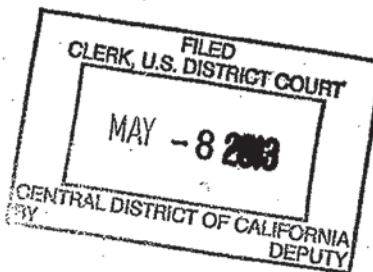


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14 Attorneys for Plaintiff AMERICAN RADIO, LLC

15
 16 **UNITED STATES DISTRICT COURT**
 17 **CENTRAL DISTRICT OF CALIFORNIA, WESTERN DIVISION**

18 AMERICAN RADIO LLC,

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20 Plaintiff,

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22 vs.

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24 CISCO SYSTEMS INCORPORATED,

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26 Defendant.

Case No.: CV12-05909 MRP (Ex)

**THIRD AMENDED COMPLAINT
FOR PATENT INFRINGEMENT**

JURY TRIAL DEMANDED

1 Plaintiff American Radio LLC (“American Radio”), by its attorneys, files
2 this Third Amended Complaint against defendant Cisco Systems Incorporated
3 (“Cisco”) as follows:

4 **PARTIES**

5 1. Plaintiff American Radio is a limited liability corporation organized
6 under the laws of California with its principal place of business at 1007 Goldeneye
7 View, Carlsbad, CA 92011. American Radio is the assignee of all right, title, and
8 interest in and to the ‘942 Patent, U.S. Patent No. 8,045,942; the ‘233 Patent, U.S.
9 Patent No. 7,831,233; and the ‘519 Patent, U.S. Patent No. 8,170,519.

10 2. On information and belief, defendant Cisco is a Delaware corporation
11 with its principal place of business at 170 West Tasman Drive, San Jose, California
12 95134.

13 **JURISDICTION**

14 3. This is an action arising under the patent laws of the United States,
15 Title 35 of the United States Code. This Court has subject matter jurisdiction
16 under 28 U.S.C. §§ 1331 and 1338(a).

17 4. Cisco, directly and/or through intermediaries or established
18 distribution channels (including distributors, online retailers, and others), ships,
19 distributes, offers for sale, sells, provides instructions on how to use, and/or
20 advertises its products in or into the United States, the State of California, and this
21 District. Cisco has purposefully and voluntarily placed one or more of its
22 infringing products into the stream of commerce with the expectation that they will
23 be purchased by customers within this District. These infringing products have
24 been, and continue to be, purchased by customers within this District.

25 5. Cisco derives substantial revenue from the sale of infringing products
26 distributed within this District, and/or expects or should reasonably expect its
27 actions to have consequences within this District, and derives substantial revenue
28 from interstate and international commerce.

1 6. For these reasons this Court has personal jurisdiction over Cisco.

2 **VENUE**

3 7. Venue is proper in this judicial district under 28 U.S.C. §§ 1391(b),
4 (c) and (d) and 1400(b) because this is an action for patent infringement, and Cisco
5 resides in this State. Moreover, venue is proper because this State and District has
6 personal jurisdiction over Cisco.

7 **'942 PATENT**

8 8. United States Patent No. 8,045,942 (“the ‘942 Patent”), entitled
9 “System And Method For Radio Signal Reconstruction Using Signal Processor,”
10 was duly and legally issued by the United States Patent and Trademark Office on
11 October 25, 2011. A true and correct copy of the ‘942 Patent is attached hereto as
12 Exhibit A and is incorporated herein by reference.

13 9. American Radio is the owner of all right, title and interest in and to
14 the ‘942 Patent and is entitled to sue for past and future infringement and recover
15 damages.

16 **'233 PATENT**

17 10. United States Patent No. 7,831,233 (“the ‘233 Patent”), entitled
18 “System And Method For Radio Signal Reconstruction Using Signal Processor,”
19 was duly and legally issued by the United States Patent and Trademark Office on
20 November 9, 2010. A true and correct copy of the ‘233 Patent is attached hereto as
21 Exhibit B and is incorporated herein by this reference.

22 11. American Radio is the owner of all right, title and interest in and to
23 the ‘233 Patent and is entitled to sue for past and future infringement and recover
24 damages.

25 **'519 PATENT**

26 12. United States Patent No. 8,170,519 (“the ‘519 Patent”), entitled
27 “System And Method For Radio Signal Reconstruction Using Signal Processor,”
28 was duly and legally issued by the United States Patent and Trademark Office on

1 May 1, 2012. A true and correct copy of the '519 Patent is attached hereto as
2 Exhibit C and is incorporated herein by this reference.

3 13. American Radio is the owner of all right, title and interest in and to
4 the '519 Patent and is entitled to sue for past and future infringement and recover
5 damages.

6 **COUNT 1 – DIRECT INFRINGEMENT OF**
7 **U.S. PATENT NO. 8,045,942**

8 14. American Radio repeats and realleges the allegations in paragraphs 1-
9 13, inclusive.

10 15. Cisco has directly infringed, and is continuing to directly infringe, one
11 or more of the '942 Patent claims, including but not limited to claims 1-3, by
12 making, using, selling, offering for sale, and/or importing at least the following
13 Cisco Products: the Cisco uBR10K series routers (including the UBR10012
14 router); the uBR7200 series routers, and; all other Cisco products that include
15 Broadcom chips BCM3138 and BCM3140. Further, the accused uBR10K series
16 routers include the MC5x20 line card, that in turn includes the BCM3140 Dual
17 Universal Advanced TDMA/SCDMA Phy-Layer Burst Receiver by Broadcom.
18 AMR00001688. The accused uBR7200 series routers include the MC28 line card,
19 that in turn includes the BCM3138 Dual Universal Advanced TDMA Phy-Layer
20 Burst Receiver by Broadcom. AMR00001868; AMR00001622; AMR00001637-
21 41.

22 16. Cisco is liable for its infringement of the '942 Patent pursuant to 35
23 U.S.C. § 271.

24 17. Cisco's direct infringement of the '942 Patent has damaged and will
25 continue to damage American Radio.

26 18. Cisco's direct infringement of the '942 Patent has caused and will
27 continue to cause American Radio irreparable harm unless enjoined by the Court.
28

1 American Radio has no adequate remedy at law. American Radio's damages from
2 the infringing activities of Cisco are not yet determined.

3 **COUNT 2 – DIRECT INFRINGEMENT OF**
4 **U.S. PATENT NO. 7,831,233**

5 19. American Radio repeats and realleges the allegations in paragraphs 1-
6 13, inclusive.

7 20. Cisco has directly infringed, and is continuing to directly infringe, one
8 or more of the '233 Patent claims, including but not limited to claim 10, by
9 making, using, selling, offering for sale, and/or importing at least the following
10 Cisco Products: the Cisco uBR10K series routers (including the UBR10012
11 router); the uBR7200 series routers, and; all other Cisco products that include
12 Broadcom chips BCM3138 and BCM3140. Further, the accused uBR10K series
13 routers include the MC5x20 line card, that in turn includes the BCM3140 Dual
14 Universal Advanced TDMA/SCDMA Phy-Layer Burst Receiver by Broadcom.
15 AMR00001688. The accused uBR7200 series routers include the MC28 line card,
16 that in turn includes the BCM3138 Dual Universal Advanced TDMA Phy-Layer
17 Burst Receiver by Broadcom. AMR00001868; AMR00001622; AMR00001637-
18 41.

19 21. Cisco is liable for its infringement of the '233 Patent pursuant to 35
20 U.S.C. § 271.

21 22. Cisco's direct infringement of the '233 Patent has damaged and will
22 continue to damage American Radio.

23 23. Cisco's direct infringement of the '233 Patent has caused and will
24 continue to cause American Radio irreparable harm unless enjoined by the Court.
25 American Radio has no adequate remedy at law. American Radio's damages from
26 the infringing activities of Cisco are not yet determined.

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COUNT 3 – DIRECT INFRINGEMENT OF
U.S. PATENT NO. 8,170,519

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24. American Radio repeats and realleges the allegations in paragraphs 1-13, inclusive.

25. Cisco has directly infringed, and is continuing to directly infringe, one or more of the '519 Patent claims, including but not limited to claims 1-3, by making, using, selling, offering for sale, and/or importing at least the following Cisco Products: the Cisco uBR10K series routers (including the UBR10012 router); the uBR7200 series routers, and; all other Cisco products that include Broadcom chips BCM3138 and BCM3140. Further, the accused uBR10K series routers include the MC5x20 line card, that in turn includes the BCM3140 Dual Universal Advanced TDMA/SCDMA Phy-Layer Burst Receiver by Broadcom. AMR00001688. The accused uBR7200 series routers include the MC28 line card, that in turn includes the BCM3138 Dual Universal Advanced TDMA Phy-Layer Burst Receiver by Broadcom. AMR00001868; AMR00001622; AMR00001637-41.

26. Cisco is liable for its infringement of the '519 Patent pursuant to 35 U.S.C. § 271.

27. Cisco's direct infringement of the '519 Patent has damaged and will continue to damage American Radio.

28. Cisco's direct infringement of the '519 Patent has caused and will continue to cause American Radio irreparable harm unless enjoined by the Court. American Radio has no adequate remedy at law. American Radio's damages from the infringing activities of Cisco are not yet determined.

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WHEREFORE, American Radio LLC, respectfully requests that this Court enter judgment in its favor against Cisco and grant the following relief:

- A. Enter a judgment that Cisco is directly infringing the ‘942 Patent;
- B. Enter a judgment that Cisco is directly infringing the ‘233 Patent;
- C. Enter a judgment that Cisco is directly infringing the ‘519 Patent;
- D. Enter an order preliminarily and permanently enjoining Cisco, its

officers, directors, agents, servants, employees and all other persons in privity or acting in concert with them who receive actual notice of the order by personal service or otherwise, from any further acts of infringement of any of the ‘942, ‘233, and ‘519 Patents;

E. Award American Radio damages in the amount adequate to compensate American Radio for Cisco’s direct and indirect infringement of the ‘942, ‘233, and ‘519 Patents;

F. Enter an order finding that this is an exceptional case and awarding American Radio its reasonable attorneys’ fees pursuant to 35 U.S.C. § 285; and

G. Award American Radio such other relief as the Court may deem appropriate and just under the circumstances.

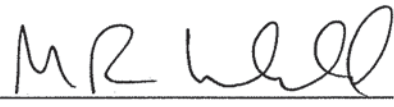
JURY DEMAND

Plaintiff American Radio LLC respectfully demands trial by jury of all matters triable to a jury.

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Dated: May 7, 2013

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Attorneys for American Radio LLC

EXHIBIT A



US008045942B2

(12) **United States Patent**
Hotto

(10) **Patent No.:** **US 8,045,942 B2**
(45) **Date of Patent:** ***Oct. 25, 2011**

(54) **SYSTEM AND METHOD FOR RADIO SIGNAL RECONSTRUCTION USING SIGNAL PROCESSOR**

(58) **Field of Classification Search** None
See application file for complete search history.

(75) **Inventor:** **Robert Hotto**, Carlsbad, CA (US)

(56) **References Cited**

(73) **Assignee:** **American Radio LLC**, Carlsbad, CA (US)

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(*) **Notice:** Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

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(21) **Appl. No.:** **12/702,498**

(22) **Filed:** **Feb. 9, 2010**

(65) **Prior Publication Data**

US 2010/0142655 A1 Jun. 10, 2010

(Continued)

Related U.S. Application Data

(63) Continuation of application No. 11/928,585, filed on Dec. 10, 2007, now Pat. No. 7,831,233, which is a continuation of application No. 11/068,585, filed on Apr. 13, 2005, now Pat. No. 7,433,664, which is a continuation of application No. 10/255,438, filed on Sep. 26, 2002, now Pat. No. 7,043,219, which is a continuation of application No. 09/771,821, filed on Jan. 29, 2001, now Pat. No. 6,577,854, which is a continuation of application No. 09/178,229, filed on Oct. 23, 1998, now Pat. No. 6,236,845, which is a continuation of application No. 08/596,551, filed on Feb. 5, 1996, now Pat. No. 5,864,754.

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(Continued)

Primary Examiner — Philip Sobutka

(74) *Attorney, Agent, or Firm* — John L. Rogitz

(57) **ABSTRACT**

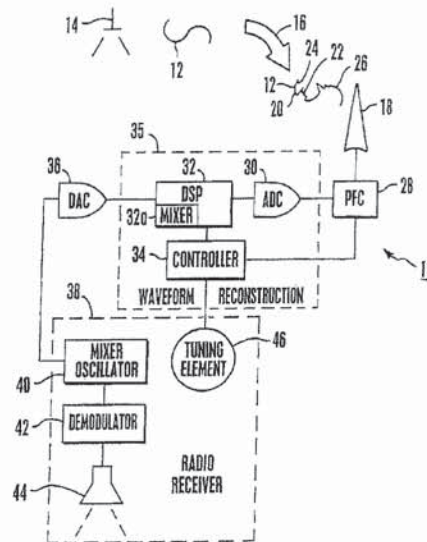
A waveform reconstruction circuit receives an rf signal from an antenna, digitizes it, and then generates an undistorted reconstructed waveform. The reconstructed waveform can then be conventionally mixed and demodulated to extract useful signal information with enhanced receiver fidelity and sensitivity.

6 Claims, 3 Drawing Sheets

(51) **Int. Cl.**

H04B 1/18 (2006.01)

(52) **U.S. Cl.** **455/280; 455/295; 455/296; 455/303; 455/307**



US 8,045,942 B2

Page 2

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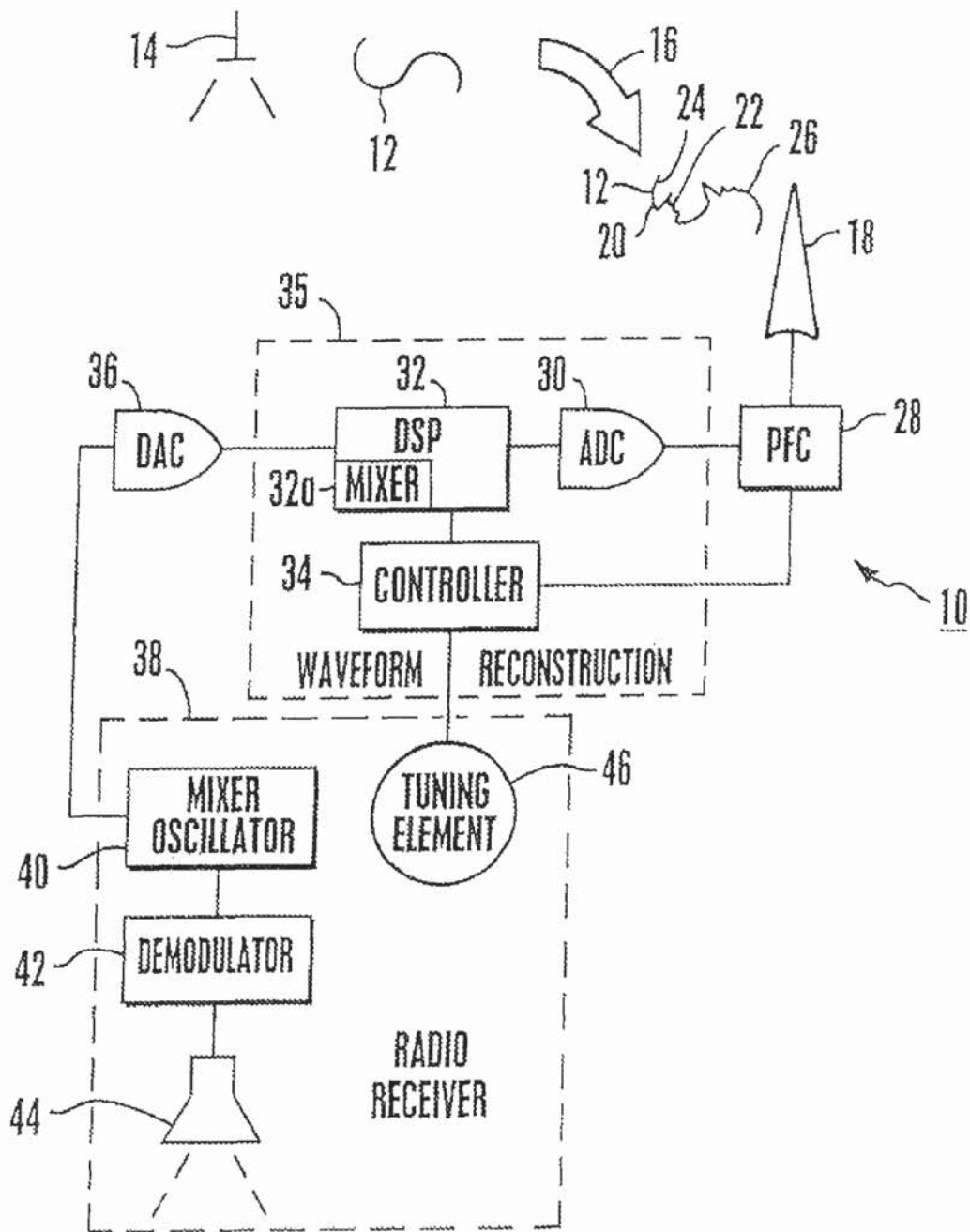


Fig. 1

Fig. 2

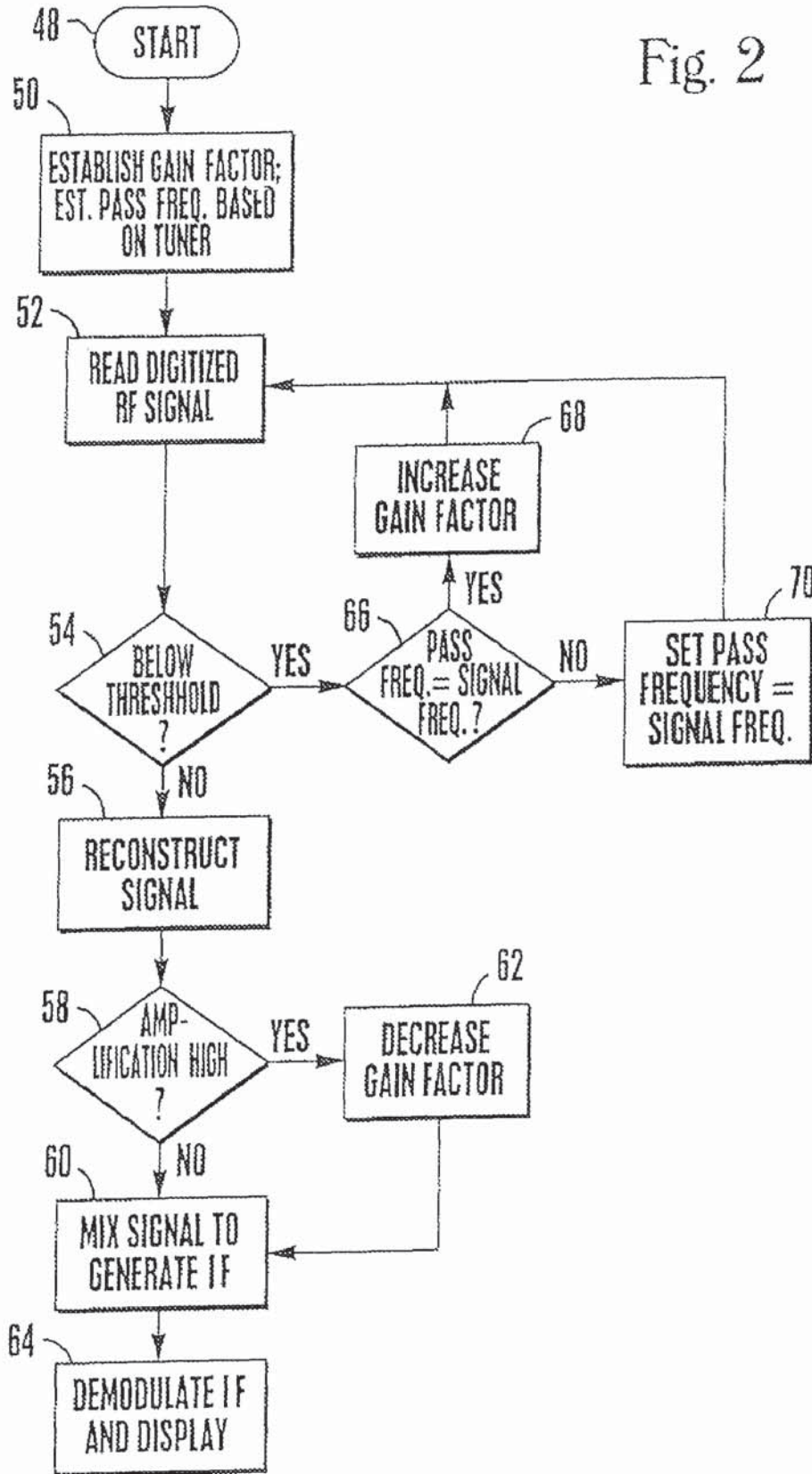
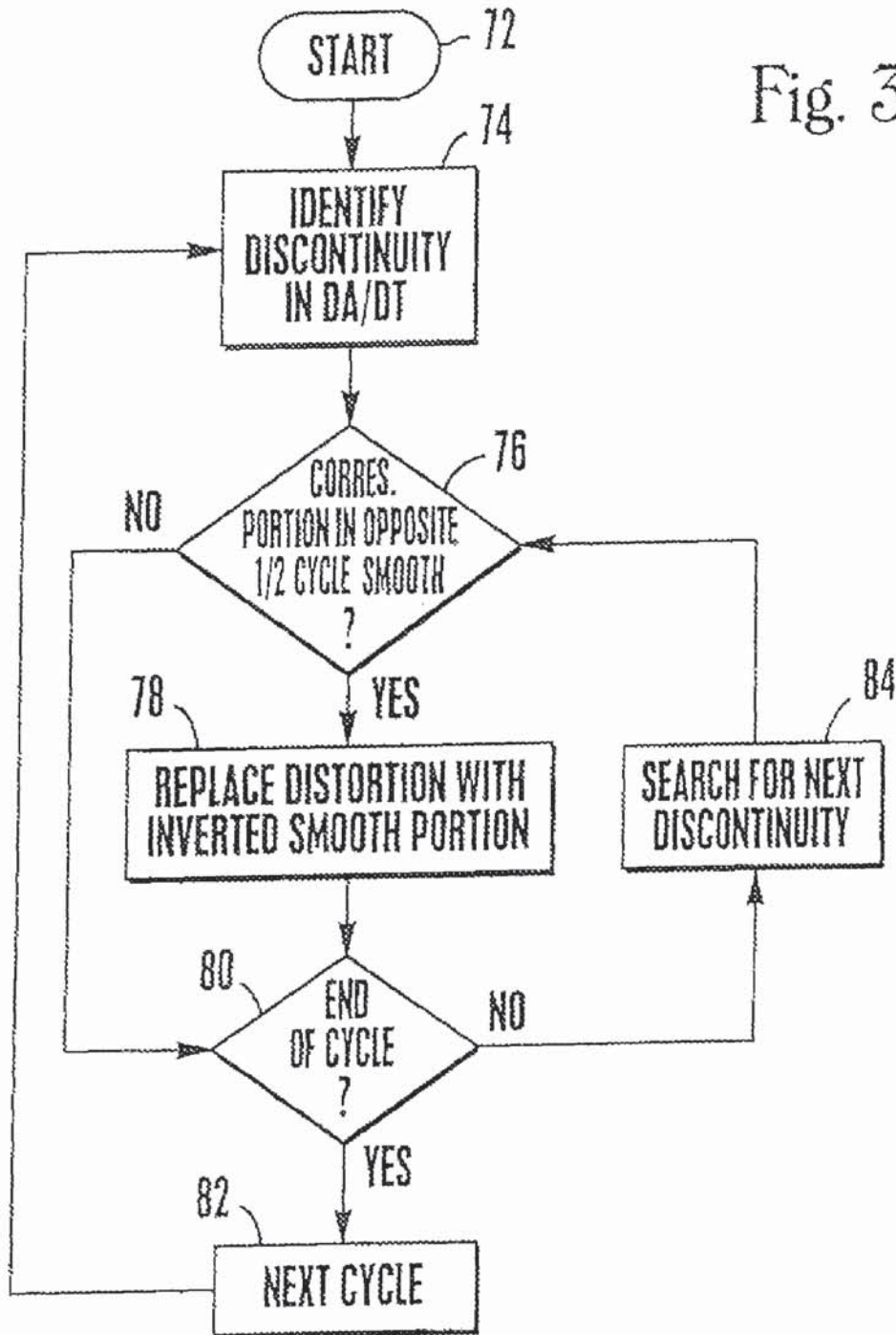


Fig. 3



US 8,045,942 B2

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SYSTEM AND METHOD FOR RADIO SIGNAL RECONSTRUCTION USING SIGNAL PROCESSOR

This application is a continuation of U.S. patent applica- 5
tion Ser. No. 11/928,585, filed Dec. 10, 2007, now U.S. Pat.
No. 7,831,233, which is a continuation of U.S. patent appli-
cation Ser. No. 11/068,585, filed Apr. 13, 2005, now U.S. Pat.
No. 7,433,664, which is a continuation of U.S. patent applica-
tion Ser. No. 10/255,438 filed Sep. 26, 2002, now U.S. Pat. 10
No. 7,043,219, which is a continuation of U.S. application
Ser. No. 09/771,821 now U.S. Pat. No. 6,577,854, filed Jan.
29, 2001, which in turn is a continuation of U.S. application
Ser. No. 09/178,229 now U.S. Pat. No. 6,236,845, filed Oct.
23, 1998, which in turn is a continuation of U.S. application 15
Ser. No. 08/596,551 now U.S. Pat. No. 5,864,754, filed Feb. 5,
1996 all of which are incorporated herein by reference and
priority from all of which is hereby claimed.

FIELD OF THE INVENTION

The present invention relates generally to radio signal pro-
cessing, and more particularly to systems and methods for
reducing distortion in rf signals and thus enhancing the fidel-
ity and sensitivity of radio receivers.

BACKGROUND

Conventional radio receivers function by receiving an rf
signal and preamplifying it, and then processing the signal 30
using a superheterodyne structure. The superheterodyne
structure, in its simplest configuration, includes a mixer oscil-
lator which mixes the received signal down to an intermediate
frequency (IF) signal. The IF signal is then sent through a
bandpass filter and demodulated by an envelope detector to 35
recover the information (colloquially referred to as "base-
band") that is carried by the received rf signal.

Of importance to the present invention is the fact that rf
signals are corrupted by environmental factors during trans-
mission. Conventional superheterodyne structures attempt to 40
correct for signal corruption by suppressing corruption-in-
duced noise using filtering techniques. Unfortunately, such
conventional filtering, whether using analog or digital tech-
niques, suppresses both noise and useful signal, thereby
reducing the fidelity of the receiver. In other words, although
filtering improves the ratio between useful signal and noise
(referred to as the signal-to-noise ratio, SNR), it typically
reduces system fidelity and signal strength.

Further, during demodulation, the envelope detector of a
conventional superheterodyne structure effectively demodu- 50
lates only one-half cycle, for example, the positive half cycle,
of the IF signal. Only one half of the signal need be used, since
the information attached to the positive half cycle during
transmission is identical to the information attached to the
negative half cycle during transmission. Accordingly, the 55
negative half of each cycle of the received rf signal is dis-
carded by the envelope detector, and replaced with a mirror
image of the positive half.

It happens, however, that either one of the positive or
negative half of a cycle can be distorted asymmetrically from 60
the other half. Consequently, in instances wherein the nega-
tive half of a cycle is relatively uncorrupted, but the positive
half cycle is corrupted, the opportunity to use the "best" half
of a cycle is lost. Thus, the portion of a corrupted IF signal that
is ultimately demodulated and output by the envelope detec- 65
tor statistically can be expected to be the corrupt half 50% of
the time.

2

In light of the above discussion as recognized by the
present invention, it would be advantageous to analyze both
the positive and negative halves of an rf signal cycle and
determine which half is the "best" half, and then extract the
useful signal from this "best" half. As further recognized by
the present invention, it would be advantageous to accom-
plish such analysis prior to the non-linear transformation of
the rf signal to the IF signal during mixing by the oscillator.
Stated differently, it would be advantageous to accomplish
such analysis prior to mixing, since the mixing function
causes certain data in the signal to be irrecoverable and there-
fore precludes identification of some distortion and corrup-
tion in the "true" signal post-mixing. As still further recog-
nized by the present invention, it would be advantageous to
adjust signal gain and tuning "on the fly" to account for
transmitter frequency drift and for sometimes constantly
changing received signal strength at the antenna.

Accordingly, it is an object of the present invention to
provide a system and method for reconstructing a radio signal
prior to mixing and demodulating the signal. Another object
of the present invention is to provide a system and method for
reconstructing a radio signal to improve the extraction of
useful portions of the originally transmitted signal that had
been corrupted. Yet another object of the present invention is
to provide a system and method for reconstructing a radio
signal which adjusts signal gain and tuning from the antenna
on the fly. Still another object of the present invention is to
provide a system and method for reconstructing a radio signal
which is easy to use and cost-effective.

SUMMARY OF THE INVENTION

An electromagnetic waveform reconstruction device
includes an analog to digital converter (ADC) that is electri-
cally connectable to an antenna for receiving an analog elec-
tromagnetic signal therefrom and digitizing the signal. The
ADC outputs the digitized electromagnetic signal to a digital
signal processor (DSP), which in turn outputs a reconstructed
electromagnetic signal in accordance with a predetermined
reconstruction paradigm. As more fully discussed herein, the
DSP is electrically associable with a mixer circuit for sending
the reconstructed electromagnetic signal thereto for mixing
and demodulating the signal.

Preferably, the electromagnetic signal is an rf signal, and
the device further includes a digital to analog converter
(DAC) for converting the reconstructed rf signal to an analog
reconstructed rf signal, prior to sending the reconstructed rf
signal to the mixer circuit. Alternatively, the DSP digitally
mixes the reconstructed rf signal and outputs an intermediate
frequency (IF) signal to a demodulator.

As envisioned by the preferred embodiment, the DSP
includes reconstruction means for effecting method steps to
implement the predetermined reconstruction paradigm. In
accordance with the present invention, the method steps
include receiving both a positive half and a negative half of
the digitized rf signal, and then analyzing the positive and
negative halves to identify distorted portions and undistorted
portions thereof. At least some of the distorted portions are
removed and replaced with respective replacement portions.
Thereby, the reconstructed rf signal is produced, with each
replacement portion being based on at least some of the
undistorted portions.

In one presently preferred embodiment, a controller is elec-
trically connected to the DSP. Also, a preamplifier filter cir-
cuit (PFC) is electrically connectable to the antenna and to the
ADC for amplifying and filtering the analog rf signal from the
antenna prior to sending the analog rf signal to the ADC.

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Moreover, the PFC is also electrically connected to the controller. Advantageously, the PFC includes a frequency band-pass filter for attenuating signals having a frequency not equal to a pass frequency, and the controller dynamically establishes the pass frequency.

Furthermore, in the presently preferred embodiment, the PFC includes an amplifier for increasing, by a gain factor, the amplitude of signals having the pass frequency. As intended by the preferred embodiment, the controller establishes the gain factor. To this end, the DSP outputs a gain adjust signal to the controller when the rf signal input to the DSP is characterized by an amplitude outside of a predetermined amplitude range. Stated somewhat differently, the DSP generates the gain adjust signal when its input signal is characterized by distortions due to a weak or clipped signal, and the DSP generates the gain adjust signal by determining information content of the signal. In response to the gain adjust signal, and the controller dynamically establishes the gain factor based on the gain adjust signal. If desired, the device of the present invention can be combined with an electromagnetic signal transmitter.

In another aspect of the present invention, an rf receiver includes an antenna and a signal reconstruction circuit electrically connected to the antenna. Accordingly, the signal reconstruction circuit receives an analog rf signal from the antenna. Per the principles of the present invention, the signal reconstruction circuit generates a substantially undistorted reconstructed waveform. A mixer circuit is electrically associated with the signal reconstruction circuit for generating an intermediate frequency (IF) signal based on the reconstructed waveform, and a demodulator decodes useful information from the IF signal.

In yet another aspect, a computer-implemented method is disclosed for processing a transmitted electromagnetic signal to extract useful information from the signal. The present method includes receiving the electromagnetic signal and reconstructing it in accordance with a predetermined reconstruction paradigm, and then, after reconstruction, mixing and demodulating the electromagnetic signal to extract useful information therefrom.

In still another aspect, a computer program device includes a computer program storage device which is readable by a digital processing system. A program means is provided on the program storage device, and the program means includes instructions that are executable by the digital processing system for performing method steps for reconstructing an rf signal prior to mixing and demodulating the rf signal. The method steps advantageously include receiving both a positive half and a negative half of the rf signal, and analyzing the positive and negative halves to identify distorted portions and undistorted portions thereof. The method steps further include removing at least some of the distorted portions and replacing each with a respective replacement portion to thereby produce a reconstructed rf signal, with each replacement portion being based on at least some of the undistorted portions.

In another aspect of the present invention, a device is disclosed for dynamically preamplifying and filtering an rf signal from an antenna, prior to mixing and demodulating the signal to extract useful information from it. The device includes a controller and a preamplifier filter circuit (PFC) electrically connectable to the antenna and in electrical communication with the controller for amplifying and filtering the rf signal. Per the present invention, the PFC includes a frequency bandpass filter for attenuating signals having a frequency not equal to a pass frequency. Additionally, the PFC includes an amplifier for increasing, by a gain factor, the

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amplitude of signals having the pass frequency. The controller dynamically establishes/adjusts the pass frequency and gain factor, based on the signal amplitude and distortion.

The details of the present invention, both as to its structure and operation, can best be understood in reference to the accompanying drawings, in which like reference numerals refer to like parts, and in which:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic block diagram of the system of the present invention;

FIG. 2 is a flow chart showing the overall method steps of the present invention; and

FIG. 3 is a flow chart showing the steps of a waveform reconstruction method in accordance with the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring initially to FIG. 1, a system, generally designated 10, is shown for reconstructing an rf waveform signal 12 that has been transmitted by an rf transmitter 14, before the signal 12 is mixed and demodulated. As schematically shown in FIG. 1, the rf signal 12 is an analog, sinusoidally-shaped signal that is relatively smooth and undistorted when transmitted, but which can become degraded and distorted as it propagates in the direction of the arrow 16 toward an rf antenna 18. Consequently, upon reaching the antenna 18, a negative half 20 of the rf signal 12 can have distorted portions 22 and undistorted portions 24. Likewise, a positive half 26 of the rf signal 12 can have distorted portions and undistorted portions as shown. The present invention is directed to removing distortions from rf signals, prior to mixing and demodulating the signals incident to the decoding of useful information therefrom, thereby improving the fidelity and sensitivity of radio receivers.

While the disclosure herein focuses on rf waveform reconstruction, it is to be understood that the principles of the present invention apply equally to other forms of modulated electromagnetic waves that are modulated as appropriate for the data the waves represent. For example, the principles of the present invention can be applied to processing modulated light waves that are transmitted through fiber optic bundles incident to the transfer of computer, video, or voice data.

FIG. 1 shows that the rf signal detected by the antenna 18 is sent to a preamplifying and filtering circuit 28. In accordance with the present invention, the preamplifying and filtering circuit 28 includes an amplifying circuit which preamplifies, by a gain factor, the signal from the antenna 18. Furthermore, the preamplifying and filtering circuit 28 includes a frequency bandpass filter for attenuating signals having a frequency not equal to a pass frequency. As described in greater detail below, the pass frequency and gain factor are dynamically established under the principles of the present invention.

Continuing with the description of FIG. 1, an analog to digital converter (ADC) 30 is electrically connected to the antenna 18 for receiving the analog rf signal therefrom. The ADC 30 is structure well-known in the art that outputs a digitized rf signal in response to the analog rf input from the antenna 18.

Additionally, a digital signal processor (DSP) 32 is electrically connected to the ADC 30. Accordingly, the DSP 32 receives the digitized signal from the ADC 30. Per the present invention, the DSP 32 outputs a reconstructed rf signal in

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accordance with a predetermined waveform reconstruction paradigm as more fully disclosed below. The reconstructed waveform has substantially no distorted portions. Instead, distorted portions in the input signal to the DSP 32 are replaced by smooth, undistorted portions.

As shown in FIG. 1, a digital computer or controller 34 is electrically connected to or integrated with the DSP 32. In one preferred embodiment, the DSP 32, controller 34, and ADC 30 establish a waveform reconstruction circuit 35. As intended by the present invention, the DSP 32 outputs a gain adjust signal to the controller 34 when the rf signal input to the DSP 32 is characterized by an amplitude outside of a predetermined amplitude range. In other words, when the amplitude of the input signal to the DSP 32 is too high or too low, the DSP 32 sends a gain adjust signal representing this fact to the controller 34.

In turn, the controller 34 is electrically connected to the preamplifying and filtering circuit 28, and the controller 34 dynamically establishes the gain factor of the preamplifying and filtering circuit 28, based on the gain adjust signal. Moreover, the controller 34 can also dynamically establish the pass frequency of the preamplifying and filtering circuit 28, based on the gain adjust signal, to adjust the signal to optimize reception thereof.

After reconstructing the rf waveform, the DSP 32 sends the reconstructed digitized signal to a digital-to-analog converter (DAC) 36, which converts the digitized output of the DSP 32 to an analog waveform. The DAC 36 is in turn electrically connected to the mixing circuit of a radio receiver 38. More specifically, the DAC 36 is electrically connected to an oscillator mixer 40 of the radio receiver 38, and the mixer 40 outputs an intermediate frequency (IF) signal in accordance with principles well-known in the art, based upon the analog signal from the DAC 36. The IF output from the mixer 40 is then sent to a demodulator 42, which decodes the signal to extract useful information therefrom. As but one example of how such useful information is used, an audio speaker 44 can be electrically connected to the demodulator 42 for producing audio signals, based on the output signal of the demodulator 42.

As the skilled artisan will recognize, the configuration shown in FIG. 1 is conducive to operably associating the waveform reconstruction circuit of the present invention with existing conventional radio receivers. In other words, the waveform reconstruction circuit 35 can be implemented in, e.g., a computer chip, and the chip then electrically engaged with a conventional radio receiver between the receiver and antenna as described, for enhancing the fidelity and sensitivity of the radio receiver. Alternatively, a mixer circuit can be incorporated in the DSP 32 to digitally implement the function of the mixer 40 after reconstruction of the waveform. In such an embodiment, the digitized output of the DSP 32 accordingly represents a reconstructed IF signal to be analogized by a DAC and then decoded by a demodulator.

As can be further appreciated in reference to FIG. 1, the radio receiver 38 typically includes one or more a tuning control elements, such as, for example, a knob-like tuning element 46. As is well known in the art, the tuning element 46 is manipulable by a person to establish a channel frequency selection. As shown in FIG. 1, the tuning element 46 is electrically connected to the controller 34, such that the controller 34 can establish the pass frequency based on the channel frequency. As stated above however, once the channel frequency has been set by a person, the controller 34 can further dynamically vary the pass frequency from the channel frequency as may be required by the gain adjust signal from the DSP 32, to compensate for transmitter 14 frequency drift.

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Stated differently, because the gain adjust signal generated by the DSP 32 is based on the received rf signal, the controller 34 can dynamically establish the pass frequency and/or gain factor, based on the received rf signal.

Now referring to FIGS. 2 and 3, the operational steps of the present invention can be appreciated. It is to be understood that FIGS. 2 and 3 represent logic flow charts of the present reconstruction means for implementing the predetermined reconstruction paradigm of the present invention. As recognized herein, the advantages of the present invention can be realized by removing at least some of the distorted portions of a received waveform and replacing each distorted portion with a respective replacement portion that is based on at least some of the undistorted portions of the received waveform. Thereby, a reconstructed rf signal is produced.

FIGS. 2 and 3 illustrate the logical structure of the waveform reconstruction of the present invention. This logical structure can be embodied in hardware, firmware, or computer program software. When the waveform reconstruction logic is embodied in software, it will be appreciated that the Figures illustrate the structures of computer program code elements that function according to this invention. Manifestly, the software-implemented invention is practiced in its essential embodiment by a machine component that renders the computer program code elements in a form that instructs a digital processing apparatus (that is, a computer) to perform a sequence of function steps corresponding to those shown in the Figures.

These software instructions may reside on a program storage device including a data storage medium, such as may be included in the DSP 32. The machine component in such an embodiment is a combination of program code elements in computer readable form that are embodied in a computer-readable data medium on the DSP 32. Alternatively, such media can also be found in semiconductor devices, on magnetic tape, on optical and magnetic disks, on a DASD array, on magnetic tape, on a conventional hard disk drive, on electronic read-only memory or on electronic random access memory, or other appropriate data storage device. In an illustrative embodiment of the invention, the computer-executable instructions may be lines of compiled C++ language code.

Referring particularly to FIG. 2, the waveform reconstruction logic of the DSP 32 begins at start oval 48, wherein positive and negative half cycles of a digitized waveform having distorted and undistorted portions are received from the ADC 30. At block 50, the gain factor and pass frequency of the preamplifying and filtering circuit 28 are established. Initially, the gain factor is established at a default value, and the pass frequency is established to be equal to the channel frequency established by the timing element 46 (FIG. 1).

Next, at block 52, the digitized rf signal input to the DSP 32 is read. The present logic proceeds to decision diamond 54 to determine whether the amplitude of the input signal is below a predetermined threshold. If not, the logic moves to block 56 to reconstruct the signal as discussed in greater detail below.

From block 56, the logic proceeds to decision diamond 58, wherein it is determined whether the amplification of the reconstructed signal exceeds a predetermined value. If not, the logic proceeds to block 60, wherein the reconstructed signal is mixed (after being analogized, if appropriate) to generate an IF signal.

On the other hand, if, at decision diamond 58, it is determined that the amplification of the reconstructed signal indeed exceeds a predetermined value, the logic proceeds to block 62, wherein the DSP 32 outputs a gain adjust signal to the controller 34 to cause the controller 34 to decrease the gain factor of the preamplifying and filtering circuit 28. From

blocks 60 or 62, the logic moves to block 64, wherein the IF signal is demodulated, and the useful information that is thereby extracted is displayed audibly, visually, or indeed stored or otherwise input to a device requiring the information.

Recall that at decision diamond 54 it is determined whether the amplitude of the input signal is below a predetermined threshold. In other words, as recognized by the present invention, the signal input to the DSP 32 should be characterized by an amplitude that is sufficient to permit decoding of useful information from the signal.

If the amplitude is below the threshold, the logic of the present invention proceeds to decision diamond 66, wherein it is determined whether the pass frequency is equal to the frequency of the received rf signal. If it is, the logic moves to block 68, wherein the gain adjust signal from the DSP 32 is generated to cause the controller 34 increase the gain factor of the preamplifying and filtering circuit 28.

In contrast, if, at decision diamond 66, it is determined that the pass frequency is not equal to the frequency of the received rf signal (i.e., that the pass frequency is not optimized for receiving the desired rf signal), the logic moves to block 70. As shown in Figure, at block 70, the controller 34 dynamically varies the pass frequency to set the pass frequency equal to the frequency of the received rf signal. From blocks 68 and 70, the logic returns to block 52.

Now referring to FIG. 3, the details of one embodiment of the waveform reconstruction paradigm of the present invention are shown. The paradigm begins at start oval 72, and moves to block 74, wherein discontinuities in the slope (referred to as "dA/dt") of the input waveform to the DSP 32 are identified. As recognized by the present invention, such discontinuities should not exist in a perfect waveform, and consequently indicate distorted portions of the waveform. On the other hand, a smooth slope (i.e., dA/dt is a smooth sinusoidal function) indicates an undistorted waveform portion.

From block 74, the logic proceeds to decision diamond 76, wherein it is determined whether the corresponding waveform portion in the opposite half-cycle that corresponds to the distorted portion is smooth (i.e., whether dA/dt of the corresponding waveform portion is a smooth sinusoidal function). By "corresponding waveform portion" is meant the portion of the waveform that occupies the segment along the time axis in the opposite half-cycle from the distorted portion which corresponds to the segment along the time axis occupied by the distorted portion in its own half-cycle.

If the test at decision diamond 76 is positive, the logic moves to block 78, wherein the distorted portion is replaced with the inverse of the corresponding waveform portion. Next, the logic moves to decision diamond 82, wherein it is determined whether the complete waveform cycle (i.e., one positive half-cycle and its negative half-cycle) has been analyzed. If it has been, the process proceeds to block 82, to analyze the next cycle, returning to block 74. Otherwise, the process proceeds to block 84 to search for the next discontinuity in the current cycle, thence to loop back to decision diamond 76. Also, if the test at decision diamond 76 is negative, the process skips to decision diamond 80.

It is to be understood that the waveform reconstruction paradigm of the present invention may use analysis methods other than the one shown in FIG. 3. For example, a fast Fourier transform (FFT) may be used to reconstruct a smooth waveform from a distorted waveform by replacing the distorted input waveform with a series of smooth regular waveforms from a waveform library, with each replacement waveform having a unique frequency and an amplitude based upon its relative contribution to the reconstructed waveform.

Accordingly, using FFT analysis, distorted portions of waveforms are replaced by smooth portions, with the smooth portions being based in accordance with FFT principles on the undistorted portions of the input waveform.

As yet another alternative, distorted portions of the input waveform can be replaced by smooth portions that are based on the undistorted portions of the input waveform using so-called "wavelet analysis". In wavelet analysis, small undistorted waveform segments are stored in a library and are fitted to the undistorted portions of the input waveform as needed to replace distorted waveform portions. Examples of such analysis are disclosed by, e.g., Donoho in "Nonlinear Wavelet Methods for Recovery of Signals, Densities, and Spectra from Indirect and Noisy Data", *Proceedings of Symposia in Applied Mathematics*, Vol. 00. 1993 (American Mathematical Society); Basseville et al., "Modeling and Estimation of Multiresolution Stochastic Processes", *IEEE Transactions on Information Theory*, vol. 38. no. 2, 1992 (IEEE); and Coffman et al., "Wavelet Analysis and Signal Processing", pps. 153-178, Jones and Barlett, Boston, Mass. 1992 all of which publications are incorporated herein by reference.

While the particular SYSTEM AND METHOD FOR RADIO SIGNAL RECONSTRUCTION USING SIGNAL PROCESSOR as herein shown and described in detail is fully capable of attaining the above-described objects of the invention, it is to be understood that it is the presently preferred embodiment of the present invention and is thus representative of the subject matter which is broadly contemplated by the present invention, that the scope of the present invention fully encompasses other embodiments which may become obvious to those skilled in the art, and that the scope of the present invention is accordingly to be limited by nothing other than the appended claims.

What is claimed is:

1. A receiver, comprising:

an analog to digital converter (ADC) receiving as input an rf signal that has not been downconverted in the analog domain to IF by the receiver, the ADC outputting a digitized signal representing the rf signal; and

a digital processor electrically connected to the ADC, the digital processor being programmed with software to decode and extract baseband information from the digitized signal.

2. The receiver of claim 1, wherein the module replaces at least one distorted portion of the signal with a replacement portion that is based on at least some undistorted portions of the signal.

3. A receiver, comprising:

a reconstruction circuit receiving an analog rf signal and generating a reconstructed waveform having substantially no distortions therein, wherein the reconstruction circuit includes:

an analog to digital converter (ADC) for receiving the analog rf signal that has not been downconverted in the analog domain and outputting a digitized rf signal in response; and

a module electrically connected to the ADC for receiving the digitized if signal and in response outputting the reconstructed waveform in accordance with a predetermined reconstruction paradigm.

4. The receiver of claim 3, wherein the paradigm includes replacing at least one distorted portion of the signal with a replacement portion that is based on at least some undistorted portions of the signal.

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5. A receiver, comprising:
a signal repair circuit receiving an analog waveform carried in an optical transmission line and generating a repaired waveform, wherein the signal repair circuit includes:
an analog to digital converter (ADC) for receiving the signal prior to any extraction of basedband information therefrom and outputting a digitized signal in response;
and

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a module electrically connected to the ADC for receiving the digitized signal and in response outputting the repaired waveform in accordance with a predetermined repair paradigm.

5 6. The receiver of claim 5, wherein the paradigm includes replacing at least one distorted portion of the signal with a replacement portion that is based on at least some undistorted portions of the signal.

* * * * *

EXHIBIT B



US007831233B2

(12) **United States Patent**
Hotto

(10) **Patent No.:** **US 7,831,233 B2**
(45) **Date of Patent:** ***Nov. 9, 2010**

(54) **SYSTEM AND METHOD FOR RADIO SIGNAL RECONSTRUCTION USING SIGNAL PROCESSOR**

(75) Inventor: **Robert Hotto**, Carlsbad, CA (US)

(73) Assignee: **American Radio LLC**, Carlsbad, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 328 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **11/928,585**

(22) Filed: **Dec. 10, 2007**

(65) **Prior Publication Data**

US 2008/0119156 A1 May 22, 2008

Related U.S. Application Data

(63) Continuation of application No. 11/068,585, filed on Apr. 13, 2005, now Pat. No. 7,433,664, which is a continuation of application No. 10/255,438, filed on Sep. 26, 2002, now Pat. No. 7,043,219, which is a continuation of application No. 09/771,821, filed on Jan. 29, 2001, now Pat. No. 6,577,854, which is a continuation of application No. 09/178,229, filed on Oct. 23, 1998, now Pat. No. 6,236,845, which is a continuation of application No. 08/596,551, filed on Feb. 5, 1996, now Pat. No. 5,864,754.

(51) **Int. Cl.**
H04B 1/18 (2006.01)

(52) **U.S. Cl.** **455/280**; 455/295; 455/296; 455/303; 455/307

(58) **Field of Classification Search** None
 See application file for complete search history.

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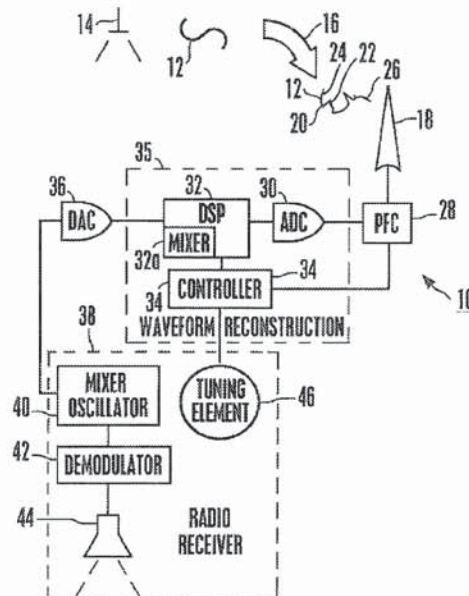
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(57) **ABSTRACT**

A waveform reconstruction circuit receives an rf signal from an antenna, digitizes it, and then generates an undistorted reconstructed waveform. The reconstructed waveform can then be conventionally mixed and demodulated to extract useful signal information with enhanced receiver fidelity and sensitivity.

11 Claims, 3 Drawing Sheets



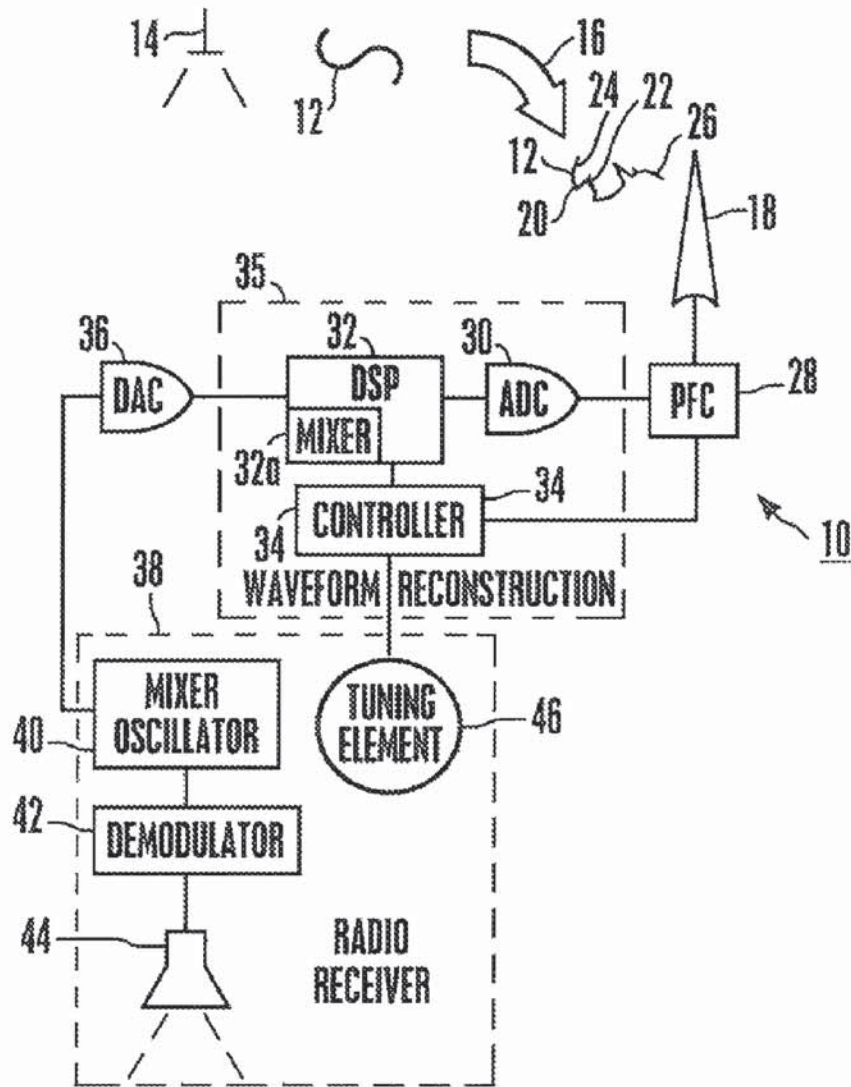


Figure 1

Figure 2

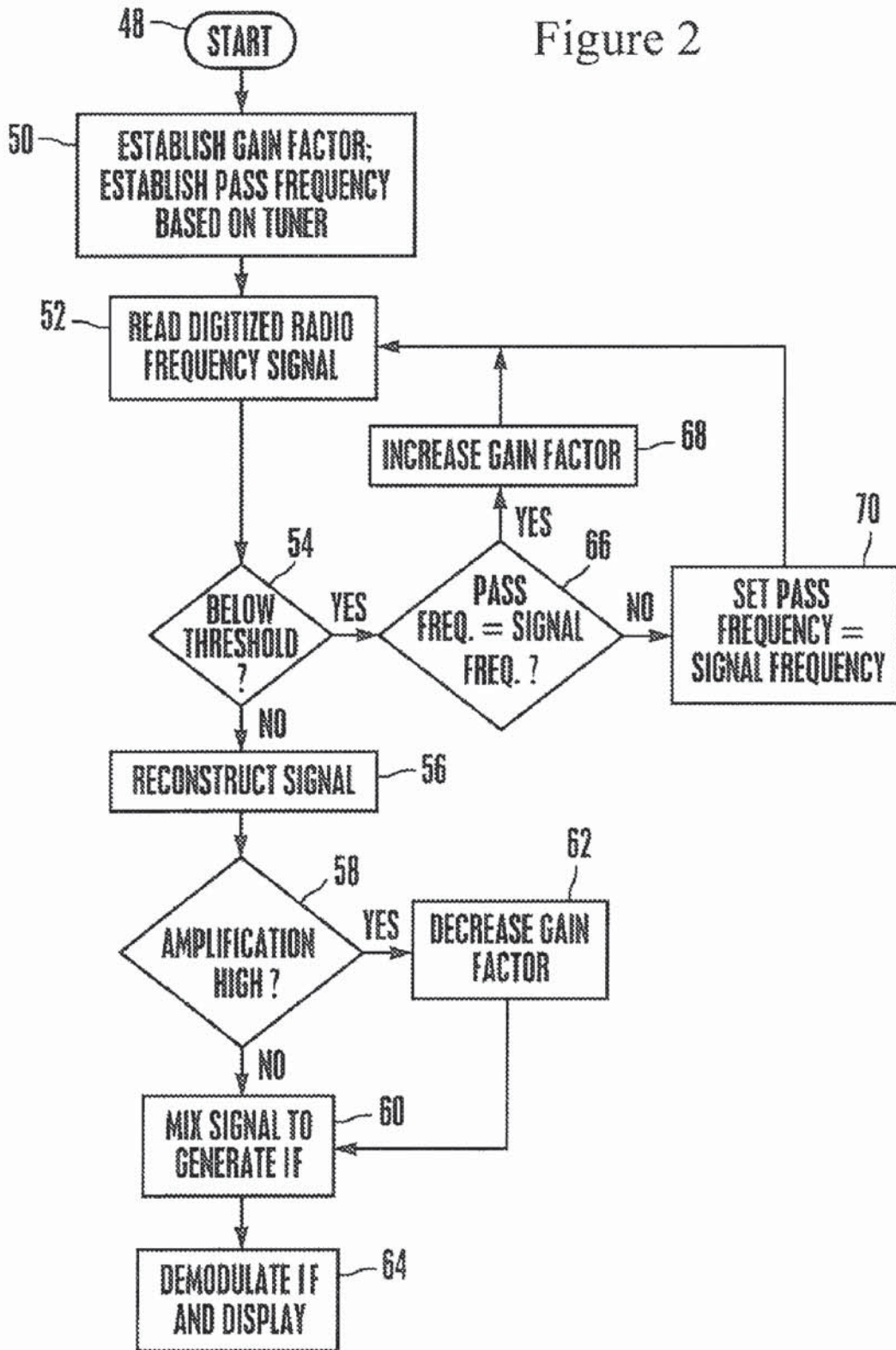
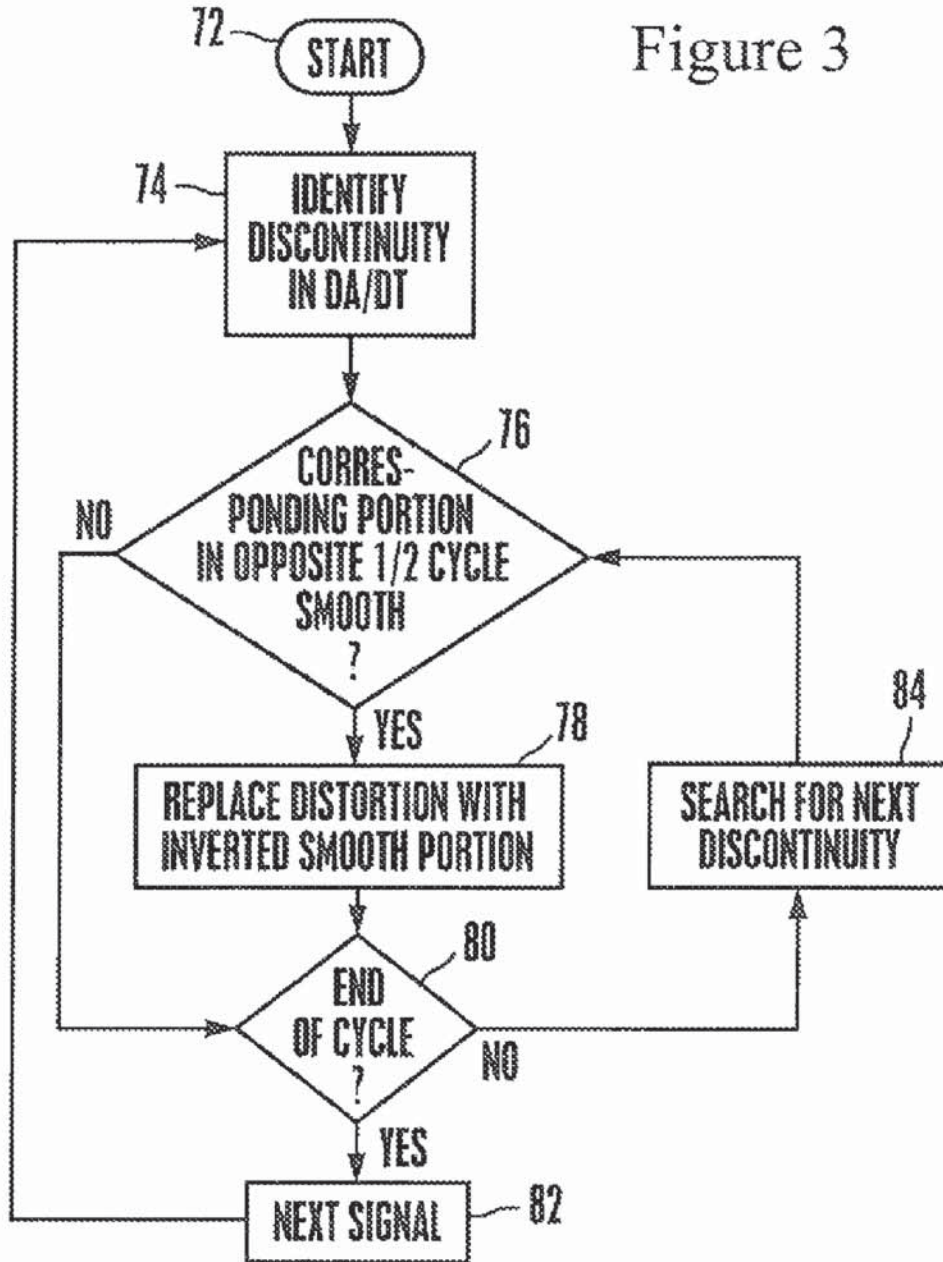


Figure 3



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SYSTEM AND METHOD FOR RADIO SIGNAL RECONSTRUCTION USING SIGNAL PROCESSOR

This application is a continuation of U.S. patent applica- 5
tion Ser. No. 11/068,585, filed Apr. 13, 2005, now U.S. Pat.
No. 7,433,664 which is a continuation of U.S. patent appli-
cation Ser. No. 10/255,438 filed Sep. 26, 2002, now U.S. Pat.
No. 7,043,219, which is a continuation of U.S. patent appli-
cation Ser. No. 09/771,821 now U.S. Pat. No. 6,577,854, filed 10
Jan 29, 2001, which in turn is a continuation of U.S. patent
application Ser. No. 09/178,229 now U.S. Pat. No. 6,236,845,
filed Oct. 23, 1998, which in turn is a continuation of U.S.
patent application Ser. No. 08/596,551 U.S. Pat. No. 5,864,
354, filed Feb. 5, 1996 all of which are incorporated herein by 15
reference and priority from all of which is hereby claimed.

FIELD OF THE INVENTION

The present invention relates generally to radio signal pro- 20
cessing, and more particularly to systems and methods for
reducing distortion in rf signals and thus enhancing the fidel-
ity and sensitivity of radio receivers.

BACKGROUND

Conventional radio receivers function by receiving an rf 25
signal and preamplifying it, and then processing the signal
using a superheterodyne structure. The superheterodyne
structure, in its simplest configuration, includes a mixer oscil-
lator which mixes the received signal down to an intermediate
frequency (IF) signal. The IF signal is then sent through a
bandpass filter and demodulated by an envelope detector to
recover the information (colloquially referred to as "base-
band") that is carried by the received rf signal.

Of importance to the present invention is the fact that rf 30
signals are corrupted by environmental factors during trans-
mission. Conventional superheterodyne structures attempt to
correct for signal corruption by suppressing corruption-in-
duced noise using filtering techniques. Unfortunately, such
conventional filtering, whether using analog or digital tech-
niques, suppresses both noise and useful signal, thereby
reducing the fidelity of the receiver. In other words, although
filtering improves the ratio between useful signal and noise
(referred to as the signal-to-noise ratio, SNR), it typically 35
reduces system fidelity and signal strength.

Further, during demodulations the envelope detector of a 40
conventional superheterodyne structure effectively demodu-
lates only one-half cycle, for example, the positive half cycle,
of the IF signal. Only one half of the signal need be used, since
the information attached to the positive half cycle during
transmission is identical to the information attached to the
negative half cycle during transmission. Accordingly, the
negative half of each cycle of the received rf signal is dis-
carded by the envelope detector, and replaced with a mirror 45
image of the positive half.

It happens, however, that either one of the positive or 50
negative half of a cycle can be distorted asymmetrically from
the other half. Consequently, in instances wherein the nega-
tive half of a cycle is relatively uncorrupted, but the positive
half cycle is corrupted, the opportunity to use the "best" half
of a cycle is lost. Thus, the portion of a corrupted IF signal that
is ultimately demodulated and output by the envelope detec-
tor statistically can be expected to be the corrupt half 55
50% of the time.

In light of the above discussion as recognized by the
present invention, it would be advantageous to analyze both

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the positive and negative halves of an rf signal cycle and
determine which half is the "best" half, and then extract the
useful signal from this "best" half. As further recognized by
the present invention, it would be advantageous to accom-
plish such analysis prior to the non-linear transformation of
the rf signal to the IF signal during mixing by the oscillator.
Stated differently, it would be advantageous to accomplish
such analysis prior to mixing, since the mixing function
causes certain data in the signal to be irrecoverable and there-
fore precludes identification of some distortion and corrup-
tion in the "true" signal post-mixing. As still further recog-
nized by the present invention, it would be advantageous to
adjust signal gain and tuning "on the fly" to account for
transmitter frequency drift and for sometimes constantly
changing received signal strength at the antenna.

Accordingly, it is an object of the present invention to
provide a system and method for reconstructing a radio signal
prior to mixing and demodulating the signal. Another object
of the present invention is to provide a system and method for
reconstructing a radio signal to improve the extraction of
useful portions of the originally transmitted signal that had
been corrupted. Yet another object of the present invention is
to provide a system and method for reconstructing a radio
signal which adjusts signal gain and tuning from the antenna
on the fly. Still another object of the present invention is to
provide a system and method for reconstructing a radio signal
which is easy to use and cost-effective.

SUMMARY OF THE INVENTION

An electromagnetic waveform reconstruction device 30
includes an analog to digital converter (ADC) that is electri-
cally connectable to an antenna for receiving an analog elec-
tromagnetic signal therefrom and digitizing the signal. The
ADC outputs the digitized electromagnetic signal to a digital
signal processor (DSP), which in turn outputs a reconstructed
electromagnetic signal in accordance with a predetermined
reconstruction paradigm. As more fully discussed herein, the
DSP is electrically associable with a mixer circuit for sending
the reconstructed electromagnetic signal thereto for mixing
and demodulating the signal.

Preferably, the electromagnetic signal is an rf signal, and
the device further includes a digital to analog converter
(DAC) for converting the reconstructed rf signal to an analog
reconstructed rf signal, prior to sending the reconstructed rf
signal to the mixer circuit. Alternatively, the DSP digitally
mixes the reconstructed rf signal and outputs an intermediate
frequency (IF) signal to a demodulator.

As envisioned by the preferred embodiment, the DSP
includes reconstruction means for effecting method steps to
implement the predetermined reconstruction paradigm. In
accordance with the present invention, the method steps
include receiving both a positive half and a negative half of
the digitized rf signal, and then analyzing the positive and
negative halves to identify distorted portions and undistorted
portions thereof. At least some of the distorted portions are
removed and replaced with respective replacement portions.
Thereby, the reconstructed rf signal is produced, with each
replacement portion being based on at least some of the
undistorted portions.

In one presently preferred embodiment, a controller is elec-
trically connected to the DSP. Also, a preamplifier filter cir-
cuit (PFC) is electrically connectable to the antenna and to the
ADC for amplifying and filtering the analog rf signal from the
antenna prior to sending the analog rf signal to the ADC.
Moreover, the PFC is also electrically connected to the con-
troller. Advantageously, the PFC includes a frequency band- 65

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pass filter for attenuating signals having a frequency not equal to a pass frequency, and the controller dynamically establishes the pass frequency.

Furthermore, in the presently preferred embodiments the PFC includes an amplifier for increasing, by a gain factor, the amplitude of signals having the pass frequency. As intended by the preferred embodiments the controller establishes the gain factor. To this end, the DSP outputs a gain adjust signal to the controller when the rf signal input to the DSP is characterized by an amplitude outside of a predetermined amplitude range. Stated somewhat differently, the DSP generates the gain adjust signal when its input signal is characterized by distortions due to a weak or clipped signal, and the DSP generates the gain adjust signal by determining information content of the signal. In response to the gain adjust signal, and the controller dynamically establishes the gain factor based on the gain adjust signal. If desired, the device of the present invention can be combined with an electromagnetic signal transmitter.

In another aspect of the present invention, an rf receiver includes an antenna and a signal reconstruction circuit electrically connected to the antenna. Accordingly, the signal reconstruction circuit receives an analog rf signal from the antenna. Per the principles of the present invention, the signal reconstruction circuit generates a substantially undistorted reconstructed waveform. A mixer circuit is electrically associated with the signal reconstruction circuit for generating an intermediate frequency (IF) signal based on the reconstructed waveform, and a demodulator decodes useful information from the IF signal.

In yet another aspect, a computer-implemented method is disclosed for processing a transmitted electromagnetic signal to extract useful information from the signal. The present method includes receiving the electromagnetic signal and reconstructing it in accordance with a predetermined reconstruction paradigm, and then, after reconstruction, mixing and demodulating the electromagnetic signal to extract useful information therefrom.

In still another aspect, a computer program device includes a computer program storage device which is readable by a digital processing system. A program means is provided on the program storage device, and the program means includes instructions that are executable by the digital processing system for performing method steps for reconstructing an rf signal prior to mixing and demodulating the rf signal. The method steps advantageously include receiving both a positive half and a negative half of the rf signal, and analyzing the positive and negative halves to identify distorted portions and undistorted portions thereof. The method steps further include removing at least some of the distorted portions and replacing each with a respective replacement portion to thereby produce a reconstructed rf signal, with each replacement portion being based on at least some of the undistorted portions.

In another aspect of the present invention, a device is disclosed for dynamically preamplifying and filtering an rf signal from an antenna, prior to mixing and demodulating the signal to extract useful information from it. The device includes a controller and a preamplifier filter circuit (PFC) electrically connectable to the antenna and in electrical communication with the controller for amplifying and filtering the rf signal. Per the present invention, the PFC includes a frequency bandpass filter for attenuating signals having a frequency not equal to a pass frequency. Additionally, the PFC includes an amplifier for increasing, by a gain factor, the amplitude of signals having the pass frequency. The control-

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ler dynamically establishes/adjusts the pass frequency and gain factor, based on the signal amplitude and distortion.

The details of the present invention, both as to its structure and operation, can best be understood in reference to the accompanying drawings, in which like reference numerals refer to like parts, and in which:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic block diagram of the system of the present invention;

FIG. 2 is a flow chart showing the overall method steps of the present invention; and

FIG. 3 is a flow chart showing the steps of a waveform reconstruction method in accordance with the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring initially to FIG. 1, a system, generally designated 10, is shown for reconstructing an rf waveform signal 12 that has been transmitted by an rf transmitter 14, before the signal 12 is mixed and demodulated. As schematically shown in FIG. 1, the rf signal 12 is an analog, sinusoidally-shaped signal that is relatively smooth and undistorted when transmitted, but which can become degraded and distorted as it propagates in the direction of the arrow 16 toward an rf antenna 18. Consequently, upon reaching the antenna 18, a negative half 20 of the rf signal 12 can have distorted portions 22 and undistorted portions 24. Likewise, a positive half 26 of the rf signal 12 can have distorted portions and undistorted portions as shown. The present invention is directed to removing distortions from rf signals, prior to mixing and demodulating the signals incident to the decoding of useful information therefrom, thereby improving the fidelity and sensitivity of radio receivers.

While the disclosure herein focuses on rf waveform reconstruction, it is to be understood that the principles of the present invention apply equally to other forms of modulated electromagnetic waves that are modulated as appropriate for the data the waves represent. For example, the principles of the present invention can be applied to processing modulated light waves that are transmitted through fiber optic bundles incident to the transfer of computer, video, or voice data.

FIG. 1 shows that the rf signal detected by the antenna 18 is sent to a preamplifying and filtering circuit 28. In accordance with the present invention, the preamplifying and filtering circuit 28 includes an amplifying circuit which preamplifies, by a gain factor, the signal from the antenna 18. Furthermore, the preamplifying and filtering circuit 28 includes a frequency bandpass filter for attenuating signals having a frequency not equal to a pass frequency. As described in greater detail below, the pass frequency and gain factor are dynamically established under the principles of the present invention.

Continuing with the description of FIG. 1, an analog to digital converter (ADC) 30 is electrically connected to the antenna 18 for receiving the analog rf signal therefrom. The ADC 30 is structure well-known in the art that outputs a digitized rf signal in response to the analog rf input from the antenna 18.

Additionally, a digital signal processor (DSP) 32 is electrically connected to the ADC 30. Accordingly, the DSP 32 receives the digitized signal from the ADC 30. Per the present invention, the DSP 32 outputs a reconstructed rf signal in accordance with a predetermined waveform reconstruction