectrum 2209 (at f_1 Hz), and adjacent spectrums are separated by f_2 Hz. The number of redundant spectrums 2208a-n generated by generator 2311 is arbitrary and unlimited, similar to spectrums 2206a-n discussed above. Therefore, optional spectrum processing

module 2304 may also include a filter with passband 2325 to select, for example, spectrums 2208c,d for transmission over communications medium 2108. In addition, optional spectrum processing module 2304 may also include a filter (such as a bandstop filter) to attenuate unmodulated spectrum 2209. Alternatively, unmodulated spectrum 2209 may be attenuated by using phasing techniques during redundant spectrum generation. Finally, (optional) medium interface module 2320 transmits redundant spectrums 2208c,d over communications medium 2108.

Receiver 2112 will now be explored in greater detail to illustrate recovery of a demodulated baseband signal from received redundant spectrums. FIG. 24A illustrates receiver 2430, which is one embodiment of receiver 2112. Receiver 2430 includes optional medium interface module 2402, down-converter 2404, spectrum isolation module 2408, and data extraction module 2414. Spectrum isolation module 2408 includes filters 2410a-c. Data extraction module 2414 includes demodulators 2416a-c, error check modules 2420a-c, and arbitration module 2424. Receiver 2430 will be discussed in relation to the signal diagrams in FIGS. 24B-24J.

In one embodiment, optional medium interface module 2402 receives redundant spectrums 2210b-d (FIG. 22E, and FIG. 24B). Each redundant spectrum 2210b-d includes the necessary amplitude, phase, and frequency information to substantially reconstruct the modulating baseband signal used to generated the redundant spectrums. However, in the present example, spectrum 2210c also contains jamming signal 2211, which may interfere with the recovery of a baseband signal from spectrum 2210c. Down-converter 2404 down-converts received redundant spectrums 2210b-d to lower intermediate frequencies, resulting in redundant spectrums 2406a-c (FIG. 24C). Jamming signal 2211 is also down-converted to jamming signal 2407, as it is contained within redundant spectrum 2406b. Spectrum isolation module 2408 includes filters 2410a-c that isolate redundant spectrums

2406a-c from each other (FIGS. 24D-24F, respectively). Demodulators 2416a-c independently demodulate spectrums 2406a-c, resulting in demodulated baseband signals 2418a-c, respectively (FIGS. 24G-24I). Error check modules 2420a-c analyze demodulated baseband signal 2418a-c to detect any errors. In one embodiment, each error check module 2420a-c sets an error flag 2422a-c whenever an error is detected in a demodulated baseband signal. Arbitration module 2424 accepts the demodulated baseband signals and associated error flags, and selects a substantially error-free demodulated baseband signal (FIG. 24J). In one embodiment, the substantially error-free demodulated baseband signal will be substantially similar to the modulating baseband signal used to generate the received redundant spectrums, where the degree of similarity is application dependent.

Referring to FIGS. 24G-I, arbitration module 2424 will select either demodulated baseband signal 2418a or 2418c, because error check module 2420b will set the error flag 2422b that is associated with demodulated baseband signal 2418b.

The error detection schemes implemented by the error detection modules include but are not limited to: cyclic redundancy check (CRC) and parity check for digital signals, and various error detections schemes for analog signal.

Further details of enhanced signal reception as described in this section are presented in pending U.S. application "Method and System for Ensuring Reception of a Communications Signal," Attorney Docket No. 1744.0030000, incorporated herein by reference in its entirety.

(5) Unified Down-conversion and Filtering

The present invention is directed to systems and methods of unified down-conversion and filtering (UDF), and applications of same.

In particular, the present invention includes a unified down-converting and filtering (UDF) module that performs frequency selectivity and frequency translation in a unified (i.e., integrated) manner. By operating in this manner, the invention achieves high frequency selectivity prior to frequency translation (the invention is not limited to this embodiment). The invention achieves high frequency selectivity at substantially any frequency, including but not limited to RF (radio frequency) and greater frequencies. It should be understood that the invention is not limited to this example of RF and greater frequencies. The invention is intended, adapted, and capable of working with lower than radio frequencies.

FIG. 17 is a conceptual block diagram of a UDF module 1702 according to an embodiment of the present invention. The UDF module 1702 performs at least frequency translation and frequency selectivity.

The effect achieved by the UDF module 1702 is to perform the frequency selectivity operation prior to the performance of the frequency translation operation. Thus, the UDF module 1702 effectively performs input filtering.

According to embodiments of the present invention, such input filtering involves a relatively narrow bandwidth. For example, such input filtering may represent channel select filtering, where the filter bandwidth may be, for example, 50 KHz to 150 KHz. It should be understood, however, that the invention is not limited to these frequencies. The invention is intended, adapted, and capable of achieving filter bandwidths of less than and greater than these values.

In embodiments of the invention, input signals 1704 received by the UDF module 1702 are at radio frequencies. The UDF module 1702 effectively operates to input filter these RF input signals 1704. Specifically, in these embodiments, the

UDF module 1702 effectively performs input, channel select filtering of the RF input signal 1704. Accordingly, the invention achieves high selectivity at high frequencies.

The UDF module 1702 effectively performs various types of filtering, including but not limited to bandpass filtering, low pass filtering, high pass filtering, notch filtering, all pass filtering, band stop filtering, etc., and combinations thereof.

Conceptually, the UDF module 1702 includes a frequency translator 1708. The frequency translator 1708 conceptually represents that portion of the UDF module 1702 that performs frequency translation (down conversion).

The UDF module 1702 also conceptually includes an apparent input filter 1706 (also sometimes called an input filtering emulator). Conceptually, the apparent input filter 1706 represents that portion of the UDF module 1702 that performs input filtering.

In practice, the input filtering operation performed by the UDF module 1702 is integrated with the frequency translation operation. The input filtering operation can be viewed as being performed concurrently with the frequency translation operation. This is a reason why the input filter 1706 is herein referred to as an "apparent" input filter 1706.

The UDF module 1702 of the present invention includes a number of advantages. For example, high selectivity at high frequencies is realizable using the UDF module 1702. This feature of the invention is evident by the high Q factors that are attainable. For example, and without limitation, the UDF module 1702 can be designed with a filter center frequency f_c on the order of 900 MHz, and a filter bandwidth on the order of 50 KHz. This represents a Q of 18,000 (Q is equal to the center frequency divided by the bandwidth).

It should be understood that the invention is not limited to filters with high Q factors. The filters contemplated by the present invention may have lesser or

greater Q_s , depending on the application, design, and/or implementation. Also, the scope of the invention includes filters where Q factor as discussed herein is not applicable.

5 The invention exhibits additional advantages. For example, the filtering center frequency f_c of the UDF module 1702 can be electrically adjusted, either statically or dynamically.

Also, the UDF module 1702 can be designed to amplify input signals.

Further, the UDF module 1702 can be implemented without large resistors, capacitors, or inductors. Also, the UDF module 1702 does not require that tight tolerances be maintained on the values of its individual components, i.e., its resistors, capacitors, inductors, etc. As a result, the architecture of the UDF module 1702 is friendly to integrated circuit design techniques and processes.

10 The features and advantages exhibited by the UDF module 1702 are achieved at least in part by adopting a new technological paradigm with respect to frequency selectivity and translation. Specifically, according to the present invention, the UDF module 1702 performs the frequency selectivity operation and the frequency translation operation as a single, unified (integrated) operation. According to the invention, operations relating to frequency translation also contribute to the performance of frequency selectivity, and vice versa.

20 According to embodiments of the present invention, the UDF module generates an output signal from an input signal using samples/instances of the input signal and samples/instances of the output signal.

More particularly, first, the input signal is under-sampled. This input sample includes information (such as amplitude, phase, etc.) representative of the input signal existing at the time the sample was taken.

As described further below, the effect of repetitively performing this step is to translate the frequency (that is, down-convert) of the input signal to a desired lower frequency, such as an intermediate frequency (IF) or baseband.

Next, the input sample is held (that is, delayed).

5 Then, one or more delayed input samples (some of which may have been scaled) are combined with one or more delayed instances of the output signal (some of which may have been scaled) to generate a current instance of the output signal.

Thus, according to a preferred embodiment of the invention, the output signal is generated from prior samples/instances of the input signal and/or the output signal. (It is noted that, in some embodiments of the invention, current samples/instances of the input signal and/or the output signal may be used to generate current instances of the output signal.). By operating in this manner, the UDF module preferably performs input filtering and frequency down-conversion in a unified manner.

10
15 FIG. 19 illustrates an example implementation of the unified down-converting and filtering (UDF) module 1922. The UDF module 1922 performs the frequency translation operation and the frequency selectivity operation in an integrated, unified manner as described above, and as further described below.

20 In the example of FIG. 19, the frequency selectivity operation performed by the UDF module 1922 comprises a band-pass filtering operation according to EQ. 1, below, which is an example representation of a band-pass filtering transfer function.

$$VO = \alpha_1 z^{-1}VI - \beta_1 z^{-1}VO - \beta_0 z^{-2}VO$$

EQ. 1

It should be noted, however, that the invention is not limited to band-pass filtering. Instead, the invention effectively performs various types of filtering, including but not limited to bandpass filtering, low pass filtering, high pass filtering, notch filtering, all pass filtering, band stop filtering, etc., and combinations thereof. As will be appreciated, there are many representations of any given filter type. The invention is applicable to these filter representations. Thus, EQ. 1 is referred to herein for illustrative purposes only, and is not limiting.

The UDF module 1922 includes a down-convert and delay module 1924, first and second delay modules 1928 and 1930, first and second scaling modules 1932 and 1934, an output sample and hold module 1936, and an (optional) output smoothing module 1938. Other embodiments of the UDF module will have these components in different configurations, and/or a subset of these components, and/or additional components. For example, and without limitation, in the configuration shown in FIG. 19, the output smoothing module 1938 is optional.

As further described below, in the example of FIG. 19, the down-convert and delay module 1924 and the first and second delay modules 1928 and 1930 include

switches that are controlled by a clock having two phases, ϕ_1 and ϕ_2 . ϕ_1 and ϕ_2 preferably have the same frequency, and are non-overlapping (alternatively, a plurality such as two clock signals having these characteristics could be used). As used herein, the term "non-overlapping" is defined as two or more signals where only one of the signals is active at any given time. In some embodiments, signals are "active" when they are high. In other embodiments, signals are active when they are low.

Preferably, each of these switches closes on a rising edge of ϕ_1 or ϕ_2 , and opens on the next corresponding falling edge of ϕ_1 or ϕ_2 . However, the invention is not limited to this example. As will be apparent to persons skilled in the relevant art(s), other clock conventions can be used to control the switches.

In the example of FIG. 19, it is assumed that α_1 is equal to one. Thus, the output of the down-convert and delay module 1924 is not scaled. As evident from the embodiments described above, however, the invention is not limited to this example.

The example UDF module 1922 has a filter center frequency of 900.2 MHZ and a filter bandwidth of 570 KHz. The pass band of the UDF module 1922 is on the order of 899.915 MHz to 900.485 MHz. The Q factor of the UDF module 1922 is approximately 1879 (i.e., 900.2 MHZ divided by 570 KHz).

The operation of the UDF module 1922 shall now be described with reference to a Table 1802 (FIG. 18) that indicates example values at nodes in the UDF module 1922 at a number of consecutive time increments. It is assumed in Table 1802 that the UDF module 1922 begins operating at time t-1. As indicated below, the UDF module 1922 reaches steady state a few time units after operation begins. The number of time units necessary for a given UDF module to reach steady state

depends on the configuration of the UDF module, and will be apparent to persons skilled in the relevant art(s) based on the teachings contained herein.

At the rising edge of ϕ_1 at time $t-1$, a switch 1950 in the down-convert and delay module 1924 closes. This allows a capacitor 1952 to charge to the current value of an input signal, VI_{t-1} , such that node 1902 is at VI_{t-1} . This is indicated by cell 1804 in FIG. 18. In effect, the combination of the switch 1950 and the capacitor 1952 in the down-convert and delay module 1924 operates to translate the frequency of the input signal VI to a desired lower frequency, such as IF or baseband. Thus, the value stored in the capacitor 1952 represents an instance of a down-converted image of the input signal VI .

The manner in which the down-convert and delay module 1924 performs frequency down-conversion is further described elsewhere in this application, and is additionally described in pending U.S. application "Method and System for Down-Converting Electromagnetic Signals," Attorney Docket No. 1744.0010000, which is herein incorporated by reference in its entirety.

Also at the rising edge of ϕ_1 at time $t-1$, a switch 1958 in the first delay module 1928 closes, allowing a capacitor 1960 to charge to VO_{t-1} , such that node 1906 is at VO_{t-1} . This is indicated by cell 1806 in Table 1802. (In practice, VO_{t-1} is undefined at this point. However, for ease of understanding, VO_{t-1} shall continue to be used for purposes of explanation.)

Also at the rising edge of ϕ_1 at time $t-1$, a switch 1966 in the second delay module 1930 closes, allowing a capacitor 1968 to charge to a value stored in a capacitor 1964. At this time, however, the value in capacitor 1964 is undefined, so the value in capacitor 1968 is undefined. This is indicated by cell 1807 in table 1802.

At the rising edge of ϕ_2 at time $t-1$, a switch 1954 in the down-convert and delay module 1924 closes, allowing a capacitor 1956 to charge to the level of the

capacitor 1952. Accordingly, the capacitor 1956 charges to $V_{I_{t-1}}$, such that node 1904 is at $V_{I_{t-1}}$. This is indicated by cell 1810 in Table 1802.

The UDF module 1922 may optionally include a unity gain module 1990A between capacitors 1952 and 1956. The unity gain module 1990A operates as a current source to enable capacitor 1956 to charge without draining the charge from capacitor 1952. For a similar reason, the UDF module 1922 may include other unity gain modules 1990B-1990G. It should be understood that, for many embodiments and applications of the invention, these unity gain modules 1990A-1990G are optional. The structure and operation of the unity gain modules 1990 will be apparent to persons skilled in the relevant art(s).

Also at the rising edge of ϕ_2 at time $t-1$, a switch 1962 in the first delay module 1928 closes, allowing a capacitor 1964 to charge to the level of the capacitor 1960. Accordingly, the capacitor 1964 charges to $V_{O_{t-1}}$, such that node 1908 is at $V_{O_{t-1}}$. This is indicated by cell 1814 in Table 1802.

Also at the rising edge of ϕ_2 at time $t-1$, a switch 1970 in the second delay module 1930 closes, allowing a capacitor 1972 to charge to a value stored in a capacitor 1968. At this time, however, the value in capacitor 1968 is undefined, so the value in capacitor 1972 is undefined. This is indicated by cell 1815 in table 1802.

At time t , at the rising edge of ϕ_1 , the switch 1950 in the down-convert and delay module 1924 closes. This allows the capacitor 1952 to charge to V_{I_t} , such that node 1902 is at V_{I_t} . This is indicated in cell 1816 of Table 1802.

Also at the rising edge of ϕ_1 at time t , the switch 1958 in the first delay module 1928 closes, thereby allowing the capacitor 1960 to charge to V_{O_t} . Accordingly, node 1906 is at V_{O_t} . This is indicated in cell 1820 in Table 1802.

Further at the rising edge of ϕ_1 at time t , the switch 1966 in the second delay module 1930 closes, allowing a capacitor 1968 to charge to the level of the capacitor

1964. Therefore, the capacitor 1968 charges to VO_{t-1} , such that node 1910 is at VO_{t-1} . This is indicated by cell 1824 in Table 1802.

At the rising edge of ϕ_2 at time t , the switch 1954 in the down-convert and delay module 1924 closes, allowing the capacitor 1956 to charge to the level of the capacitor 1952. Accordingly, the capacitor 1956 charges to VI_t , such that node 1904 is at VI_t . This is indicated by cell 1828 in Table 1802.

Also at the rising edge of ϕ_2 at time t , the switch 1962 in the first delay module 1928 closes, allowing the capacitor 1964 to charge to the level in the capacitor 1960. Therefore, the capacitor 1964 charges to VO_t , such that node 1908 is at VO_t . This is indicated by cell 1832 in Table 1802.

Further at the rising edge of ϕ_2 at time t , the switch 1970 in the second delay module 1930 closes, allowing the capacitor 1972 in the second delay module 1930 to charge to the level of the capacitor 1968 in the second delay module 1930. Therefore, the capacitor 1972 charges to VO_{t-1} , such that node 1912 is at VO_{t-1} . This is indicated in cell 1836 of FIG. 18.

At time $t+1$, at the rising edge of ϕ_1 , the switch 1950 in the down-convert and delay module 1924 closes, allowing the capacitor 1952 to charge to VI_{t+1} . Therefore, node 1902 is at VI_{t+1} , as indicated by cell 1838 of Table 1802.

Also at the rising edge of ϕ_1 at time $t+1$, the switch 1958 in the first delay module 1928 closes, allowing the capacitor 1960 to charge to VO_{t+1} . Accordingly, node 1906 is at VO_{t+1} , as indicated by cell 1842 in Table 1802.

Further at the rising edge of ϕ_1 at time $t+1$, the switch 1966 in the second delay module 1930 closes, allowing the capacitor 1968 to charge to the level of the capacitor 1964. Accordingly, the capacitor 1968 charges to VO_t , as indicated by cell 1846 of Table 1802.

In the example of FIG. 19, the first scaling module 1932 scales the value at node 1908 (i.e., the output of the first delay module 1928) by a scaling factor of -0.1. Accordingly, the value present at node 1914 at time $t+1$ is $-0.1 * VO_t$. Similarly, the second scaling module 1934 scales the value present at node 1912 (i.e., the output of the second scaling module 1930) by a scaling factor of -0.8. Accordingly, the value present at node 1916 is $-0.8 * VO_{t-1}$ at time $t+1$.

At time $t+1$, the values at the inputs of the summer 1926 are: VI_t at node 1904, $-0.1 * VO_t$ at node 1914, and $-0.8 * VO_{t-1}$ at node 1916 (in the example of FIG. 19, the values at nodes 1914 and 1916 are summed by a second summer 1925, and this sum is presented to the summer 1926). Accordingly, at time $t+1$, the summer generates a signal equal to $VI_t - 0.1 * VO_t - 0.8 * VO_{t-1}$.

At the rising edge of ϕ_1 at time $t+1$, a switch 1991 in the output sample and hold module 1936 closes, thereby allowing a capacitor 1992 to charge to VO_{t+1} . Accordingly, the capacitor 1992 charges to VO_{t+1} , which is equal to the sum generated by the adder 1926. As just noted, this value is equal to: $VI_t - 0.1 * VO_t - 0.8 * VO_{t-1}$. This is indicated in cell 1850 of Table 1802. This value is presented to the optional output smoothing module 1938, which smooths the signal to thereby generate the instance of the output signal VO_{t+1} . It is apparent from inspection that this value of VO_{t+1} is consistent with the band pass filter transfer function of EQ. 1.

Further details of unified down-conversion and filtering as described in this section are presented in pending U.S. application "Integrated Frequency Translation And Selectivity," Attorney Docket No. 1744.0130000, incorporated herein by reference in its entirety.

(6) Example Embodiments of the Invention

As noted above, the UFT module of the present invention is a very powerful and flexible device. Its flexibility is illustrated, in part, by the wide range of applications in which it can be used. Its power is illustrated, in part, by the usefulness and performance of such applications.

5 Example applications of the UFT module were described above. In particular, frequency down-conversion, frequency up-conversion, enhanced signal reception, and unified down-conversion and filtering applications of the UFT module were summarized above, and are further described below. These applications of the UFT module are discussed herein for illustrative purposes. The invention is not
10 limited to these example applications. Additional applications of the UFT module will be apparent to persons skilled in the relevant art(s), based on the teachings contained herein.

 For example, the present invention can be used in applications that involve frequency down-conversion. This is shown in FIG. 1C, for example, where an
15 example UFT module 115 is used in a down-conversion module 114. In this capacity, the UFT module 115 frequency down-converts an input signal to an output signal. This is also shown in FIG. 7, for example, where an example UFT module 706 is part of a down-conversion module 704, which is part of a receiver 702.

 The present invention can be used in applications that involve frequency up-
20 conversion. This is shown in FIG. 1D, for example, where an example UFT module 117 is used in a frequency up-conversion module 116. In this capacity, the UFT module 117 frequency up-converts an input signal to an output signal. This is also shown in FIG. 8, for example, where an example UFT module 806 is part of up-conversion module 804, which is part of a transmitter 802.

25 The present invention can be used in environments having one or more transmitters 902 and one or more receivers 906, as illustrated in FIG. 9. In such

environments, one or more of the transmitters 902 may be implemented using a UFT module, as shown for example in FIG. 8. Also, one or more of the receivers 906 may be implemented using a UFT module, as shown for example in FIG. 7.

The invention can be used to implement a transceiver. An example transceiver 1002 is illustrated in FIG. 10. The transceiver 1002 includes a transmitter 1004 and a receiver 1008. Either the transmitter 1004 or the receiver 1008 can be implemented using a UFT module. Alternatively, the transmitter 1004 can be implemented using a UFT module 1006, and the receiver 1008 can be implemented using a UFT module 1010. This embodiment is shown in FIG. 10.

Another transceiver embodiment according to the invention is shown in FIG. 11. In this transceiver 1102, the transmitter 1104 and the receiver 1108 are implemented using a single UFT module 1106. In other words, the transmitter 1104 and the receiver 1108 share a UFT module 1106.

As described elsewhere in this application, the invention is directed to methods and systems for enhanced signal reception (ESR). Various ESR embodiments include an ESR module (transmit) in a transmitter 1202, and an ESR module (receive) in a receiver 1210. An example ESR embodiment configured in this manner is illustrated in FIG. 12.

The ESR module (transmit) 1204 includes a frequency up-conversion module 1206. Some embodiments of this frequency up-conversion module 1206 may be implemented using a UFT module, such as that shown in FIG. 1D.

The ESR module (receive) 1212 includes a frequency down-conversion module 1214. Some embodiments of this frequency down-conversion module 1214 may be implemented using a UFT module, such as that shown in FIG. 1C.

As described elsewhere in this application, the invention is directed to methods and systems for unified down-conversion and filtering (UDF). An example

unified down-conversion and filtering module 1302 is illustrated in FIG. 13. The unified down-conversion and filtering module 1302 includes a frequency down-conversion module 1304 and a filtering module 1306. According to the invention, the frequency down-conversion module 1304 and the filtering module 1306 are implemented using a UFT module 1308, as indicated in FIG. 13.

Unified down-conversion and filtering according to the invention is useful in applications involving filtering and/or frequency down-conversion. This is depicted, for example, in FIGS. 15A-15F. FIGS. 15A-15C indicate that unified down-conversion and filtering according to the invention is useful in applications where filtering precedes, follows, or both precedes and follows frequency down-conversion. FIG. 15D indicates that a unified down-conversion and filtering module 1524 according to the invention can be utilized as a filter 1522 (i.e., where the extent of frequency down-conversion by the down-converter in the unified down-conversion and filtering module 1524 is minimized). FIG. 15E indicates that a unified down-conversion and filtering module 1528 according to the invention can be utilized as a down-converter 1526 (i.e., where the filter in the unified down-conversion and filtering module 1528 passes substantially all frequencies). FIG. 15F illustrates that the unified down-conversion and filtering module 1532 can be used as an amplifier. It is noted that one or more UDF modules can be used in applications that involve at least one or more of filtering, frequency translation, and amplification.

For example, receivers, which typically perform filtering, down-conversion, and filtering operations, can be implemented using one or more unified down-conversion and filtering modules. This is illustrated, for example, in FIG. 14.

The methods and systems of unified down-conversion and filtering of the invention have many other applications. For example, as discussed herein, the enhanced signal reception (ESR) module (receive) operates to down-convert a signal

containing a plurality of spectrums. The ESR module (receive) also operates to isolate the spectrums in the down-converted signal, where such isolation is implemented via filtering in some embodiments. According to embodiments of the invention, the ESR module (receive) is implemented using one or more unified down-conversion and filtering (UDF) modules. This is illustrated, for example, in FIG. 16. In the example of FIG. 16, one or more of the UDF modules 1610, 1612, 1614 operates to down-convert a received signal. The UDF modules 1610, 1612, 1614 also operate to filter the down-converted signal so as to isolate the spectrum(s) contained therein. As noted above, the UDF modules 1610, 1612, 1614 are implemented using the universal frequency translation (UFT) modules of the invention.

The invention is not limited to the applications of the UFT module described above. For example, and without limitation, subsets of the applications (methods and/or structures) described herein (and others that would be apparent to persons skilled in the relevant art(s) based on the herein teachings) can be associated to form useful combinations.

For example, transmitters and receivers are two applications of the UFT module. FIG. 10 illustrates a transceiver 1002 that is formed by combining these two applications of the UFT module, i.e., by combining a transmitter 1004 with a receiver 1008.

Also, ESR (enhanced signal reception) and unified down-conversion and filtering are two other applications of the UFT module. FIG. 16 illustrates an example where ESR and unified down-conversion and filtering are combined to form a modified enhanced signal reception system.

The invention is not limited to the example applications of the UFT module discussed herein. Also, the invention is not limited to the example combinations of

applications of the UFT module discussed herein. These examples were provided for illustrative purposes only, and are not limiting. Other applications and combinations of such applications will be apparent to persons skilled in the relevant art(s) based on the teachings contained herein. Such applications and combinations include, for example and without limitation,

applications/combinations comprising and/or involving one or more of: (1) frequency translation; (2) frequency down-conversion; (3) frequency up-conversion; (4) receiving; (5) transmitting; (6) filtering; and/or (7) signal transmission and reception in environments containing potentially jamming signals.

(7) Conclusion

Example implementations of the systems and components of the invention have been described herein. As noted elsewhere, these example implementations have been described for illustrative purposes only, and are not limiting. Other implementation embodiments are possible and covered by the invention, such as but not limited to software and software/hardware implementations of the systems and components of the invention. Such implementation embodiments will be apparent to persons skilled in the relevant art(s) based on the teachings contained herein.

While various application embodiments of the present invention have been described above, it should be understood that they have been presented by way of example only, and not limitation. Thus, the breadth and scope of the present invention should not be limited by any of the above-described exemplary embodiments, but should be defined only in accordance with the following claims and their equivalents.

What Is Claimed Is:

1. An apparatus, comprising:
a universal frequency translator (UFT); and
means for operating said UFT such that said UFT operates in at least one of
(A)-(D):
 - (A) a frequency down-converter module, in which at least said UFT operates to frequency down-convert a first signal to a second signal;
 - (B) a frequency up-converter module, in which at least said UFT operates to frequency up-convert a third signal to a fourth signal;
 - (C) a unified down-conversion and filtering module, in which at least said UFT operates to at least filter and down-convert a fifth signal; and
 - (D) an enhanced signal reception module, in which at least said UFT operates to receive a sixth signal in a environment comprising potentially jamming signals.
2. The apparatus of claim 1, wherein said UFT module, when operating in said frequency down-converter module according to (A), comprises:
a switch controlled by a control signal.
3. The apparatus of claim 2, further comprising:
means for optimizing an aperture of said control signal so as to increase energy transfer while down-converting the first signal to the second signal.

Universal Frequency Translation, and Applications of Same

Abstract

Frequency translation and applications of same are described herein. Such applications include, but are not limited to, frequency down-conversion, frequency up-conversion, enhanced signal reception, unified down-conversion and filtering, and combinations and applications of same.

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10/20/98; 11:09 AM
a225-04.wpd
SKGF Ref: 1744.0140000

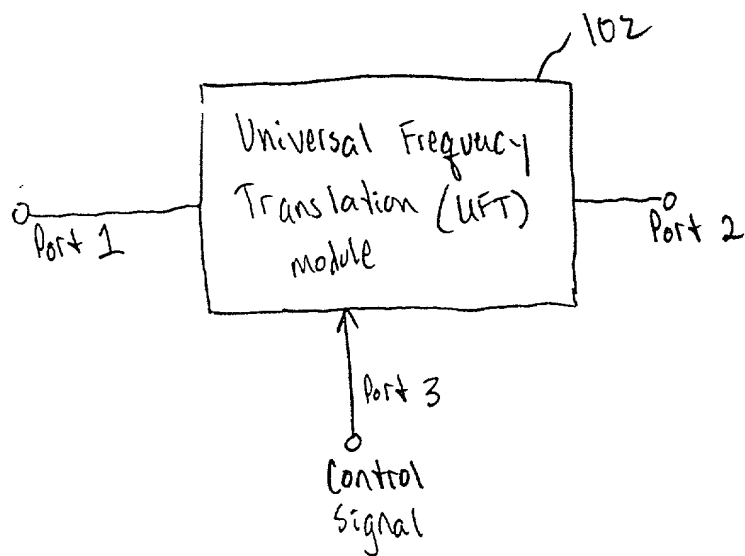


FIG. 1A

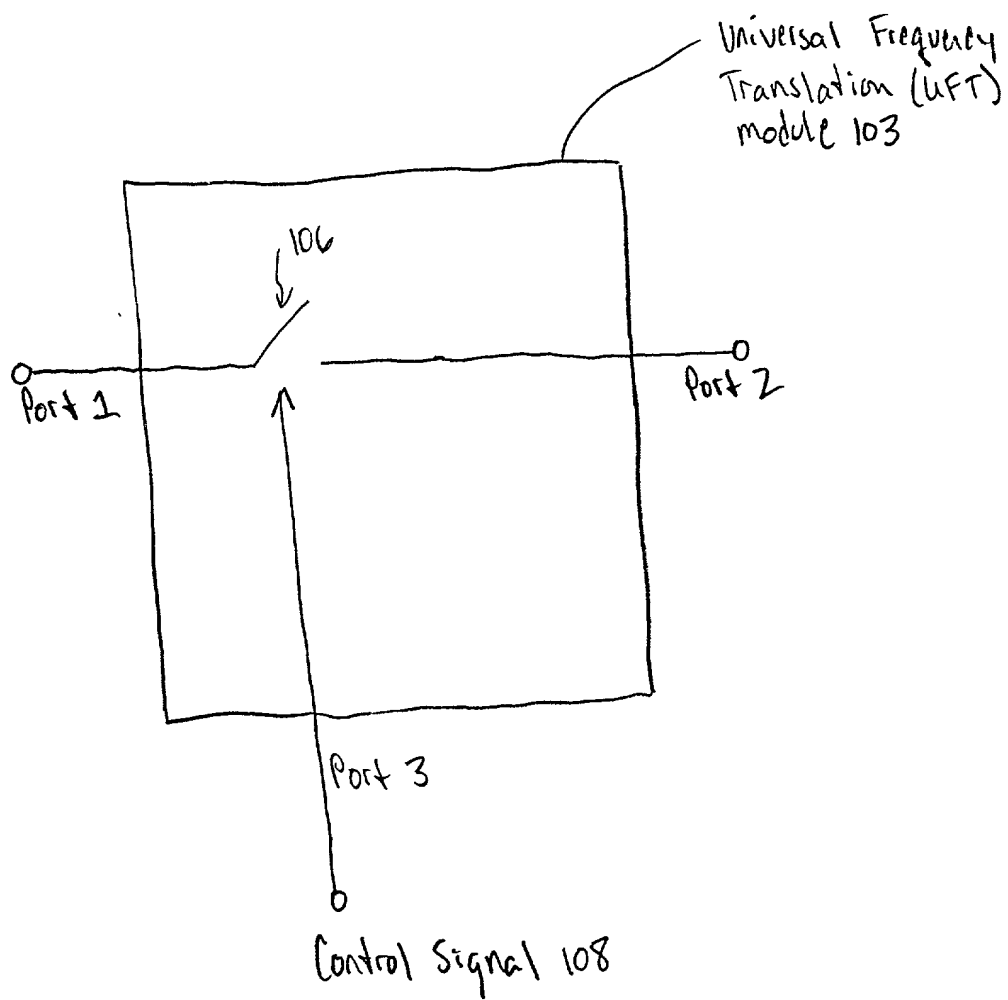


FIG. 1B

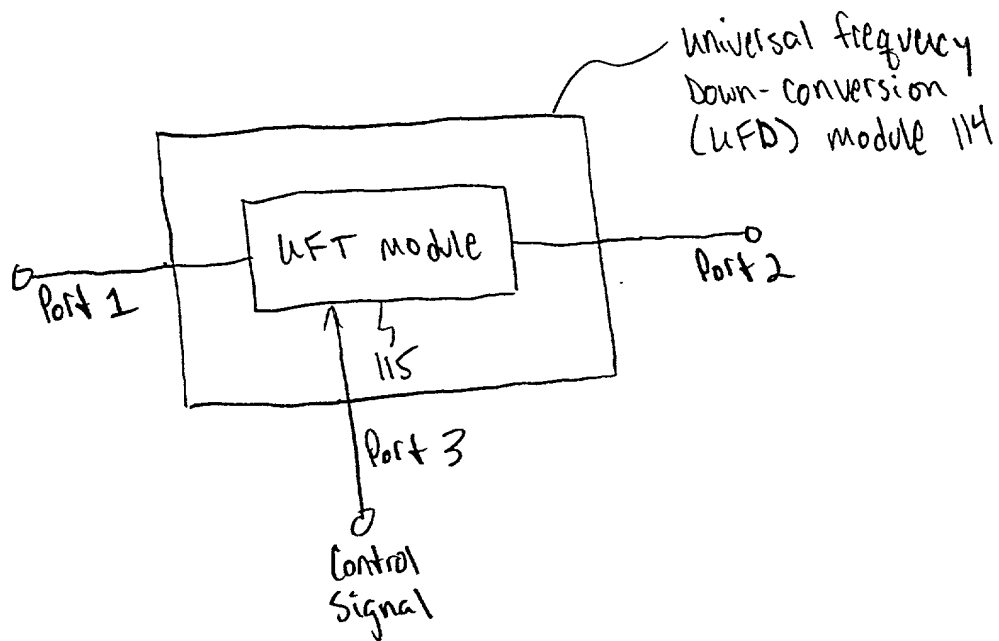


FIG. 1C

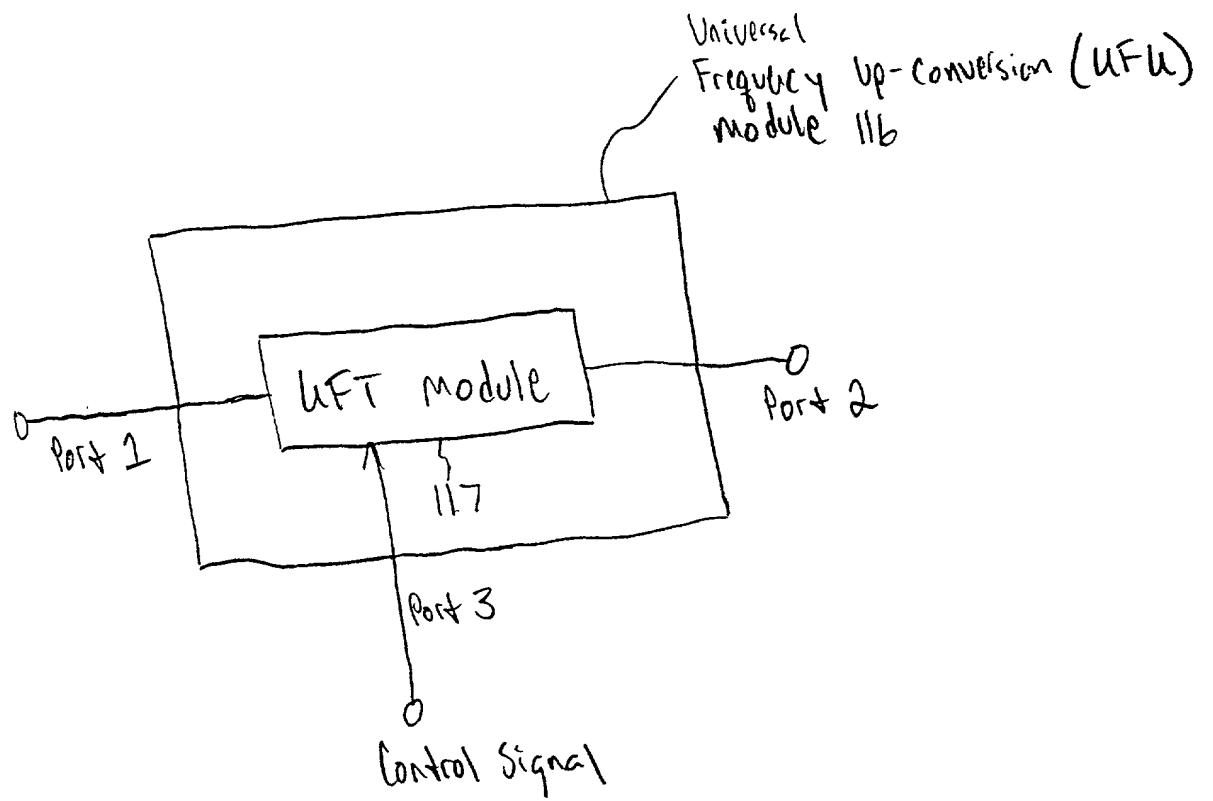


FIG. 1D

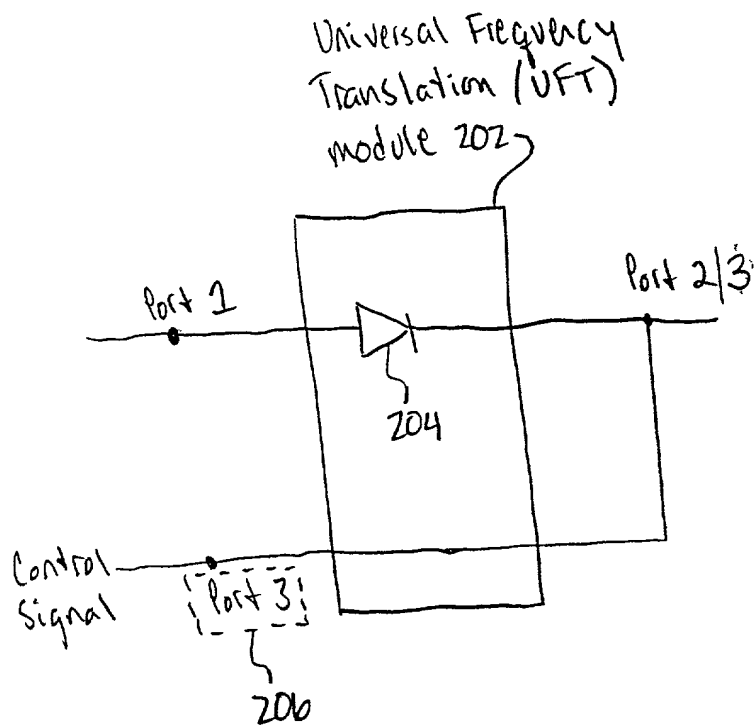
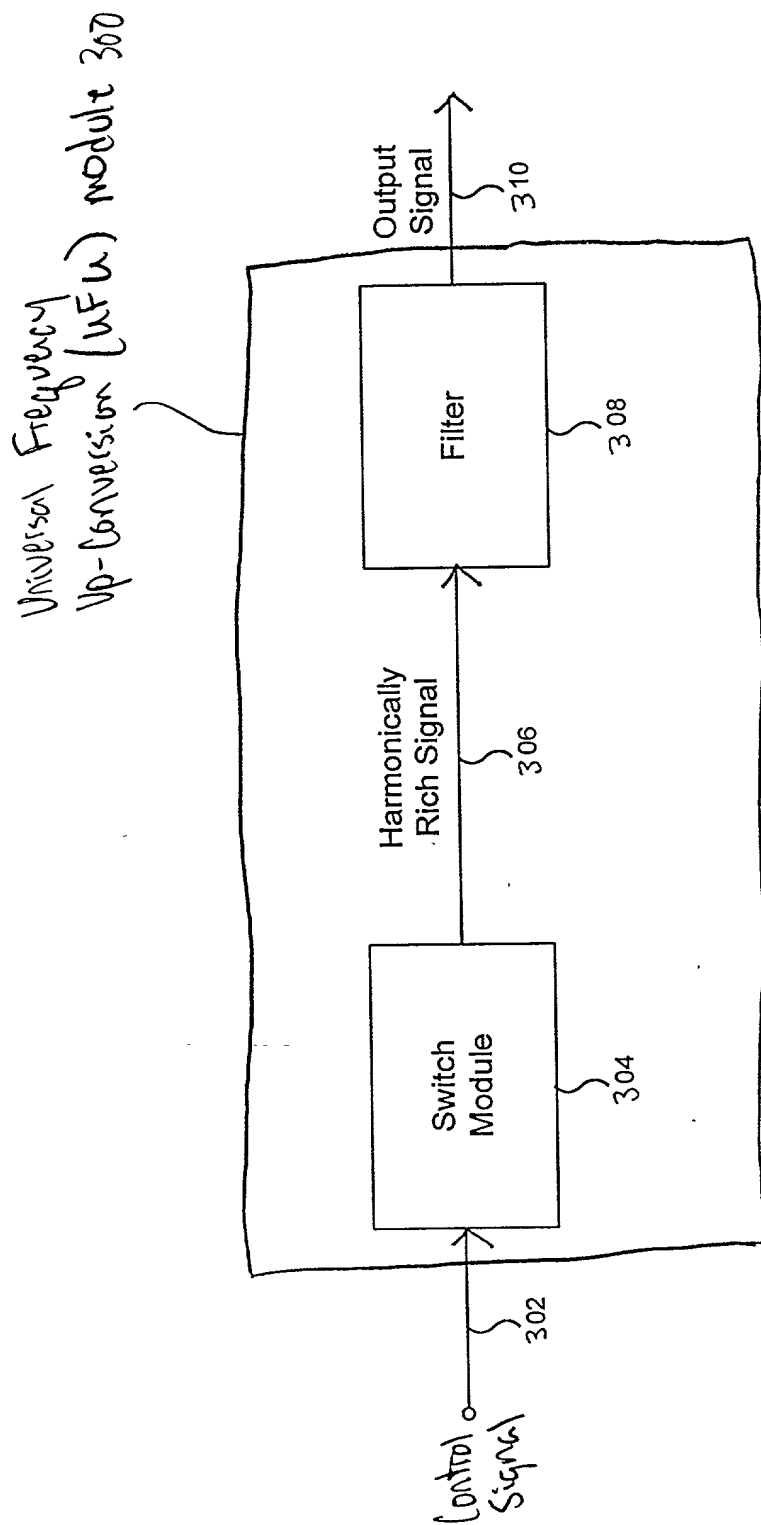


FIG. 2



W

005220-1004T566

Universal Frequency
Up-conversion (UFC) module 401

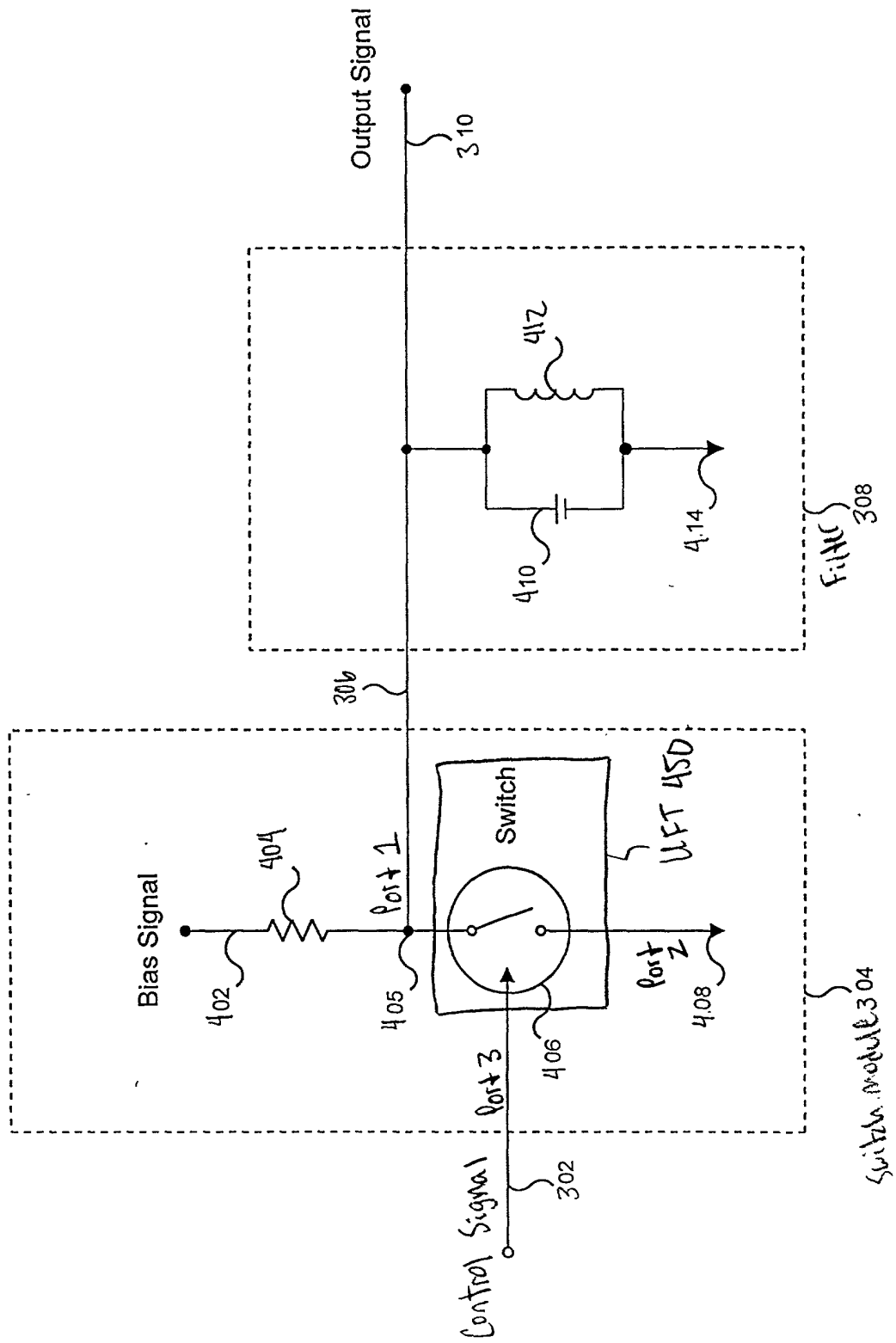
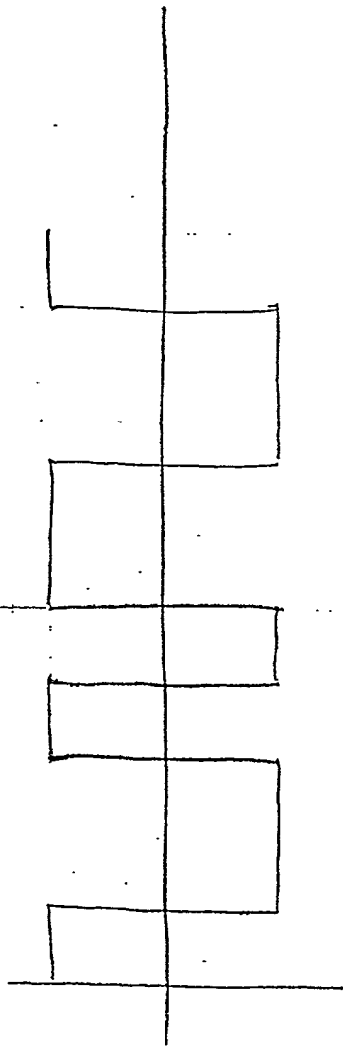


FIG. 4

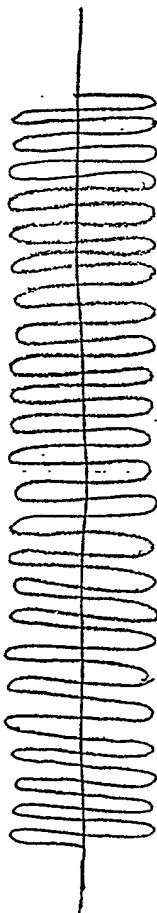
INFORMATION
 SIGNAL
 602

FIG. 6A



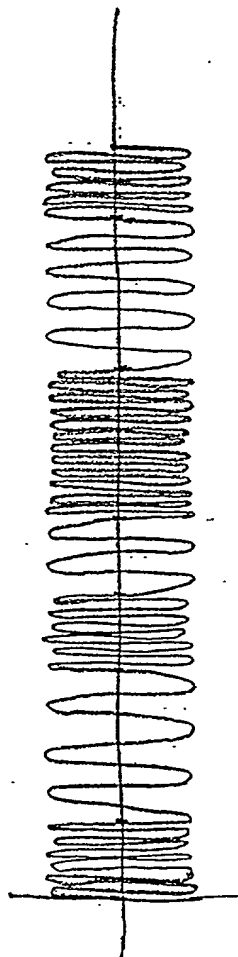
OSCILLATING
 SIGNAL
 604

FIG. 6B



FREQUENCY MODULATED
 INPUT SIGNAL
 606

FIG. 6C



HARMONICALLY
 RICH SIGNAL
 (SHOWN AS SQUARE WAVE)
 608

FIG. 6D



SEE FIG. 6E

FIG. 6

EXPANDED VIEW OF
HARMONICALLY RICH
SIGNAL 608

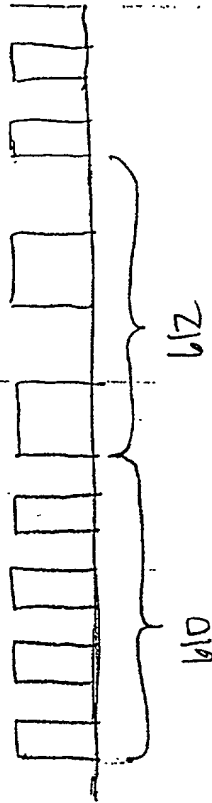


FIG 6E

SEE FIG. 6F

SEE FIG. 6G

HARMONICS OF
SIGNAL 610
(SHOWN SEPARATELY)

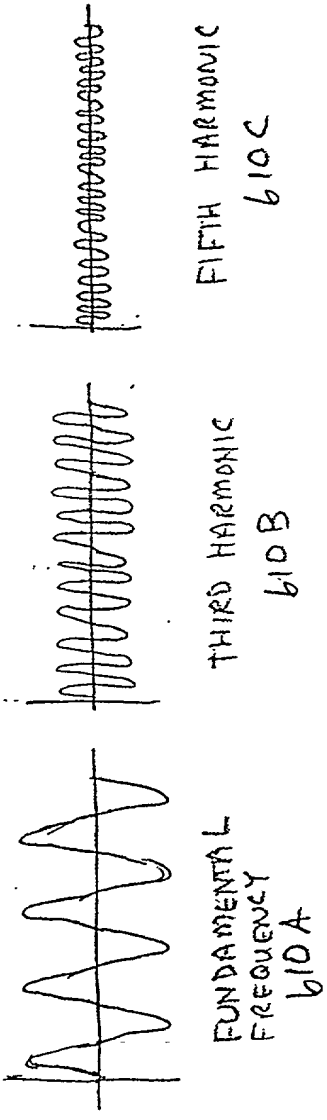


FIG. 6F

HARMONICS OF
SIGNAL 612
(SHOWN SEPARATELY)

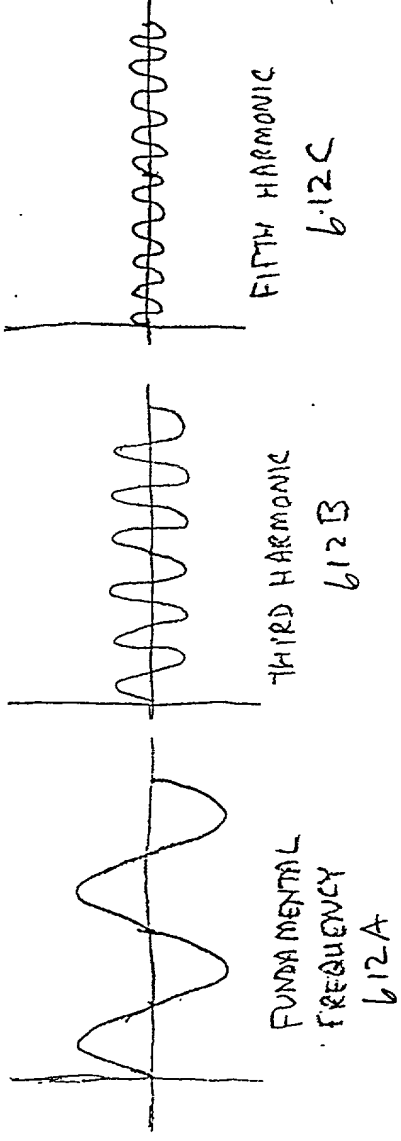


FIG 6G

FIG. 6 (cont)

00520 10047500

13/102
42-301 50 SHEETS EYEGLASS SQUARE
42-302 100 SHEETS EYEGLASS SQUARE
42-303 200 SHEETS EYEGLASS SQUARE
42-304 100 RECYCLED WHITE SQUARE
42-305 200 RECYCLED WHITE SQUARE
Made in U.S.A.



HARMONICS OF
SIGNALS 410 AND
612 (SHOWN
SIMULTANEOUSLY BUT
NOT SUMMED)

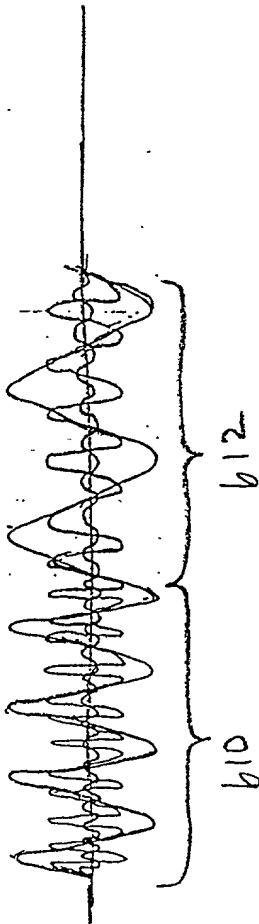


FIG. 6H

FILTERED
OUTPUT
SIGNAL
OF 614
90

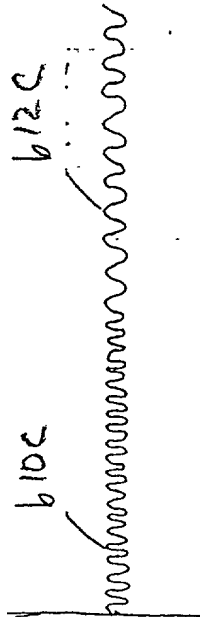


FIG. 6I

FIG. 6 (cont)

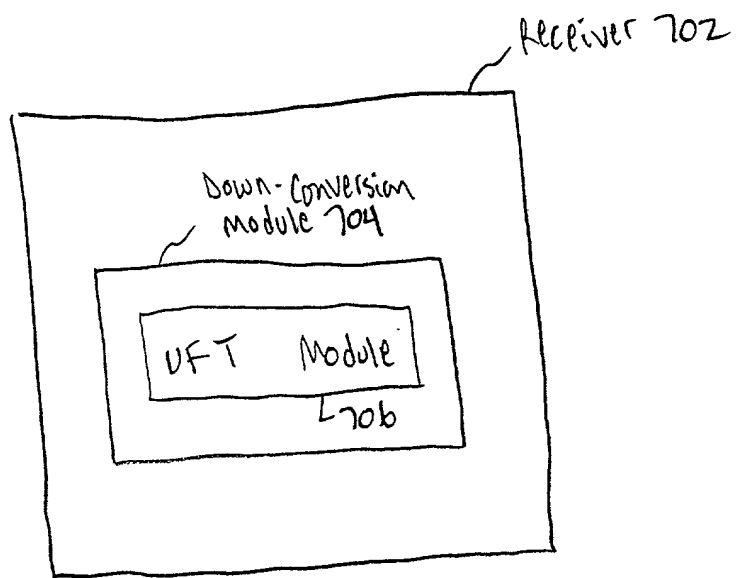


FIG. 7

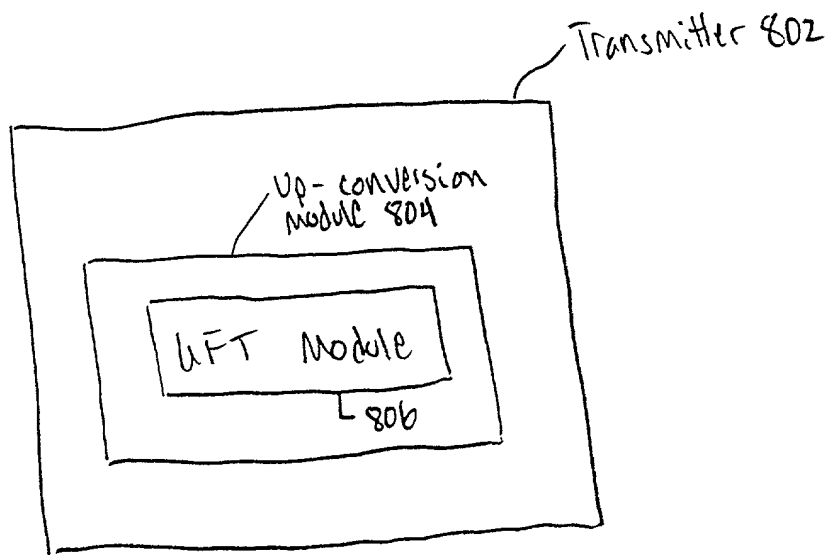


FIG. 8

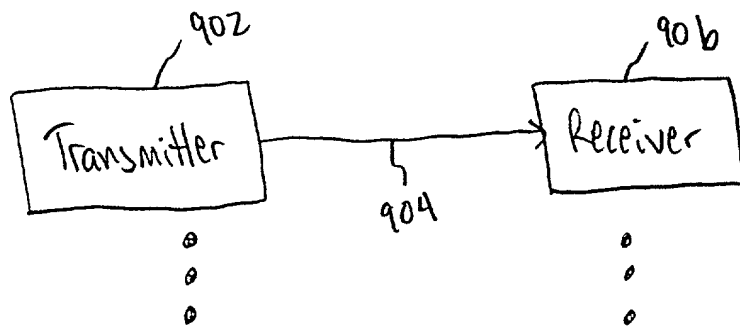


FIG. 9

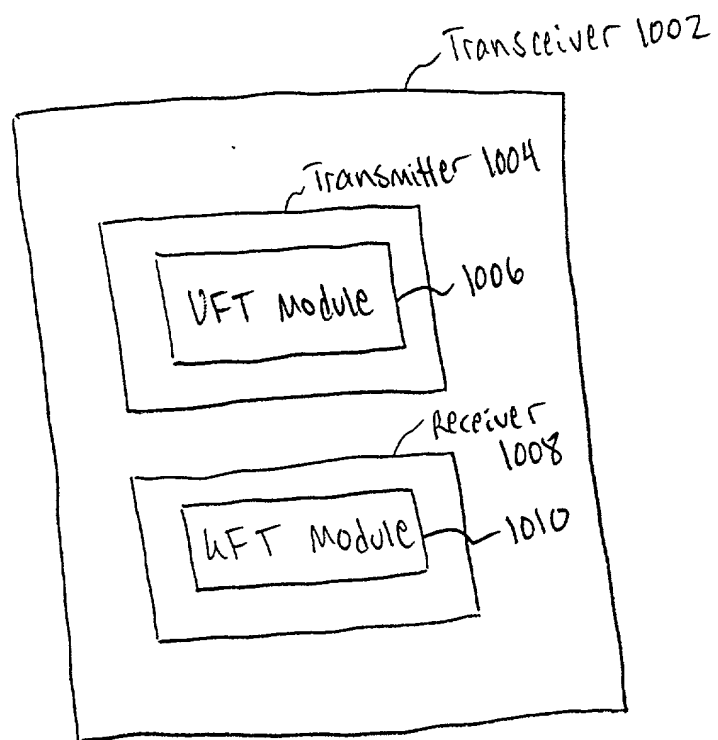


FIG. 10

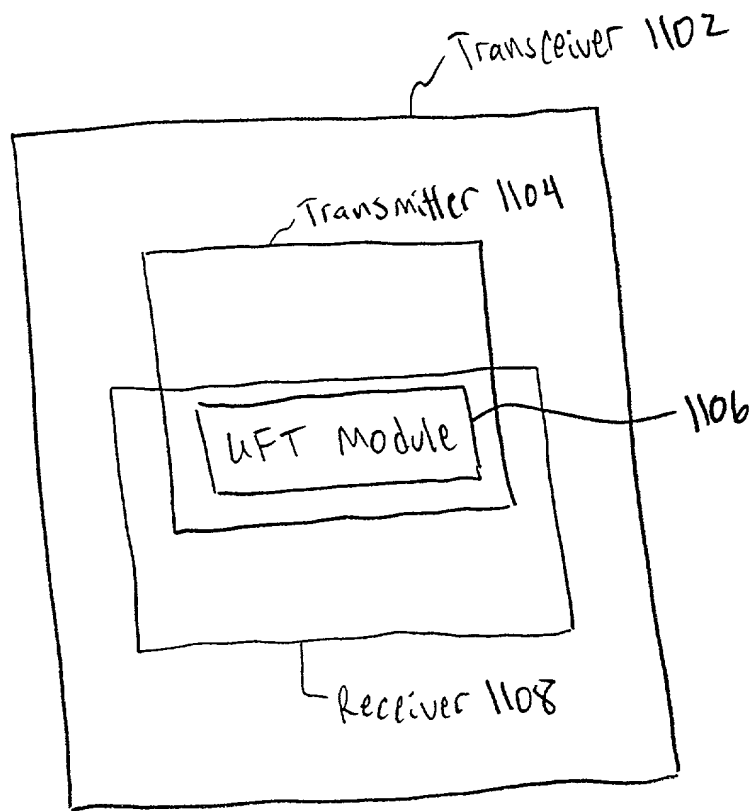


FIG. 11

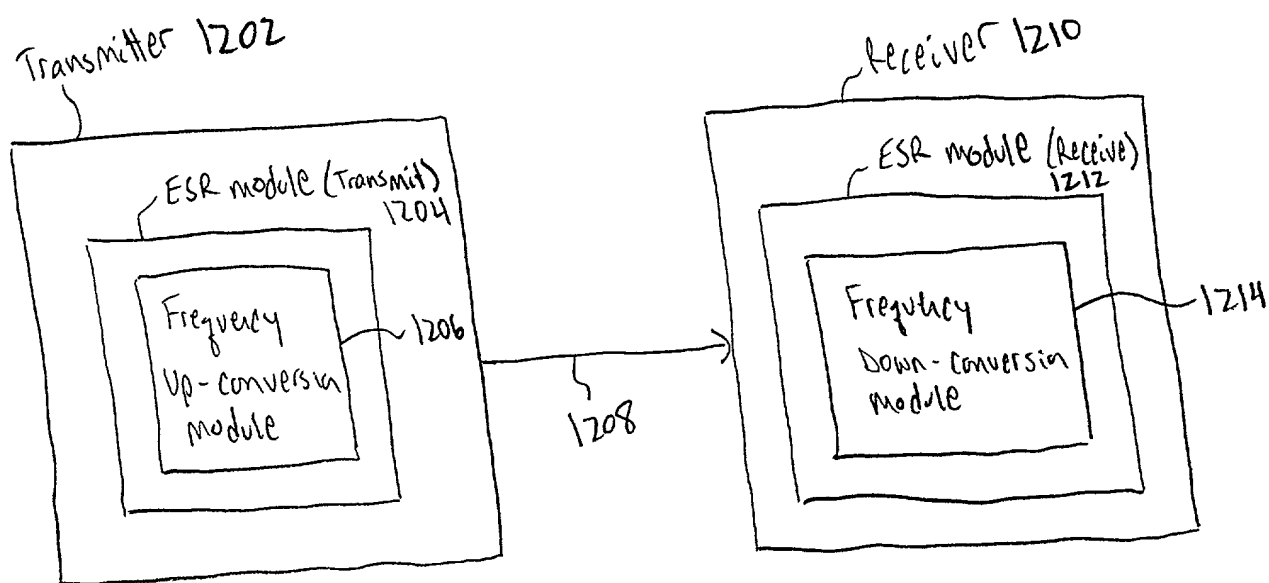


FIG. 12

Unified Down-converting
and Filtering (UDF) module 1302

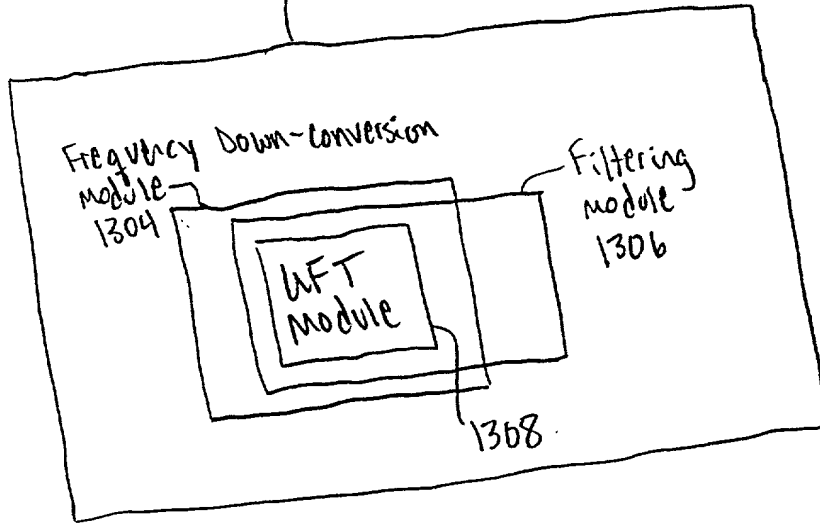


FIG. 13

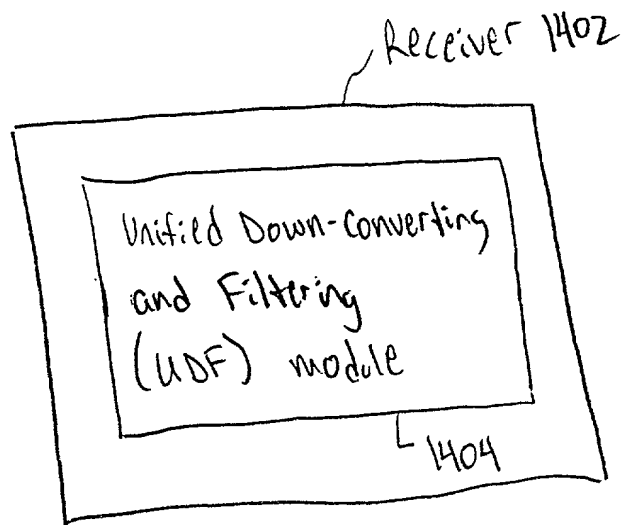


FIG. 14

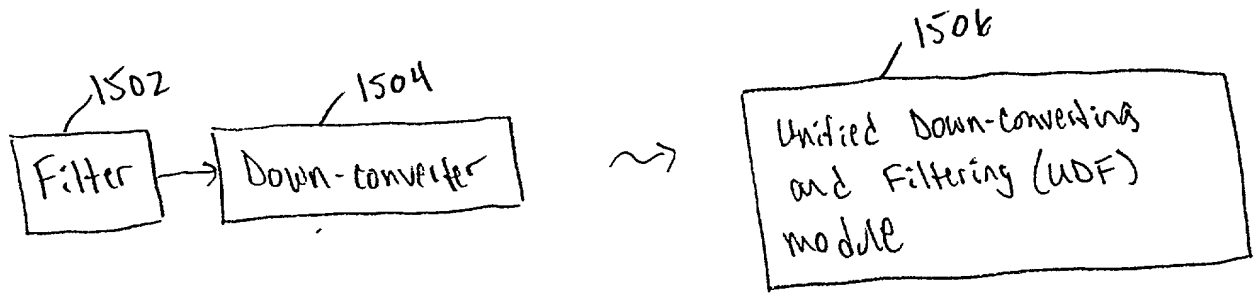


FIG. 15A

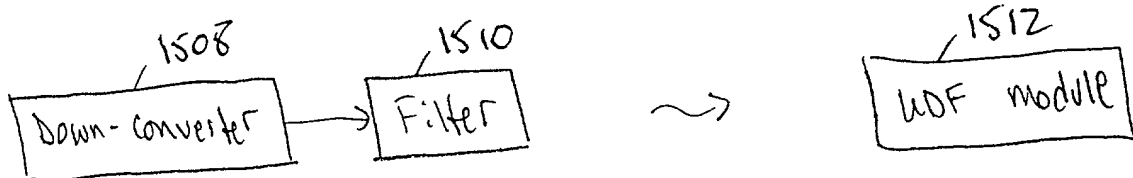


FIG. 15B



FIG. 15C



FIG. 15D

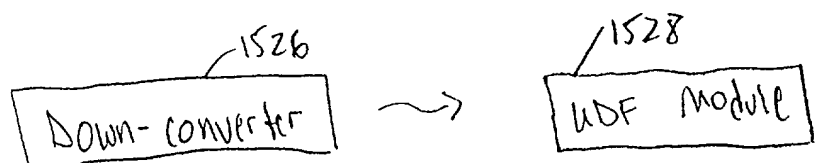


FIG. 15E

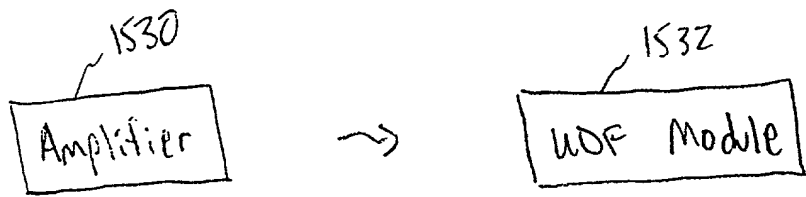


FIG. 15F

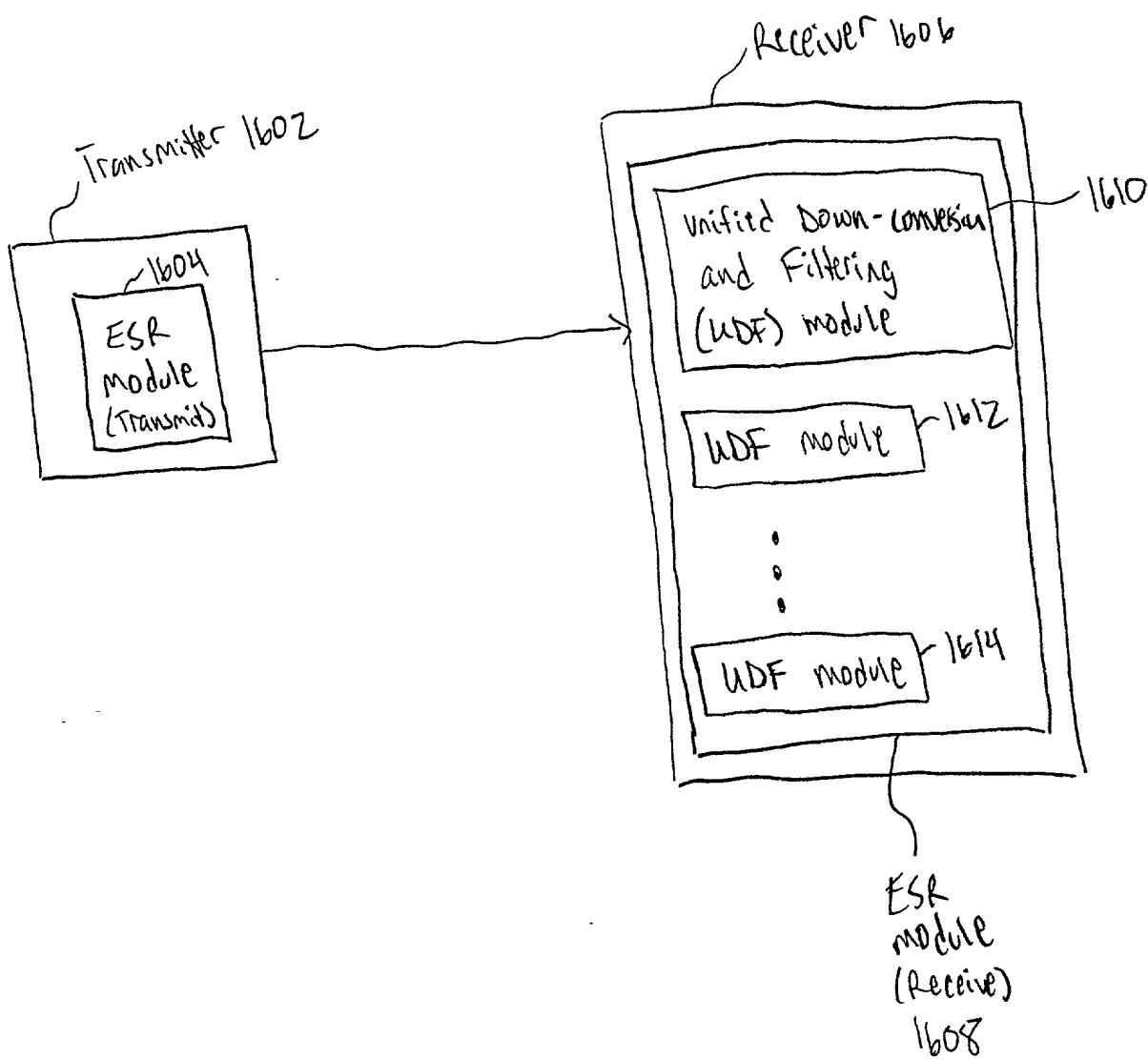


FIG. 16

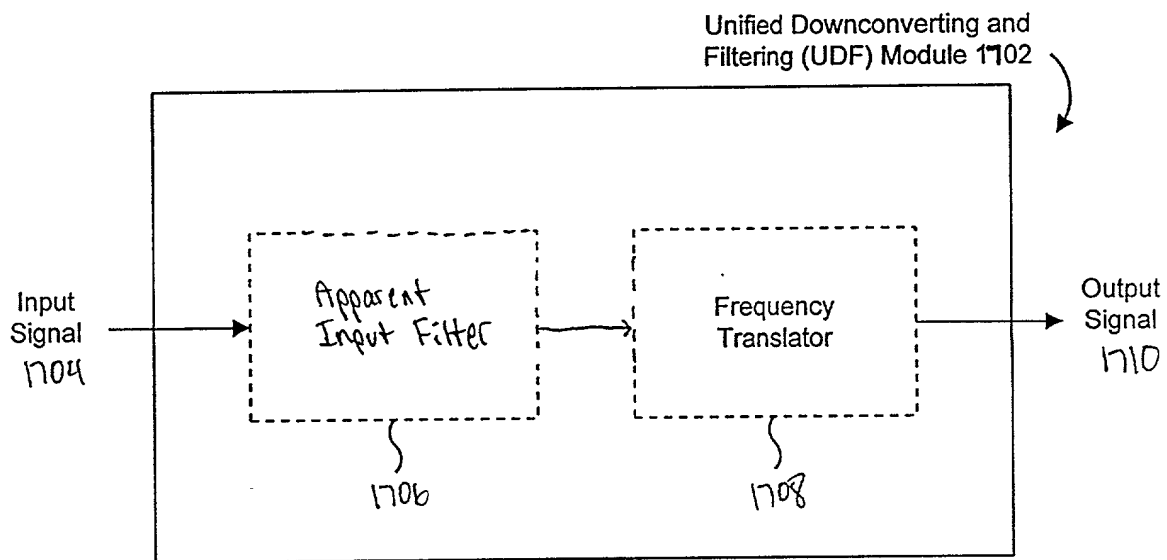


FIG. 17

1802

Time Node	t-1 (rising edge of ϕ_1)	t-1 (rising edge of ϕ_2)	t (rising edge of ϕ_1)	t (rising edge of ϕ_2)	t+1 (rising edge of ϕ_1)
1402	VI_{t-1} 1804	VI_{t-1} 1808	VI_t 1816	VI_t 1826	VI_{t+1} 1838
1404	—	VI_{t-1} 1810	VI_{t-1} 1818	VI_t 1828	VI_t 1840
1406	VO_{t-1} 1806	VO_{t-1} 1812	VO_t 1820	VO_t 1830	VO_{t+1} 1842
1408	—	VO_{t-1} 1814	VO_{t-1} 1822	VO_t 1832	VO_t 1844
1410	— 1807	—	VO_{t-1} 1824	VO_{t-1} 1834	VO_t 1846
1412	—	— 1815	—	VO_{t-1} 1836	VO_{t-1} 1848
1418	—	—	—	—	VI_t - 1850 0.1 * VO_t - 0.8 * VO_{t-1}

FIG. 18

005220-10041560

UDF module 1922
(band pass)

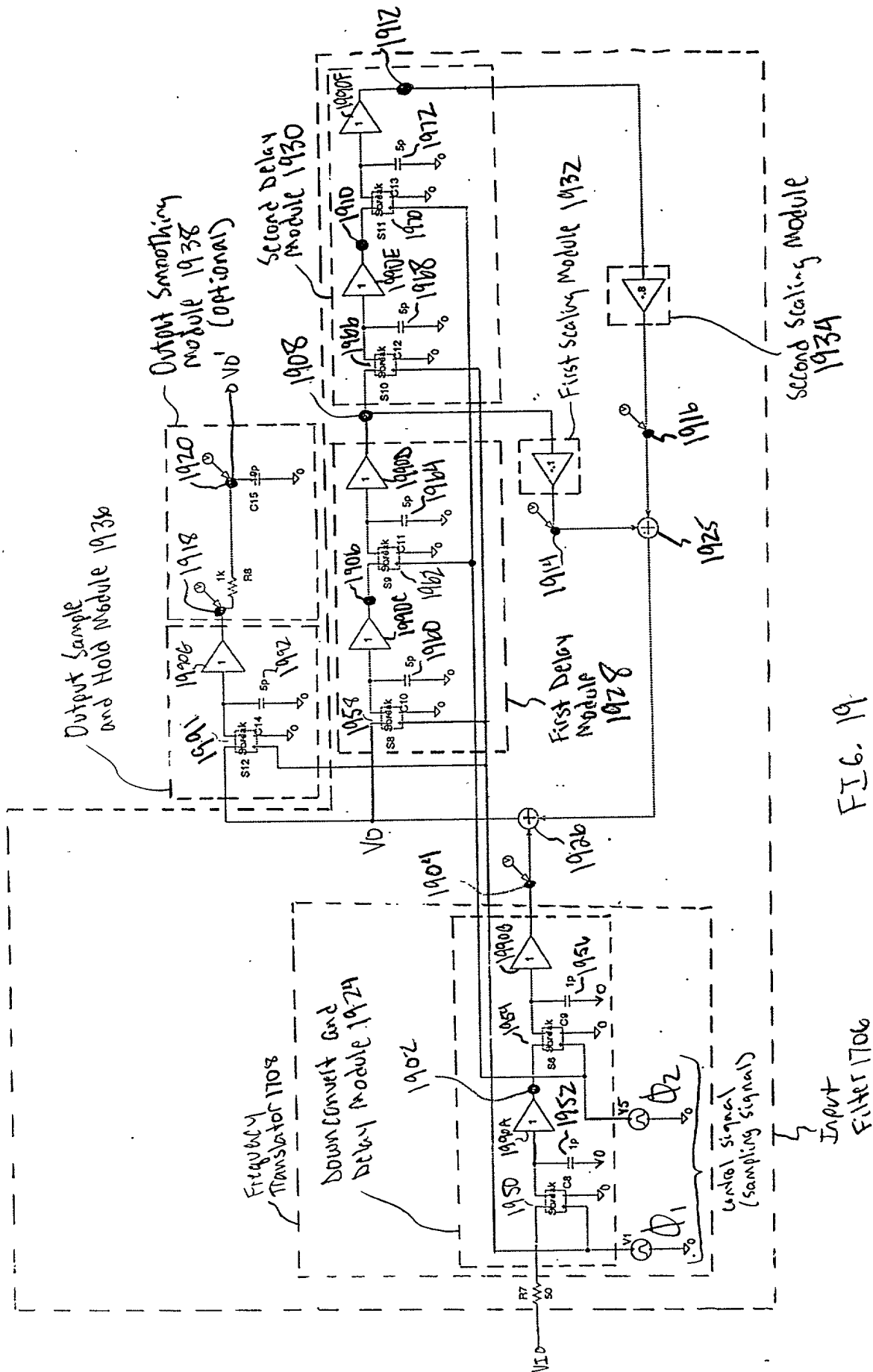


FIG. 19

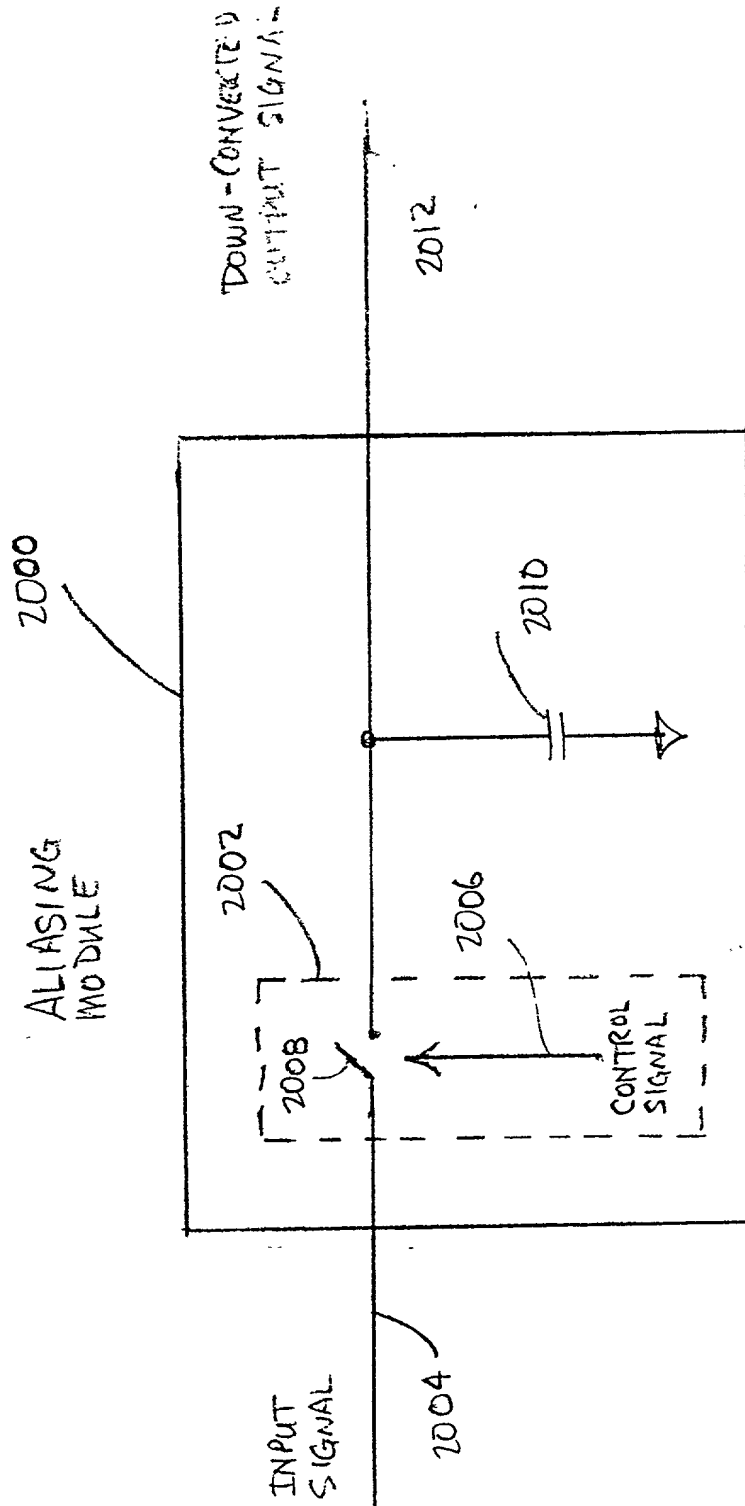


FIG. 20A

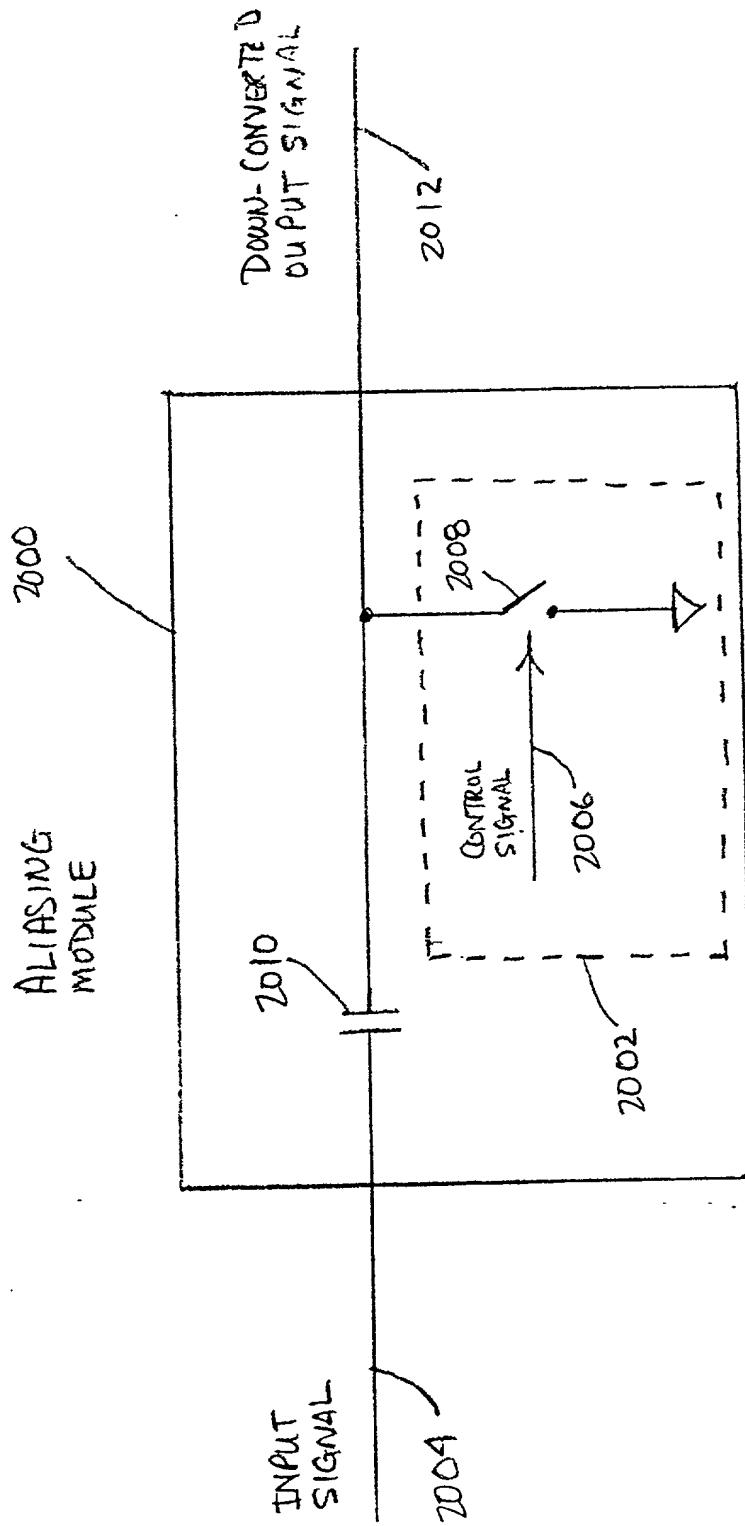


FIG. 20A-1

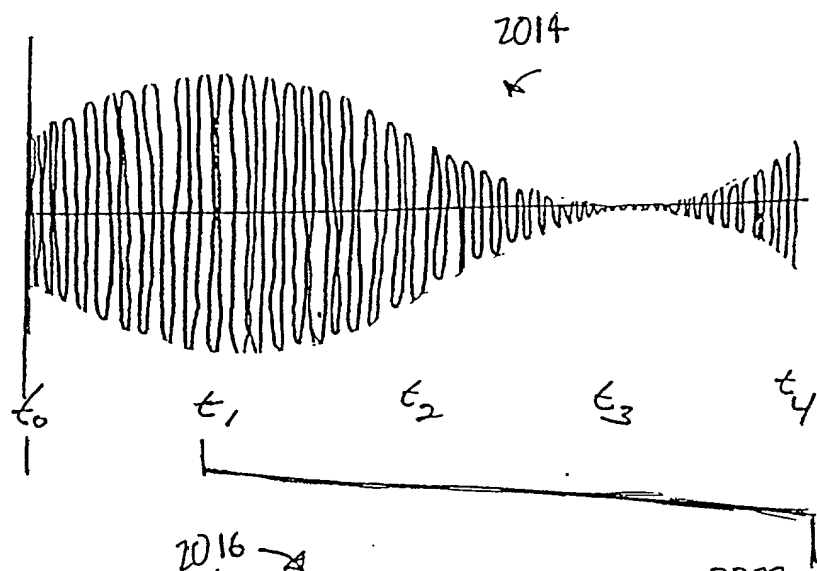


FIG. 20B

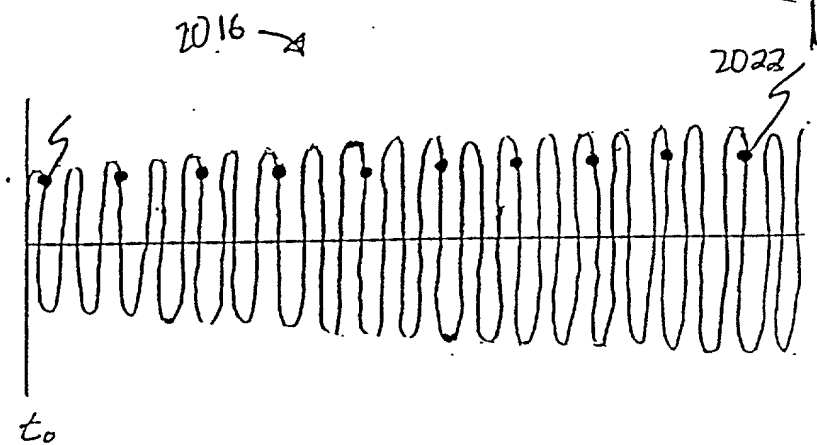


FIG. 20C

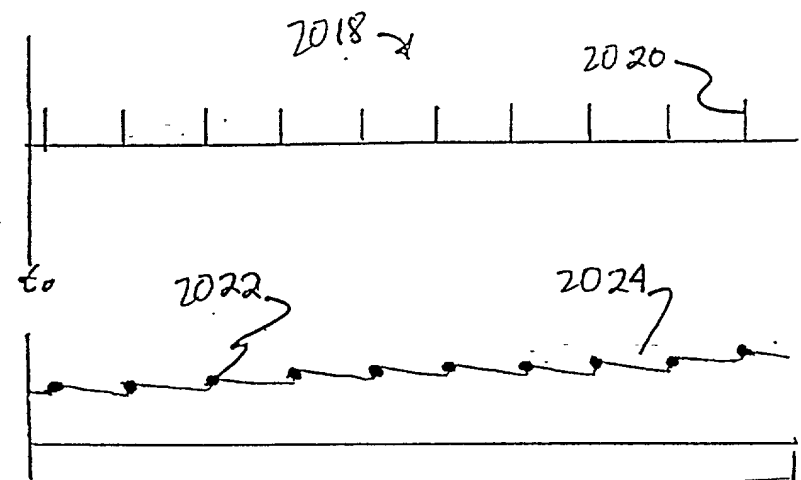


FIG. 20D

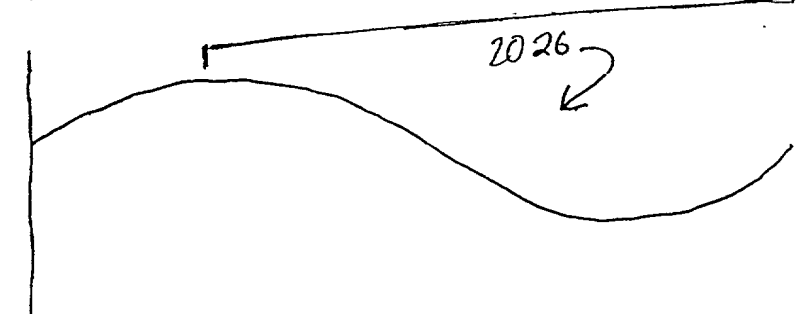


FIG. 20F

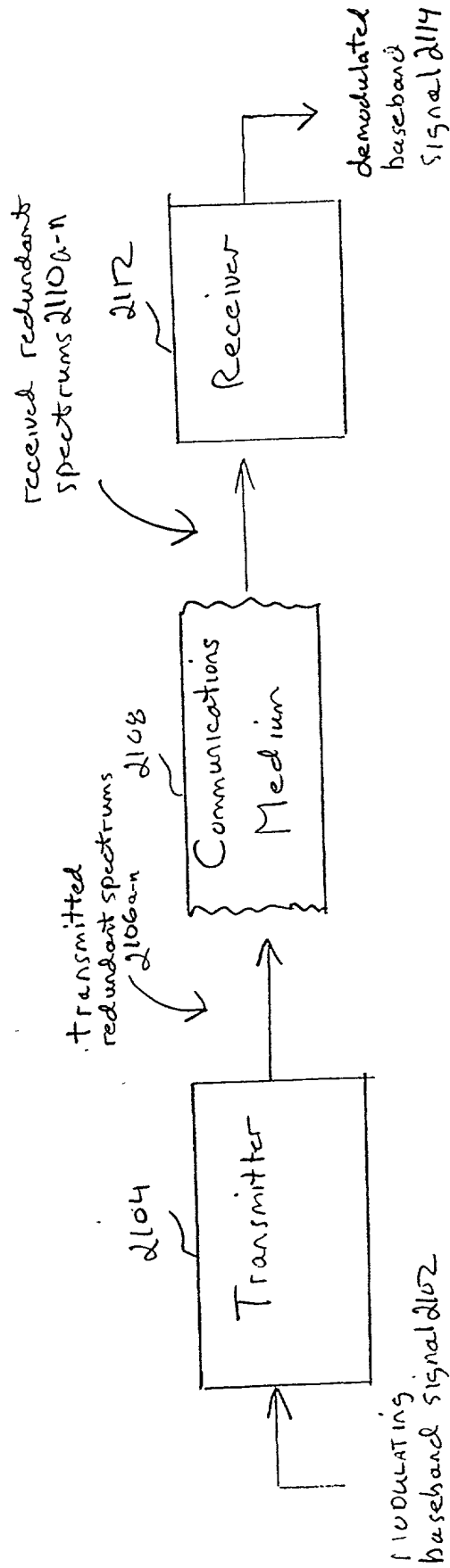
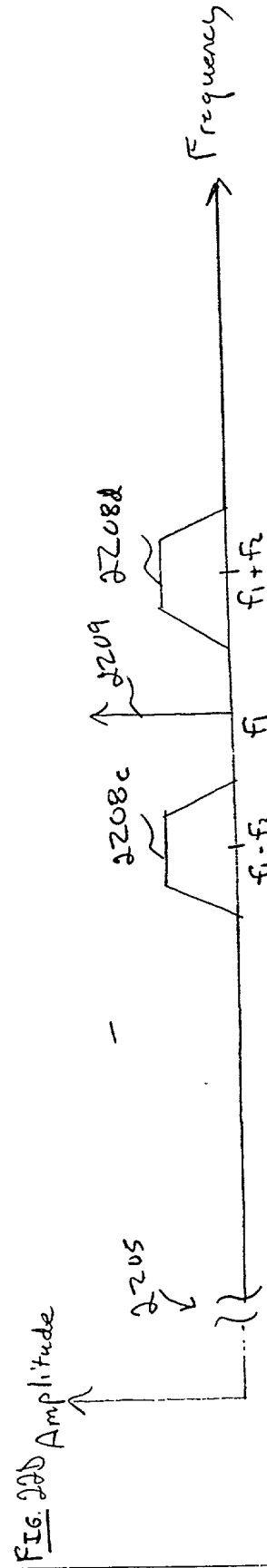
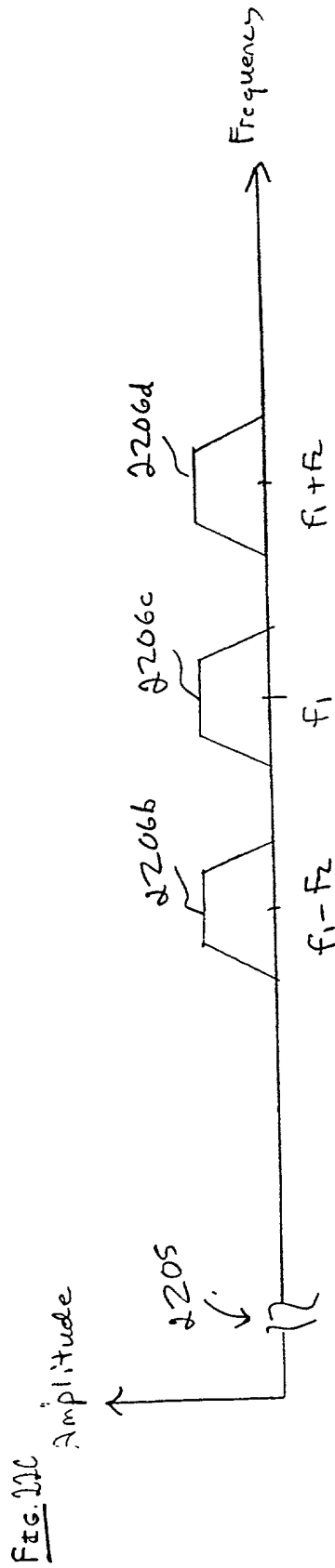
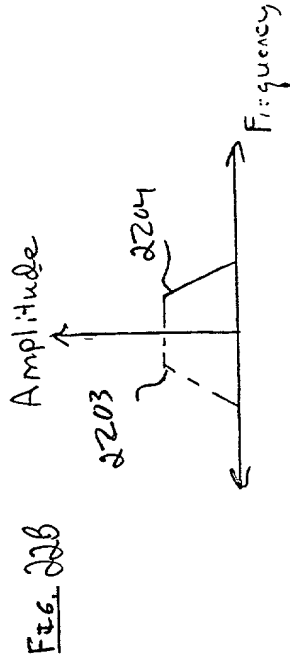
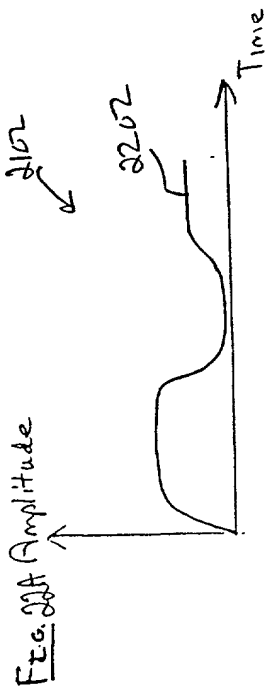
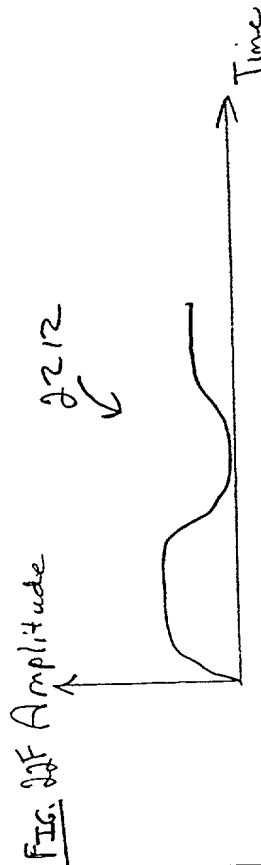
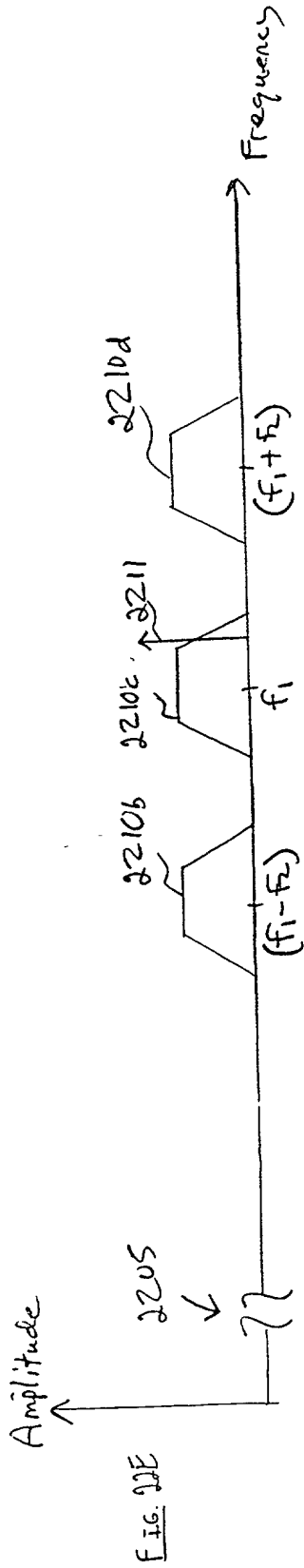


Fig. 21





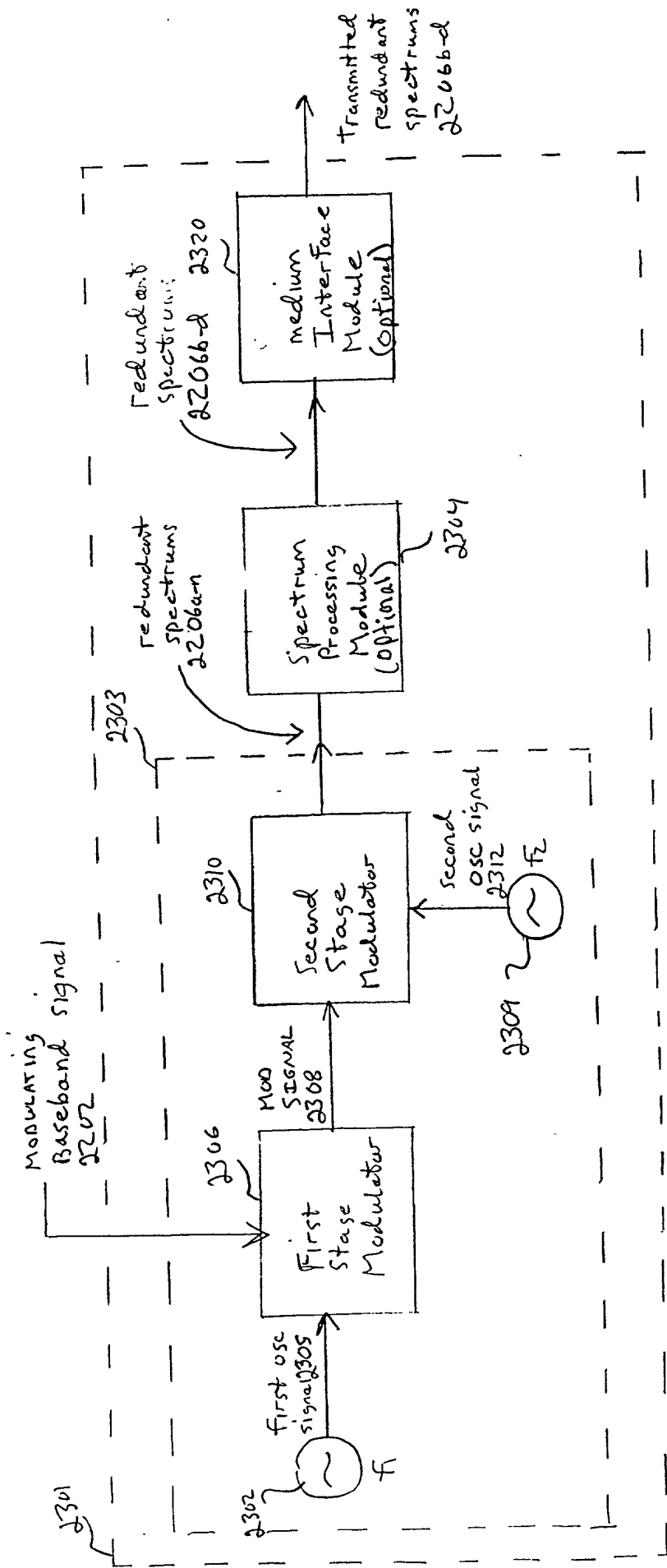
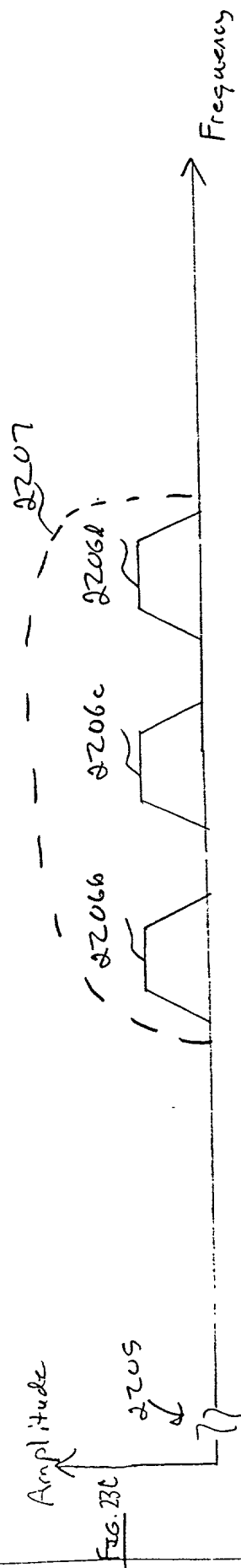
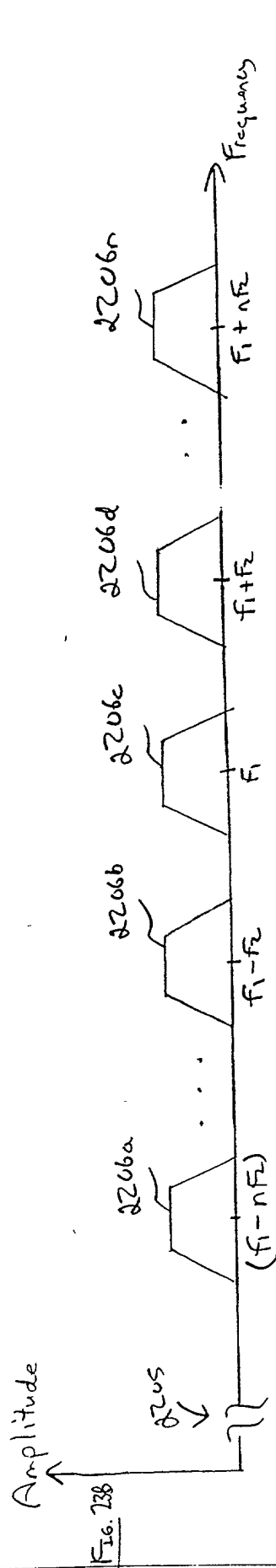


Fig. 23A



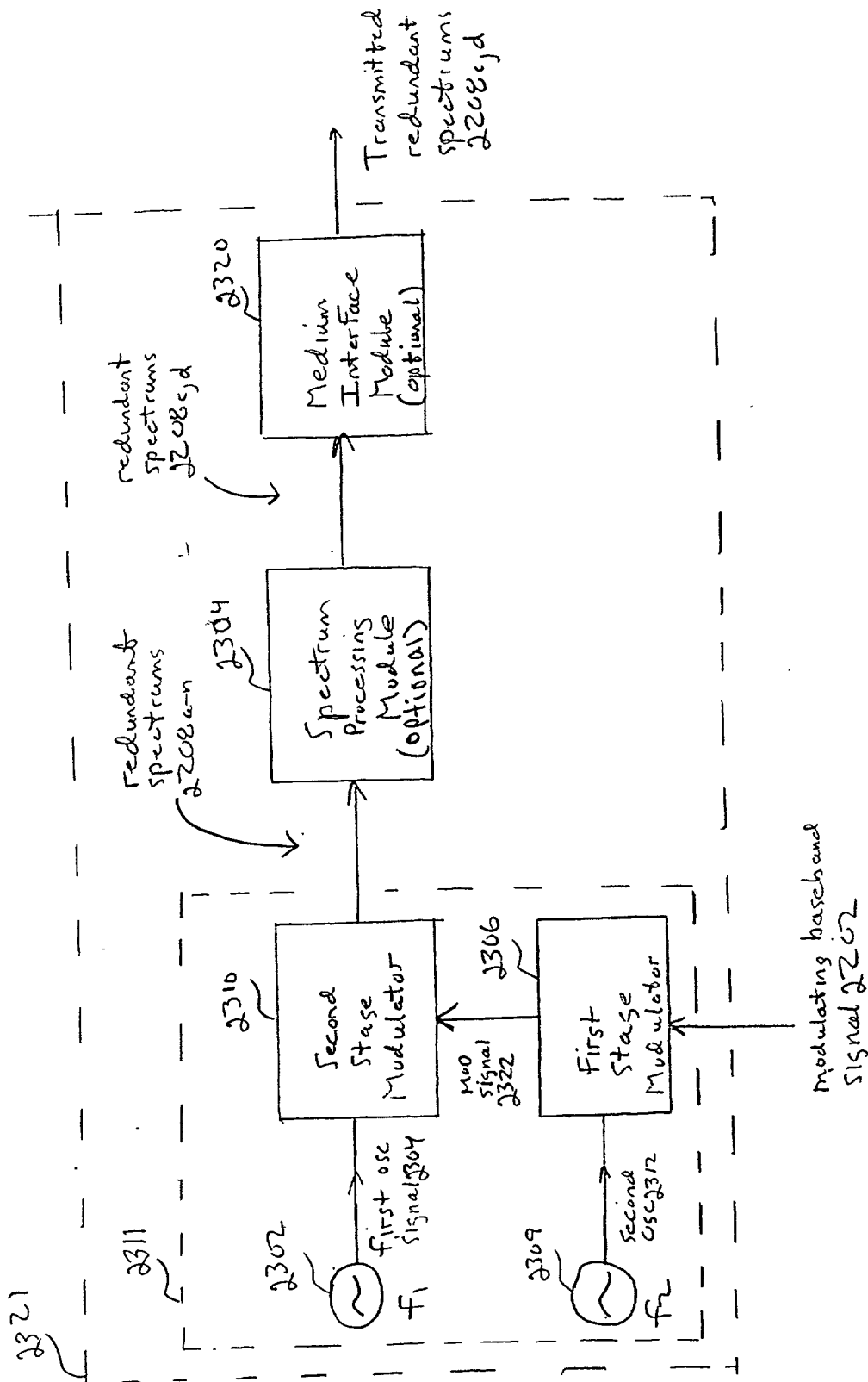


FIG. 23D

FIG. 23E

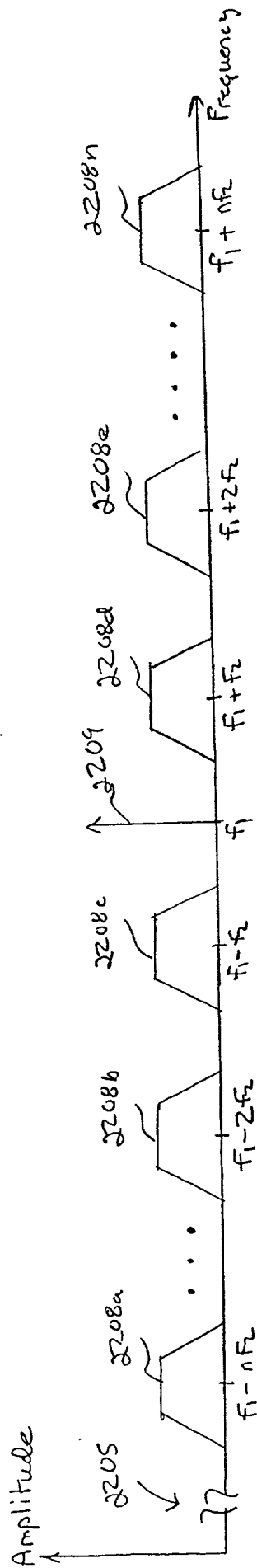
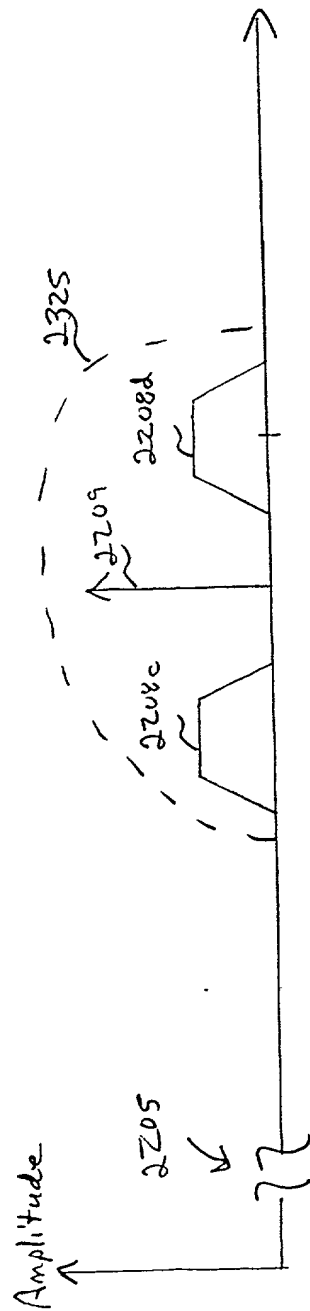


FIG. 23F





Made in U.S.A.

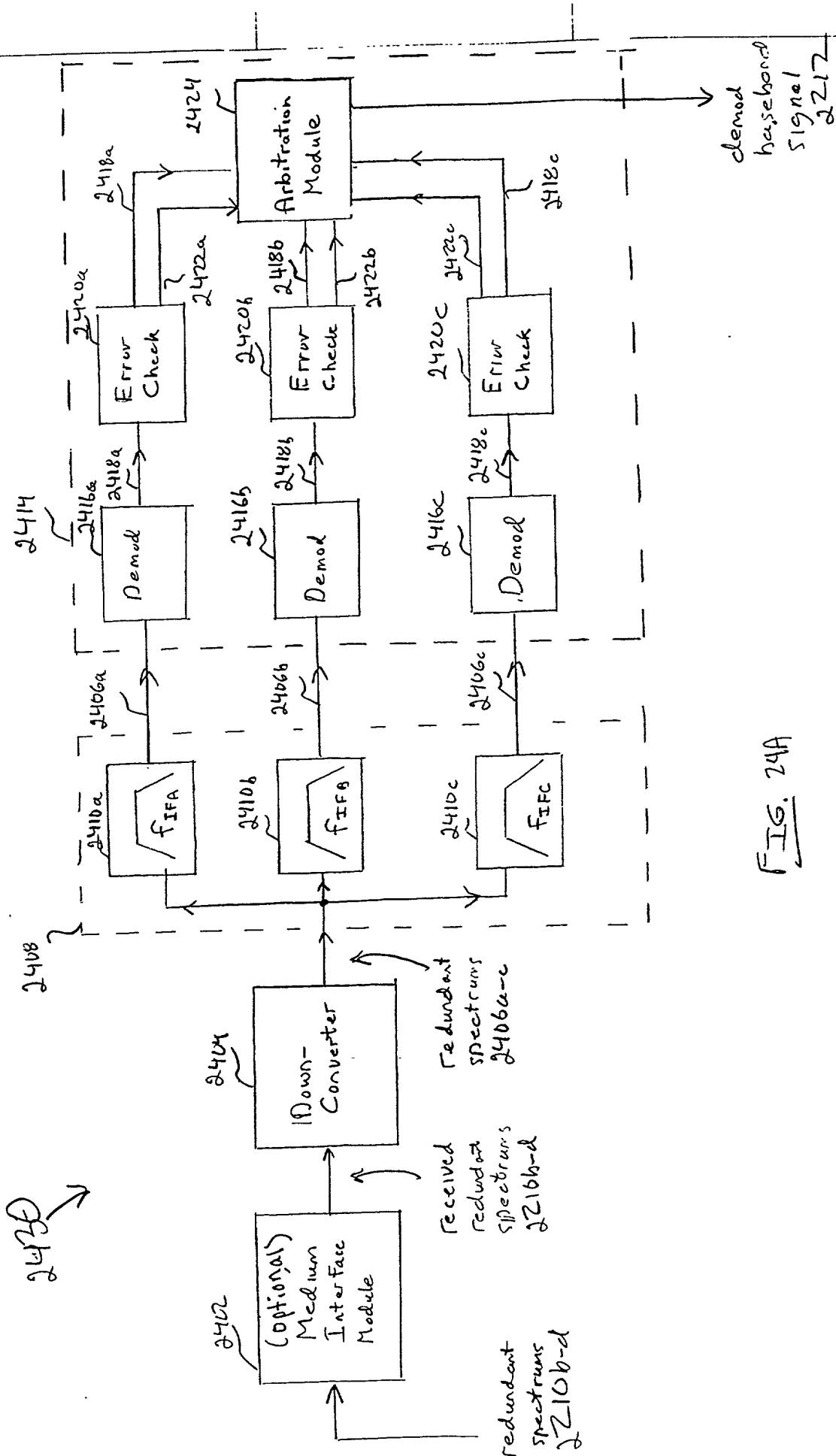
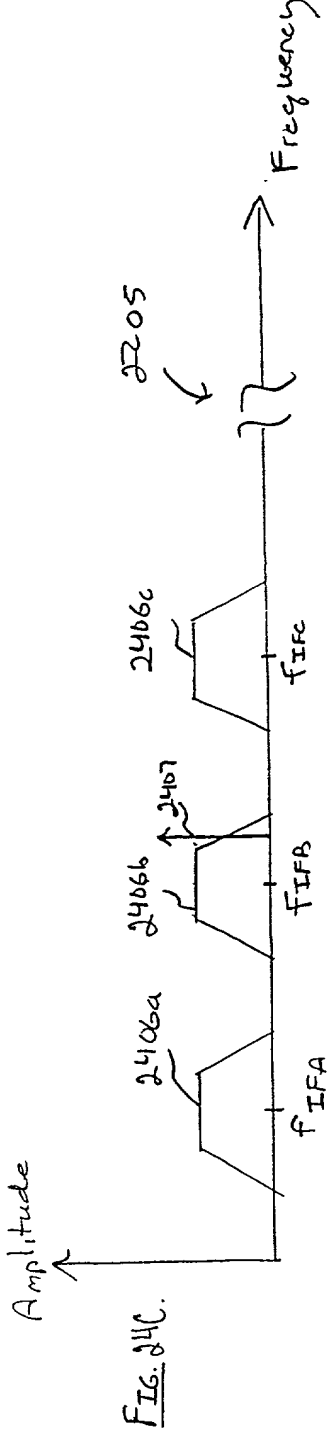
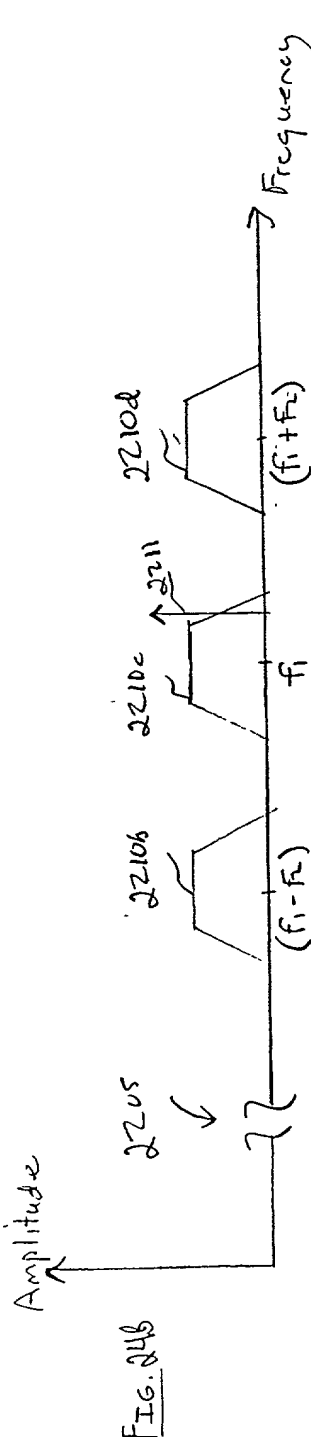
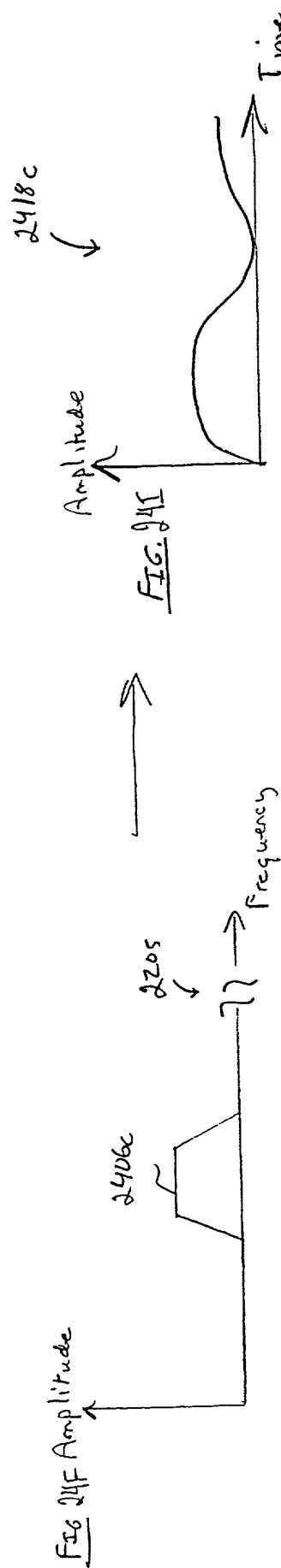
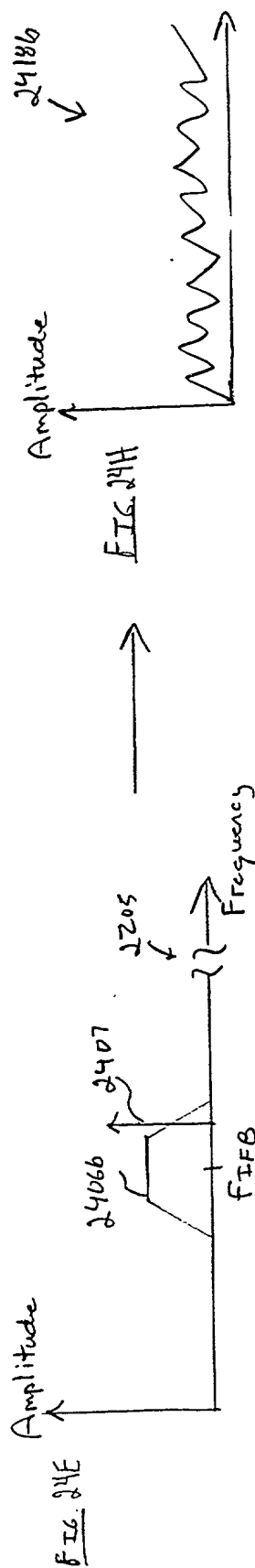
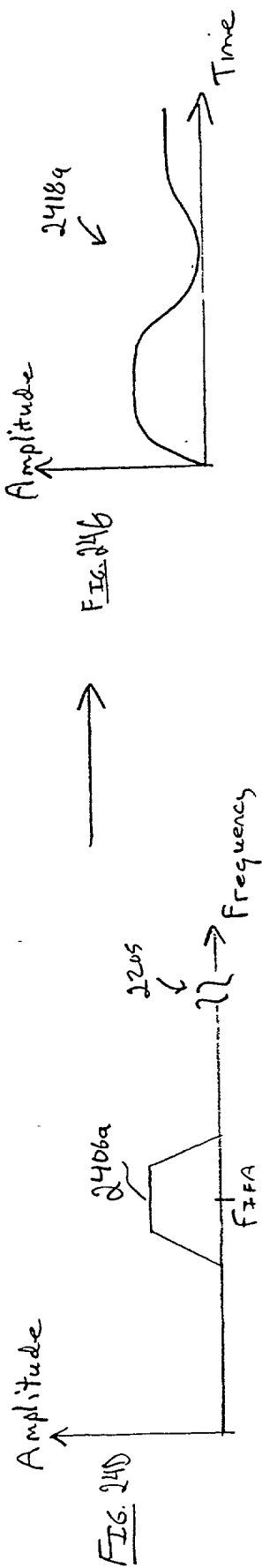
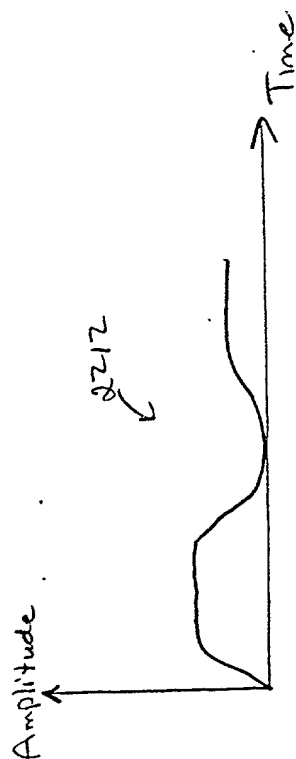


FIG. 24A





[illegible]

FTC 245

Combined Declaration and Power of Attorney for Patent Application

Docket Number: 1744.0140000

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter that is claimed and for which a patent is sought on the invention entitled Universal Frequency Translation, and Applications of Same, the specification of which is attached hereto unless the following box is checked:

- ☐ was filed on _____;
as United States Application Number or PCT International Application Number _____; and
was amended on _____ (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information that is material to patentability as defined in 37 C.F.R. § 1.56.

I hereby claim foreign priority benefits under 35 U.S.C. § 119(a)-(d) or § 365(b) of any foreign application(s) for patent or inventor's certificate, or § 365(a) of any PCT international application, which designated at least one country other than the United States listed below, and have also identified below any foreign application for patent or inventor's certificate, or PCT international application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application(s)

Priority Claimed

_____	_____	_____	☐ Yes	☐ No
(Application No.)	(Country)	(Day/Month/Year Filed)		
_____	_____	_____	☐ Yes	☐ No
(Application No.)	(Country)	(Day/Month/Year Filed)		

I hereby claim the benefit under 35 U.S.C. § 119(e) of any United States provisional application(s) listed below.

_____	_____
(Application No.)	(Filing Date)
_____	_____
(Application No.)	(Filing Date)

I hereby claim the benefit under 35 U.S.C. § 120 of any United States application(s), or under § 365(c) of any PCT international application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT international application in the manner provided by the first paragraph of 35 U.S.C. § 112, I acknowledge the duty to disclose information that is material to patentability as defined in 37 C.F.R. § 1.56 that became available between the filing date of the prior application and the national or PCT international filing date of this application.

_____	_____	_____
(Application No.)	(Filing Date)	(Status - patented, pending, abandoned)
_____	_____	_____
(Application No.)	(Filing Date)	(Status - patented, pending, abandoned)

Appl. No. to be assigned
Docket No. 1744.0140000

I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith:

Robert G. Sterne, Esq., Reg. No. 28,912; Edward J. Kessler, Esq., Reg. No. 25,688; Jorge A. Goldstein, Esq., Reg. No. 29,021; Samuel L. Fox, Esq., Reg. No. 30,353; David K.S. Cornwell, Esq., Reg. No. 31,944; Robert W. Esmond, Esq., Reg. No. 32,893; Tracy-Gene G. Durkin, Esq., Reg. No. 32,831; Michele A. Cimbala, Esq., Reg. No. 33,851; Michael B. Ray, Esq., Reg. No. 33,997; Robert E. Sokohl, Esq., Reg. No. 36,013; Eric K. Steffe, Esq., Reg. No. 36,688; and Michael Q. Lee, Esq., Reg. No. 35,239.

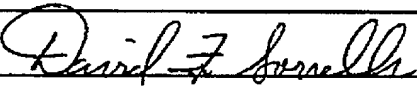
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Direct Telephone Calls to:

(202) 371-2600

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further 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 and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Full name of sole or first inventor	David F. Sorrells	
Signature of sole or first inventor		Date 10/20/98
Residence	Jacksonville, Florida	
Citizenship	U.S.A.	
Post Office Address	5250 Siesta Rio Drive South, Jacksonville, Florida 32258	
Full name of second inventor	Michael J. Bultman	
Signature of second inventor		Date 10/20/98
Residence	Jacksonville, Florida	
Citizenship	U.S.A.	
Post Office Address	2244 Aztec Drive West, Jacksonville, Florida 32246	

Appl. No. to be assigned
Docket No.1744.0140000

Full name of third inventor	Robert W. Cook
Signature of third inventor	<i>Robert W. Cook</i> Date 10/20/98
Residence	Switzerland, Florida
Citizenship	U.S.A.
Post Office Address	1432 Roberts Road, Switzerland, Florida 32259
Full name of fourth inventor	Richard C. Looke
Signature of fourth inventor	<i>R. C. Looke</i> Date 10/21/98
Residence	Jacksonville, Florida
Citizenship	U.S.A.
Post Office Address	3170 Ricky Drive, Jacksonville, Florida 32223
Full name of fifth inventor	Charley D. Moses, Jr.
Signature of fifth inventor	<i>Charley D. Moses, Jr.</i> Date 10/20/98
Residence	Jacksonville, Florida
Citizenship	U.S.A.
Post Office Address	4314 Naranja Drive, Jacksonville, Florida 32217

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(Supply similar information and signature for subsequent joint inventors, if any)

COPY

Certificate Under 37 C.F.R. § 3.73(b)

Applicants: David F. Sorrells, Michael J. Bultman, Robert W. Cook, Richard C. Looko, and Charley D. Moses, Jr.

Application No: to be assigned (Attv Dkt No. 1744.0140000) Filed: herewith

For: Universal Frequency Translation and Applications of Same

ParkerVision, Inc., a Corporation
(Name of Assignee) (Type of Assignee, e.g., corporation, partnership, university, government agency, etc.)

certifies that it is an assignee of the patent application identified above by virtue of either:

A. ☒ An Assignment from the inventor(s) of the patent application identified above. The assignment was recorded in the Patent and Trademark Office at Reel _____, Frame _____, or for which a copy thereof is attached.

[or]

B. ☐ A chain of title from the inventor(s) of the patent application identified above to the current assignee as shown below:

1. From: _____ To: _____
The document was recorded in the Patent and Trademark Office at Reel _____, Frame _____, or for which a copy thereof is attached.
2. From: _____ To: _____
The document was recorded in the Patent and Trademark Office at Reel _____, Frame _____, or for which a copy thereof is attached.
3. From: _____ To: _____
The document was recorded in the Patent and Trademark Office at Reel _____, Frame _____, or for which a copy thereof is attached.

☐ Additional documents in the chain of title are listed on a supplemental sheet.

☒ Copies of assignments or other documents in the chain of title are attached.

The undersigned (whose title is supplied below) is empowered to act on behalf of the assignee.

I hereby declare that all statements made herein of my own knowledge are true, and that all statements made on information and belief are believed to be true; and further, that these statements are made with the knowledge that willful false statements, and the like so made, are punishable by fine or imprisonment, or both under Section 1001, Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Date: 10/21/98

Name: David F. Sorrells

Title: Chief Technology Officer (Empowered to sign on behalf of the Assignee)

Signature: David F. Sorrells

POWER OF ATTORNEY FROM ASSIGNEE

COPY

ParkerVision, Inc., a corporation of Florida, having a principal place of business at 8493 Baymeadows Way, Jacksonville, Florida, is assignee of the entire right, title and interest for the United States of America (as defined in 35 U.S.C. § 100), by reason of an Assignment to the Assignee executed on October 20 & 21, 1998 of an invention known as Universal Frequency Translation and Applications of Same (Attorney Docket No. 1744.0140000), which is disclosed and claimed in a patent application of the same title by the inventor(s) David F. Sorrells, Michael J. Bultman, Robert W. Cook, Richard C. Look, and Charley D. Moses, Jr. (said application filed on herewith at the U.S. Patent and Trademark Office, having Application Number to be assigned).

The Assignee hereby appoints the following U.S. attorneys to prosecute this application and any continuation, divisional, continuation-in-part, or reissue application thereof, and to transact all business in the U.S. Patent and Trademark Office connected therewith: Robert Greene Sterne, Registration No. 28,912; Edward J. Kessler, Registration No. 25,688; Jorge A. Goldstein, Registration No. 29,021; Samuel L. Fox, Registration No. 30,353; David K.S. Cornwell, Registration No. 31,944; Robert W. Esmond, Registration No. 32,893; Tracy-Gene G. Durkin, Registration No. 32,831; Michele A. Cimbala, Registration No. 33,851; Michael B. Ray, Registration No. 33,997; Robert E. Sokohl, Registration No. 36,013; Eric K. Steffe, Registration No. 36,688, and Michael Q. Lee, Registration No. 35,239. The Assignee hereby grants said attorneys the power to insert on this Power of Attorney any further identification that may be necessary or desirable in order to comply with the rules of the U.S. Patent and Trademark Office.

Send correspondence to:

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Direct phone calls to 202-371-2600.

FOR: ParkerVision, Inc.

SIGNATURE:

David F. Sorrells

BY: David F. Sorrells

TITLE: Chief Technology Officer

(Empowered to sign on behalf of the Assignee)

DATE:

10/21/98