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LOS ANGELES

BY ________________

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UNITED STATES DISTRICT COURT
CENTRAL DISTRICT OF CALIFORNIA

AMERICAN RADIO LLC, Plaintiff, vs. QUALCOMM INCORPORATED, Defendant.	Case No. CV 12-8507 -ODW (JEMx) **COMPLAINT FOR PATENT INFRINGEMENT** **JURY TRIAL DEMANDED**

Plaintiff American Radio LLC ("American Radio"), by its attorneys, files this Complaint against defendant Qualcomm Incorporated ("Qualcomm") as follows:

PARTIES

1. Plaintiff American Radio is a limited liability corporation organized under the laws of California with its principal place of business at 1007 Goldeneye View, Carlsbad, CA 92011. American Radio is the assignee of all right, title, and interest in and to the '334 Patent, U.S. Patent No. 8,280,334 and the '754 Patent, U.S. Patent No. 5,864,754.

2. On information and belief, defendant Qualcomm is a Delaware corporation with its principal place of business at 5580 Morehouse Drive, San Diego, California.

JURISDICTION

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

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

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

6. In addition, Qualcomm actively induces infringement and contributes to infringement within this District by selling products with the knowledge and intention of facilitating infringement by others within this District.

7. For these reasons this Court has personal jurisdiction over Qualcomm.

VENUE

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

'334 PATENT

9. United States Patent No. 8,280,334 ("the '334 Patent"), entitled "System And Method For Radio Signal Reconstruction Using Signal Processor," was duly and legally issued by the United States Patent and Trademark Office on October 2, 2012. A true and correct copy of the '334 Patent is attached hereto as Exhibit A and is incorporated herein by reference.

10. American Radio is the owner of all right, title and interest in and to the '334 Patent and is entitled to sue for past and future infringement and recover damages.

'754 PATENT

11. United States Patent No. 5,864,754 ("the '754 Patent"), entitled "System And Method For Radio Signal Reconstruction Using Signal Processor," was duly and legally issued by the United States Patent and Trademark Office on January 26, 1999. A true and correct copy of the '754 Patent is attached hereto as Exhibit B and is incorporated herein by reference.

12. American Radio is the owner of all right, title and interest in and to the '754 Patent and is entitled to sue for past and future infringement and recover damages.

QUALCOMM'S KNOWLEDGE OF THE '754 PATENT

13. Qualcomm has actual notice of the '754 Patent since at least May, 2012. Qualcomm's Chief Strategist Roger Martin, at the behest of Qualcomm's CEO Paul Jacobs, reviewed the American Radio patents and admitted then that "Mr. Hotto has attempted to generate acquisition interest by Qualcomm in his patents four times over the last five years…"

COUNT 1 – DIRECT INFRINGEMENT OF U.S. PATENT NO. 8,280,334

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

15. Qualcomm has directly infringed, and is continuing to directly infringe, one or more claims of the '334 Patent, including but not limited to claim 1, by making, using, selling, offering for sale, and/or importing at least the following products: WiFi receivers; WiFi transceivers; Bluetooth receivers; Bluetooth transceivers; products described or marketed by Qualcomm under the name "Atheros;" and any products incorporating, supporting, or similar to any of these products.

16. Qualcomm is liable for its infringement of the '334 Patent pursuant to 35 U.S.C. § 271.

17. Qualcomm's direct infringement of the '334 Patent is damaging American Radio.

18. Qualcomm's direct infringement of the '334 Patent 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 Qualcomm are not yet determined.

COUNT 2 – WILLFUL INDUCED INFRINGEMENT OF U.S. PATENT NO. 5,864,754

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

20. Qualcomm has induced infringed infringement of, and is continuing to induce infringement of, one or more of claims of the '754 Patent claims, including but not limited to claim 10, by making, using, selling, offering for sale, and/or importing at least the following Qualcomm Products and providing directions for their use, as well as any similar products and related technology: Qualcomm part no. RTR8600, QRT8600L, QRT8600, QTR8200, WTR1605, WTR1605L, RTR6280, RTR6295; products described or marketed by Qualcomm as using the "Zero Intermediate-Frequency" (ZIF) technology; and any products incorporating or supporting any of the aforementioned devices.

21. When one or more of these products are purchased and used by customers of Qualcomm, they are used in electrical connection with an antenna in those customers' products.

22. Qualcomm specifically intends that these products be used by its customers in combination with antennas.

23. Customers of Qualcomm who use Qualcomm's products in that fashion directly infringe at least claim 10 of the '754 Patent.

24. Thus, Qualcomm has induced infringement and is continuing to induce infringement of the '754 Patent.

25. Qualcomm is liable for its induced infringement of the '754 Patent pursuant to 35 U.S.C. § 271.

26. Qualcomm's induced infringement of the '754 Patent was and is being done and has been done with knowledge of the '754 Patent or with willful blindness to the existence of the '754 Patent.

27. Qualcomm's induced infringement of the '754 Patent was and is willful.

28. Qualcomm's willful induced infringement of the '754 Patent has damaged and will continue to damage American Radio.

29. Qualcomm's willful induced infringement of the '754 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 Qualcomm are not yet determined.

COUNT 3 – WILLFUL CONTRIBUTORY INFRINGEMENT OF U.S. PATENT NO. 5,864,754

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

31. At least the following products and similar products and related technology are used in practicing the '754 Patent and constitute a material part of the invention: Qualcomm part no. RTR8600, QRT8600L, QRT8600, QTR8200, WTR1605, WTR1605L, RTR6280, RTR6295; products described or marketed by Qualcomm as using the "Zero Intermediate-Frequency" (ZIF) technology; and any products similar to, incorporating, or supporting any of the aforementioned devices.

32. The Qualcomm products listed in Paragraph 25 are not staple articles of commerce and are not suitable for substantial non-infringing uses.

33. Qualcomm knows these products to be especially made or especially adapted for use in infringing the '754 Patent.

34. When one or more of these products are purchased and used by customers of Qualcomm, they are used in electrical connection with an antenna in those customers' products.

35. Qualcomm specifically intends that these products be used by its customers in combination with antennas.

36. Thus, Qualcomm has contributed to the infringement of, and is continuing to contribute to the infringement of, one or more of the '754 Patent claims, including but not limited to claim 10.

37. Qualcomm is liable for its contributory infringement of the '754 Patent pursuant to 35 U.S.C. § 271.

38. Qualcomm's induced infringement of the '754 Patent was and is being done and has been done with knowledge of the '754 Patent or with willful blindness to the existence of the '754 Patent.

39. Qualcomm's contributory infringement of the '754 Patent was and is willful.

40. Qualcomm's willful contributory infringement of the '754 Patent has damaged and will continue to damage American Radio.

41. Qualcomm's willful contributory infringement of the '754 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 Qualcomm are not yet determined.

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

A. Enter a judgment that Qualcomm is directly infringing the '334 Patent;

B. Enter an order preliminarily and permanently enjoining Qualcomm, 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 the '334 Patent;

C. Award American Radio damages in the amount adequate to compensate American Radio for Qualcomm's infringement of the '334 Patent;

D. Enter an order trebling any and all damages awarded to American Radio by reason of Qualcomm's infringement of the '334 Patent, pursuant to 35 U.S.C. § 284;

E. Enter an order awarding American Radio interest on damages awarded and its costs pursuant to 35 U.S.C. § 284;

F. Enter a judgment that Qualcomm is willfuly actively inducing infringement of the '754 Patent;

G. Enter a judgment that Qualcomm is willfully contributing to the infringement of the '754 Patent;

H. Enter an order preliminarily and permanently enjoining Qualcomm, 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 the '754 Patent;

I. Award American Radio damages in the amount adequate to compensate American Radio for Qualcomm's infringement of the '754 Patent;

J. Enter an order trebling any and all damages awarded to American Radio by reason of Qualcomm's infringement of the '754 Patent, pursuant to 35 U.S.C. § 284;

K. Enter an order awarding American Radio interest on damages awarded and its costs pursuant to 35 U.S.C. § 284;

L. 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

M. 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.

Dated: October 3, 2012

STEPTOE & JOHNSON LLP

By: [signature]

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Attorneys American Radio LLC

EXHIBIT A

US008280334B2

(12) **United States Patent**
Hotto

(10) **Patent No.: US 8,280,334 B2**
(45) **Date of Patent: *Oct. 2, 2012**

(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 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **13/420,783**

(22) Filed: **Mar. 15, 2012**

(65) **Prior Publication Data**

US 2012/0178396 A1 Jul. 12, 2012

Related U.S. Application Data

(63) Continuation of application No. 12/964,215, filed on Dec. 9, 2010, now Pat. No. 8,170,519, which is a continuation of application No. 12/702,498, filed on Feb. 9, 2010, now Pat. No. 8,045,942, which is a 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.

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

(52) **U.S. Cl.** **455/289**; 455/295; 455/296; 455/303; 455/307

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

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,230,011 A * 7/1993 Gielis et al. .... 455/324 X
5,375,146 A * 12/1994 Chalmers 375/350

OTHER PUBLICATIONS

American Radio LLC vs. *Qualcomm Incorporated*, Compliant for Patent Infringement filed Jul. 6, 2012.
American Radio LLC vs. *Intel Corporation*, Complaint for Patent Infringement filed Jul. 6, 2012.
American Radio LLC vs. *Cisco Systems Incorporated*, Complaint for Patent Infringement filed Jul. 6, 2012.
American Radio LLC vs. *Broadcom Corporation*, Complaint for Patent Infringement filed Jul. 6, 2012.

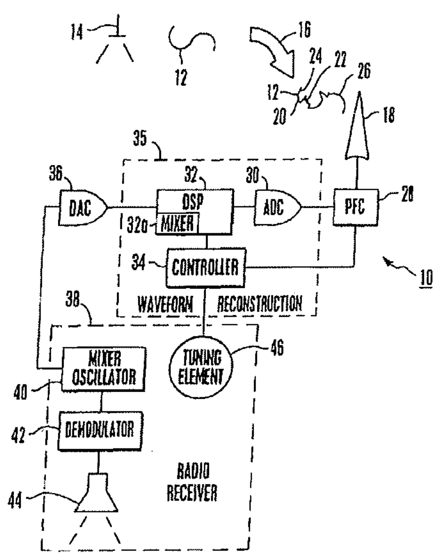
* cited by examiner

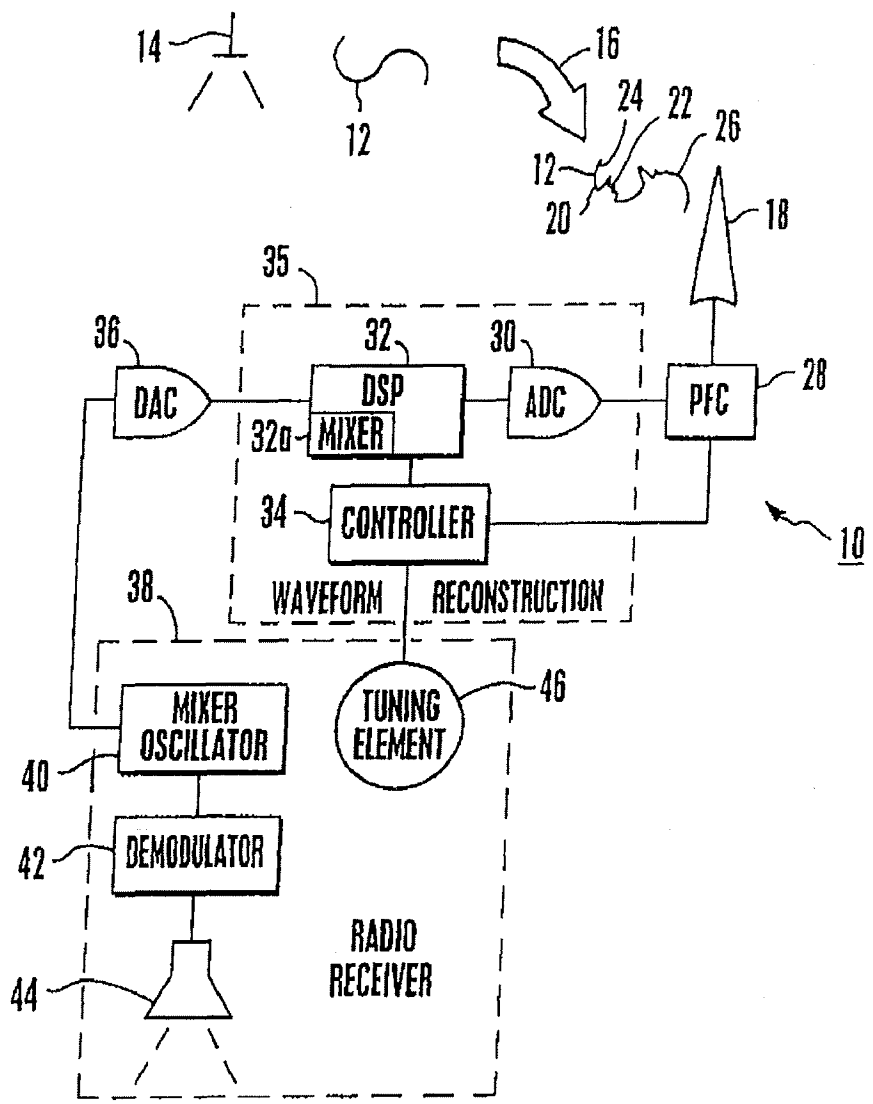
Primary Examiner — Philip Sobutka
(74) *Attorney, Agent, or Firm* — John L. Rogitz

(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.

35 Claims, 3 Drawing Sheets

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16
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18
35
36
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DAC
DSP
ADC
PFC
28
32a
MIXER
34
CONTROLLER
10
WAVEFORM RECONSTRUCTION
38
MIXER OSCILLATOR
TUNING ELEMENT
46
40
42
DEMODULATOR
RADIO RECEIVER
44

Fig. 1

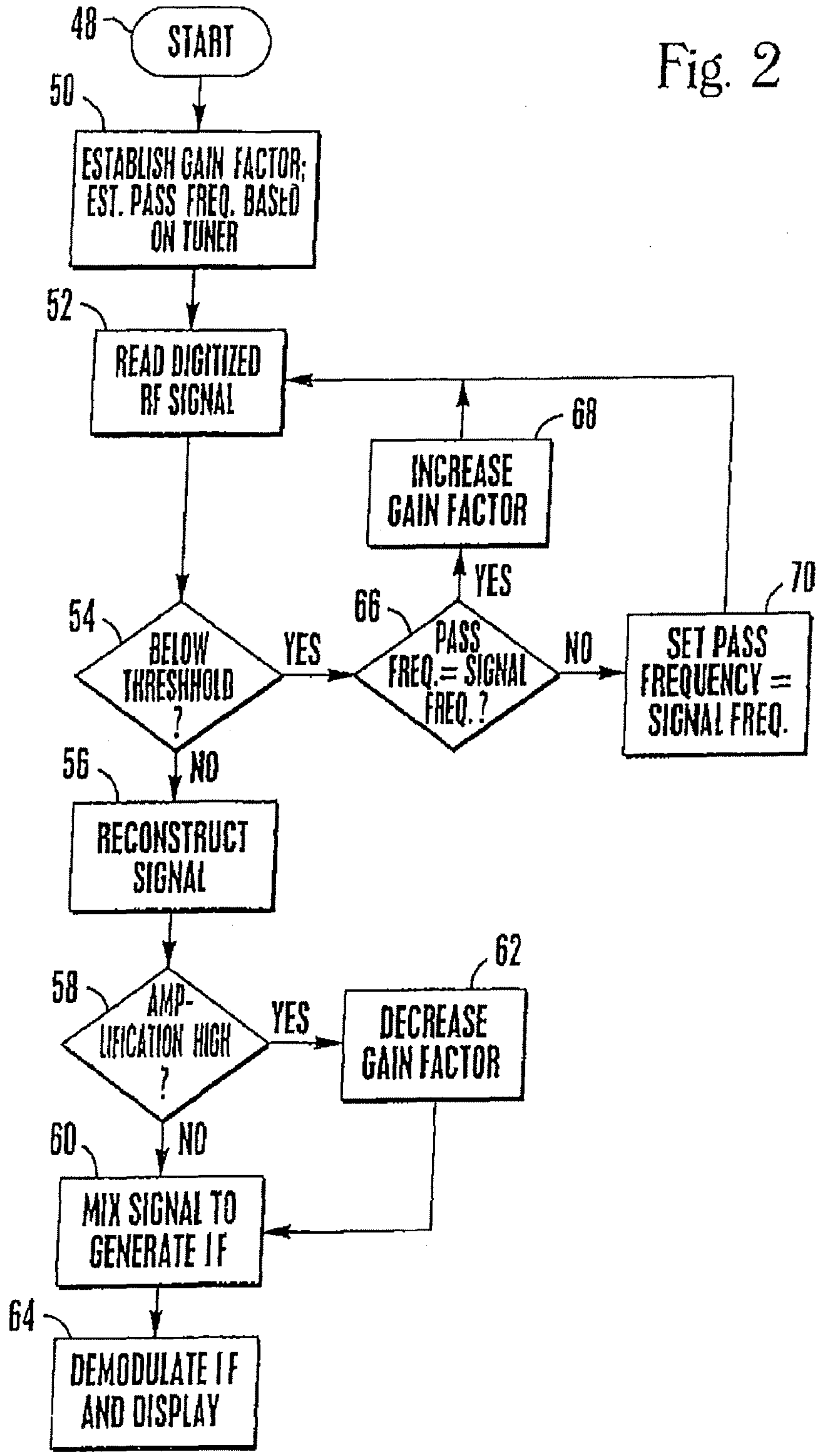
48
START
50
ESTABLISH GAIN FACTOR; EST. PASS FREQ. BASED ON TUNER
52
READ DIGITIZED RF SIGNAL
68
INCREASE GAIN FACTOR
YES
70
54
BELOW THRESHHOLD ?
YES
66
PASS FREQ. = SIGNAL FREQ. ?
NO
SET PASS FREQUENCY = SIGNAL FREQ.
56
NO
RECONSTRUCT SIGNAL
62
58
AMP-LIFICATION HIGH ?
YES
DECREASE GAIN FACTOR
60
NO
MIX SIGNAL TO GENERATE IF
64
DEMODULATE IF AND DISPLAY

Fig. 2

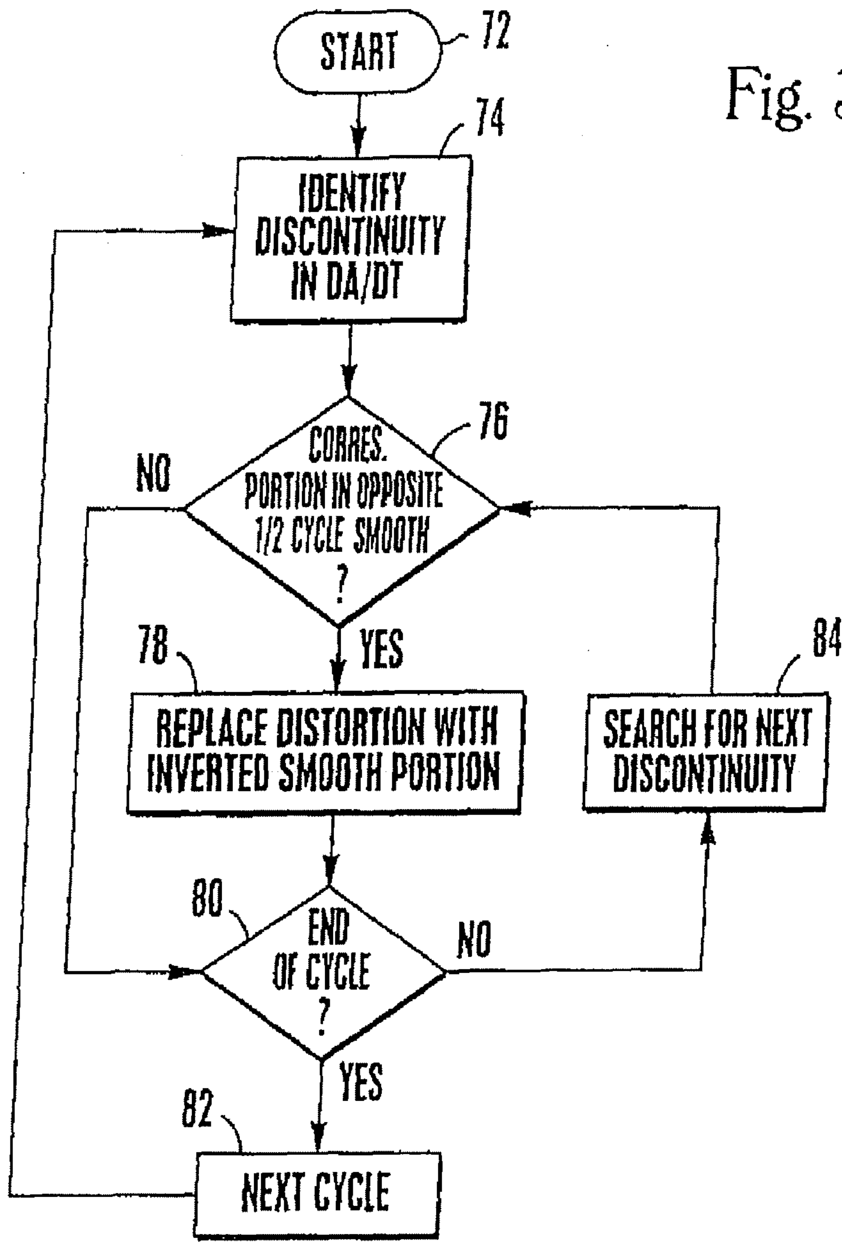
START
72
74
IDENTIFY DISCONTINUITY IN DA/DT
76
CORRES. PORTION IN OPPOSITE 1/2 CYCLE SMOOTH ?
NO
YES
78
REPLACE DISTORTION WITH INVERTED SMOOTH PORTION
84
SEARCH FOR NEXT DISCONTINUITY
80
END OF CYCLE ?
NO
YES
82
NEXT CYCLE

Fig. 3

SYSTEM AND METHOD FOR RADIO SIGNAL RECONSTRUCTION USING SIGNAL PROCESSOR

This application is a continuation of U.S. patent application Ser. No. 12/964,215, filed Dec. 9, 2010 now U.S. Pat. No. 8,170,519, which is a continuation of Ser. No. 12/702,498, filed Feb. 9, 2010 now U.S. Pat. No. 8,045,942, which is a continuation of U.S. patent application 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 application 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 application Ser. No. 10/255,438 filed Sep. 26, 2002, now U.S. Pat. No. 7,043,219, which is a continuation of Ser. No. 09/771,821, now U.S. Pat. No. 6,577,854, filed Jan. 29, 2001, which in turn is a continuation of Ser. No. 09/178,229, now U.S. Pat. No. 6,236,845, filed Oct. 23, 1998, which in turn is a continuation of Ser. No. 08/596,551, now U.S. Pat. No. 5,864,754, filed Feb. 5, 1996 all of which are incorporated by reference and priority from all of which is hereby claimed.

FIELD OF THE INVENTION

The present invention relates generally to radio signal processing, and more particularly to systems and methods for reducing distortion in rf signals and thus enhancing the fidelity and sensitivity of radio receivers.

BACKGROUND

Conventional radio receivers function by receiving an rf signal and preamplifying it, and then processing the signal using a superheterodyne structure. The superheterodyne structure, in its simplest configuration, includes a mixer oscillator 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 "baseband") 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 transmission. Conventional superheterodyne structures attempt to correct for signal corruption by suppressing corruption-induced noise using filtering techniques. Unfortunately, such conventional filtering, whether using analog or digital techniques, 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 demodulates 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 discarded 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 the other half. Consequently, in instances wherein the negative 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 detector statistically can be expected to be the corrupt half 50% of the time.

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 accomplish 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 therefore precludes identification of some distortion and corruption in the "true" signal post-mixing. As still further recognized 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 electrically connectable to an antenna for receiving an analog electromagnetic 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 electrically 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 controller. Advantageously, the PFC includes a frequency bandpass 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 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** 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 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. 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-usable 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 ransom 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 tuning 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 Informational Theory*, vol. 38. no. 2, 1992 (IEEE); and Coffman et al., "Wavelet Analysis and Signal Processing", pps. 153-178, Jones and Bartlett, 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. An apparatus comprising:

an amplifier receiving as input an rf signal that has not been downconverted in the analog domain to IF, the amplifier generating an amplified signal;

a converter receiving as input the amplified signal which has not been downconverted after amplification, the converter outputting a digitized signal representing the amplified signal; and

at least one hardware module electrically connected to the converter, the module being configured with software to implement a mixer function, the at least one module being configured to decode and extract baseband information from the digitized signal, wherein the at least one module replaces at least one distorted portion of the signal with a replacement portion.

2. An apparatus, comprising:

a reconstruction circuit receiving an analog sinusoidal signal and generating a reconstructed waveform, wherein the reconstruction circuit includes:

an amplifier receiving the analog sinusoidal signal that has not been downconverted in the analog domain by the reconstruction circuit and outputting an amplified signal;

a converter receiving the amplified signal which has not been downconverted after amplification and outputting a digitized signal in response; and

at least one module electrically connected to the converter for outputting the reconstructed waveform in accordance with a predetermined reconstruction paradigm which includes generating the reconstructed waveform using at least portions of the digitized signal.

3. The apparatus of claim 2, wherein the module controls the amplifier.

4. The apparatus of claim 2, wherein the module implements a mixer function.

5. A device, comprising:

a circuit receiving an analog waveform carried in an optical transmission line, wherein the circuit includes:

an amplifier for receiving the signal prior to any extraction of baseband information therefrom and outputting an amplified signal;

a first circuit element receiving the amplified signal prior to any downconversion of the amplified signal and outputting a non-continuous signal in response;

a second circuit element receiving the non-continuous signal and repairing at least a portion of the non-continuous signal prior to the extraction of baseband information from the non-continuous signal; and

at least one module electrically connected to the second circuit element receiving the non-continuous signal, implementing a mixer function, and outputting a baseband waveform.

6. The receiver of claim 5, wherein the element receiving the non-continuous signal controls the amplifier.

7. A method, comprising:

amplifying a continuous signal that has not been downconverted in the analog domain to render an amplified signal;

converting the amplified signal which has not been downconverted in the analog domain into a non-continuous signal, the continuous signal being a carrier for baseband information;

repairing the non-continuous signal prior to completing a downconversion operation;

generating, subsequent to the repairing, a digitized signal from the non-continuous signal; and

at least in part executing a mixing operation, extracting the baseband information from the digitized signal without converting the digitized signal to the analog domain.

8. The method of claim 7, wherein the repairing is executed in the RF domain.

9. The method of claim 7, wherein the repairing includes signal reconstruction of distorted portions of the signal using the non-continuous signal.

10. A device, comprising:

a circuit configured to receive an analog waveform carried in an optical transmission line, wherein the circuit includes:

an amplifier configured to receive the signal prior to any extraction of baseband information therefrom and to amplify the signal;

a first subcircuit receiving the amplified signal prior to any downconversion of the amplified signal and outputting a non-continuous signal;

at least a second subcircuit receiving the non-continuous signal prior to any downconversion thereof, the second subcircuit repairing at least portions of the non-continuous signal; and

at least one processing assembly electrically connected to the second subcircuit to receive the non-continuous signal and in response to output a baseband waveform at least in part using a mixer function.

11. The receiver of claim 10, wherein the processing assembly controls the amplifier.

12. An article of manufacture, comprising:

a circuit receiving an analog waveform carried in an optical transmission line and conveying baseband information useful for display to a person, wherein the circuit includes:

an amplifier configured to receive the analog waveform prior to any extraction of baseband information therefrom and to amplify the signal, outputting an amplified signal;

at least a first subcircuit configured to receive the amplified signal prior to any downconversion thereof and to output a non-continuous signal;

at least a second subcircuit configured to receive the non-continuous signal prior to any extraction of baseband information therefrom and to output a non-continuous signal in response; and

at least one processing assembly electrically connected to the second subcircuit and configured for receiving the non-continuous signal prior to any downconversion of the non-continuous signal and for outputting a baseband waveform from which baseband information for display is obtained while still in the digital domain, the processing assembly configured to repair at least one portion of the non-continuous signal.

13. The article of manufacture of claim 12, wherein the reconstructing is effected on the non-continuous signal while still in the RF domain.

14. The article of manufacture of claim 12, wherein the processing assembly controls the amplifier.

15. The article of manufacture of claim 12, wherein the processing assembly implements a mixer function.

16. A receiver, comprising:

an incoming signal port at which an rf signal that has propagated through a transmission medium is received;

an amplifier downstream of the incoming signal port and receiving an analog signal from downstream of the incoming signal port, the amplifier outputting an amplified signal;

a converter receiving the amplified signal prior to any downconversion of the amplified signal and outputting a non-analog signal representative of the analog signal; and

a digital processor electrically connected to the converter, the digital processor being configured to extract base band information from the non-analog signal at least in part by emulating a mixer without converting the non-analog signal to the analog domain after first reducing distortion in the non-analog signal.

17. The receiver of claim 16, wherein the digital processor is configured to reconstruct at least some distorted portions of the signal being processed, wherein at least one distorted portion is reconstructed by replacing the distorted portion with an undistorted portion.

18. The receiver of claim 16, wherein the converter digitizes the analog signal prior to any demodulation thereof.

19. The receiver of claim 16, further comprising a mixer generating an intermediate frequency (IF) signal based on the non-analog signal, and a demodulator decoding useful information from the IF signal, wherein at least the mixer and demodulator are embodied in the digital processor.

20. The receiver of claim 16, wherein the incoming signal port is coupled to an antenna.

21. The receiver of claim 16, wherein the digital processor controls the amplifier.

22. An rf receiver, comprising:

a signal input configured to receive an rf signal;

an amplifying component configured for receiving the rf signal from the signal input and configured to output an amplified representation thereof;

a converting component configured to receive the amplified representation of the rf signal and configured to output a non-continuous representation thereof, the converting component configured to receive the amplified representation of the rf signal prior to downconversion of the amplified representation of the rf signal; and

a processing component configured for receiving the non-continuous representation from the converting component and at least in part configured for emulating a mixer to extract baseband information from the non-continuous representation prior to any conversion of the non-continuous representation to a continuous representation, the processing component being configured to reconstruct the signal in the non-continuous domain prior to extracting baseband information.

23. The receiver of claim 22, wherein the converting component is established by an analog-to-digital converter (ADC).

24. The receiver of claim 22, wherein the processing component is established by a digital signal processor (DSP).

25. The receiver of claim 22, wherein the signal input receives rf from an antenna connected thereto.

26. The receiver of claim 22, wherein the processing component uses a fast Fourier transform (FFT) to reconstruct a distorted portion of the rf.

27. The receiver of claim 22, wherein the processing component is configured to control the amplifying component.

28. The receiver of claim 22, wherein the processing component uses wavelet analysis to reconstruct a distorted portion of the rf.

29. A receiver, comprising:

a filtering circuit receiving and filtering an electromagnetic signal;

an amplifier associated with the filtering circuit and amplifying the electromagnetic signal to render an amplified signal;

an analog to digital converter (ADC) receiving the amplified signal which has not been downconverted after amplification and outputting a digitized signal representative of the amplified signal; and

a digital processor electrically connected to the ADC, the digital processor reconstructing at least one corrupted portion of the digitized signal prior to extracting, at least in part by implementing a mixing operation, useful information from the digitized signal while the digitized signal remains a digitized signal.

30. The receiver of claim 29, wherein the digital processor reconstructs the digitized signal.

31. The receiver of claim 29, wherein the ADC digitizes the signal prior to any analog demodulation thereof.

32. The receiver of claim 29, wherein the filtering circuit is controlled and tuned by the processor.

33. The receiver of claim 29, wherein the processor reconstructs the digitized signal such that spurious signal elements and noise are removed therefrom.

34. The receiver of claim 29, wherein the processor reconstructs the digitized signal such that a desired signal is enhanced and amplified.

35. The receiver of claim 29, wherein the processor controls the amplifier.

* * * * *

EXHIBIT B

US005864754A

United States Patent [19]

Hotto

[11] **Patent Number: 5,864,754**

[45] **Date of Patent: Jan. 26, 1999**

[54] **SYSTEM AND METHOD FOR RADIO SIGNAL RECONSTRUCTION USING SIGNAL PROCESSOR**

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[21] Appl. No.: **596,551**

[22] Filed: **Feb. 5, 1996**

[51] **Int. Cl.**[6] **H04B 1/18**

[52] **U.S. Cl.** **455/280**; 455/295; 455/296; 455/303; 455/307; 375/316; 375/346

[58] **Field of Search** 455/226.1, 232.1, 455/280, 281, 283, 296, 295, 307, 303–306, 338, 284, 285, 311; 375/340, 345, 346, 350, 206, 316

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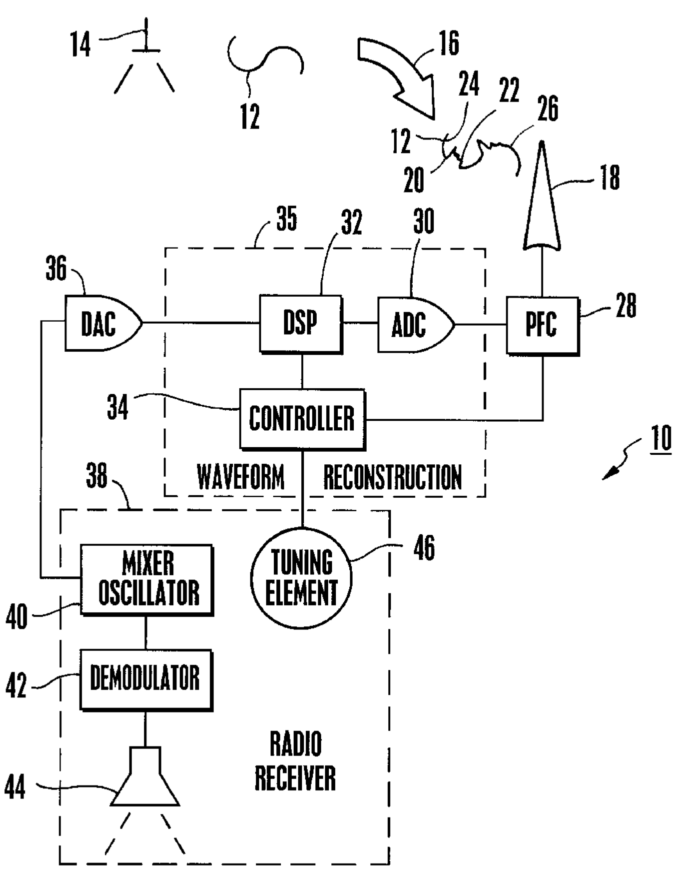
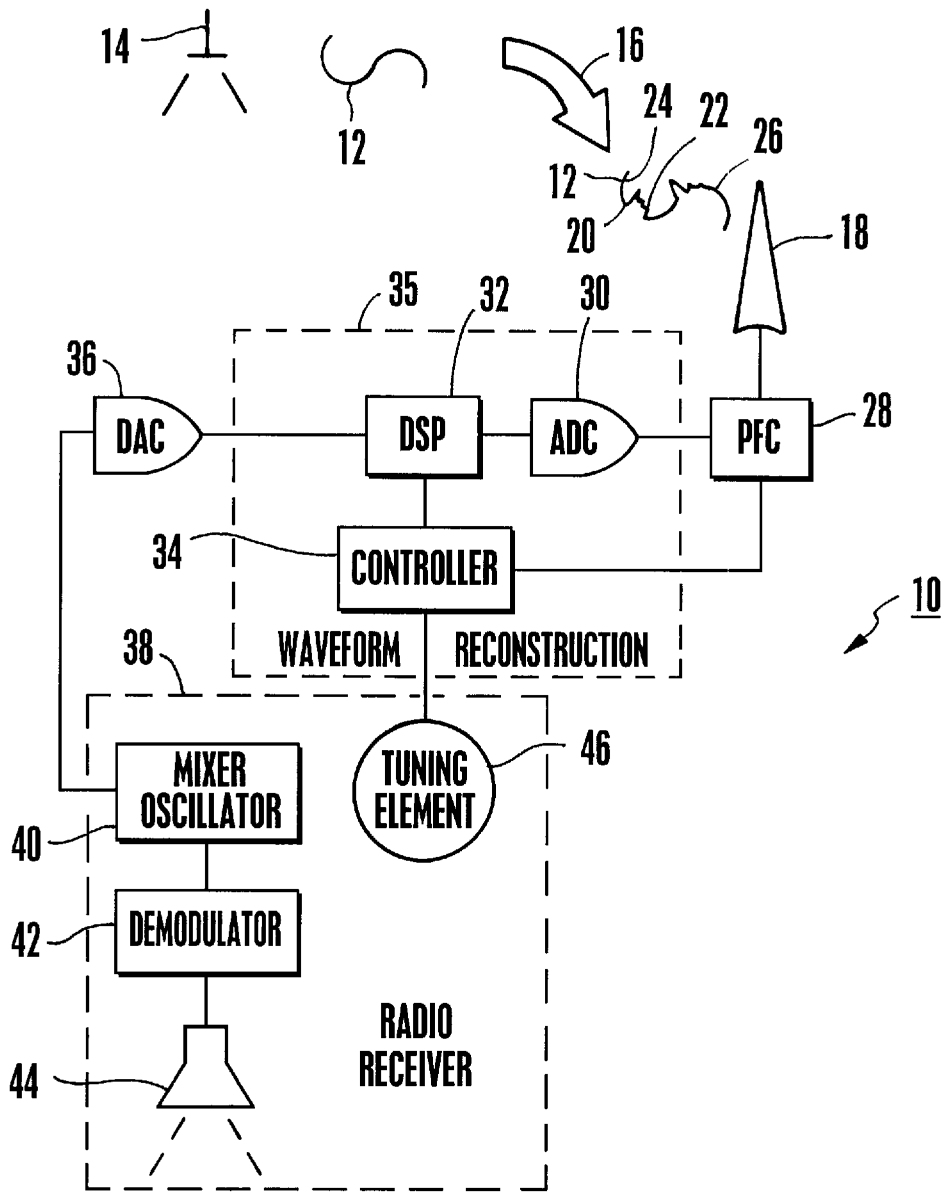
Primary Examiner—Wellington Chin
Assistant Examiner—Philip J. Sobutka
Attorney, Agent, or Firm—John L. Rogitz

[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.

22 Claims, 3 Drawing Sheets

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DAC
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ADC
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34
CONTROLLER
10
WAVEFORM RECONSTRUCTION
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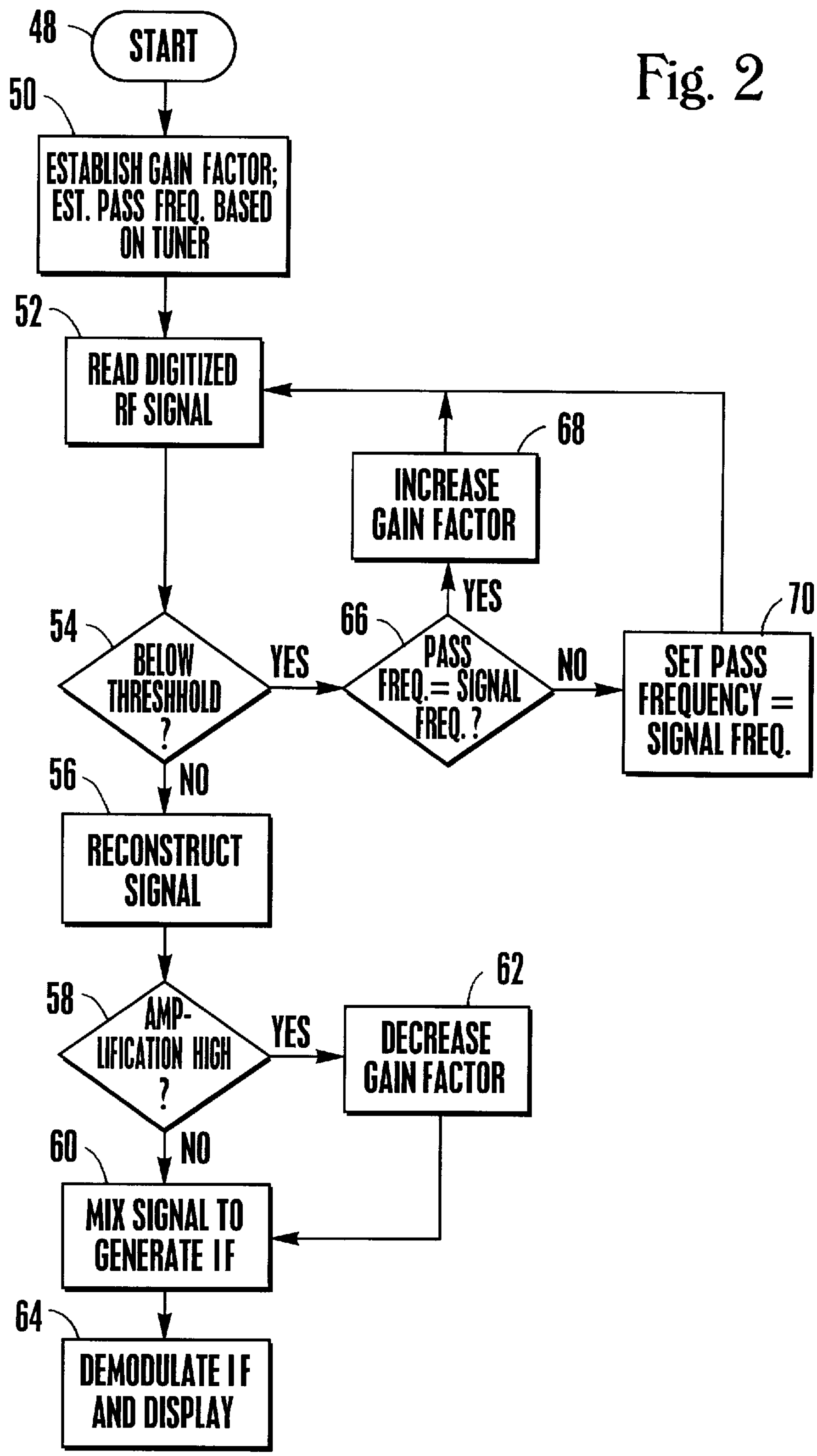
MIXER OSCILLATOR
TUNING ELEMENT
46
40
42
DEMODULATOR
RADIO RECEIVER
44

Fig. 1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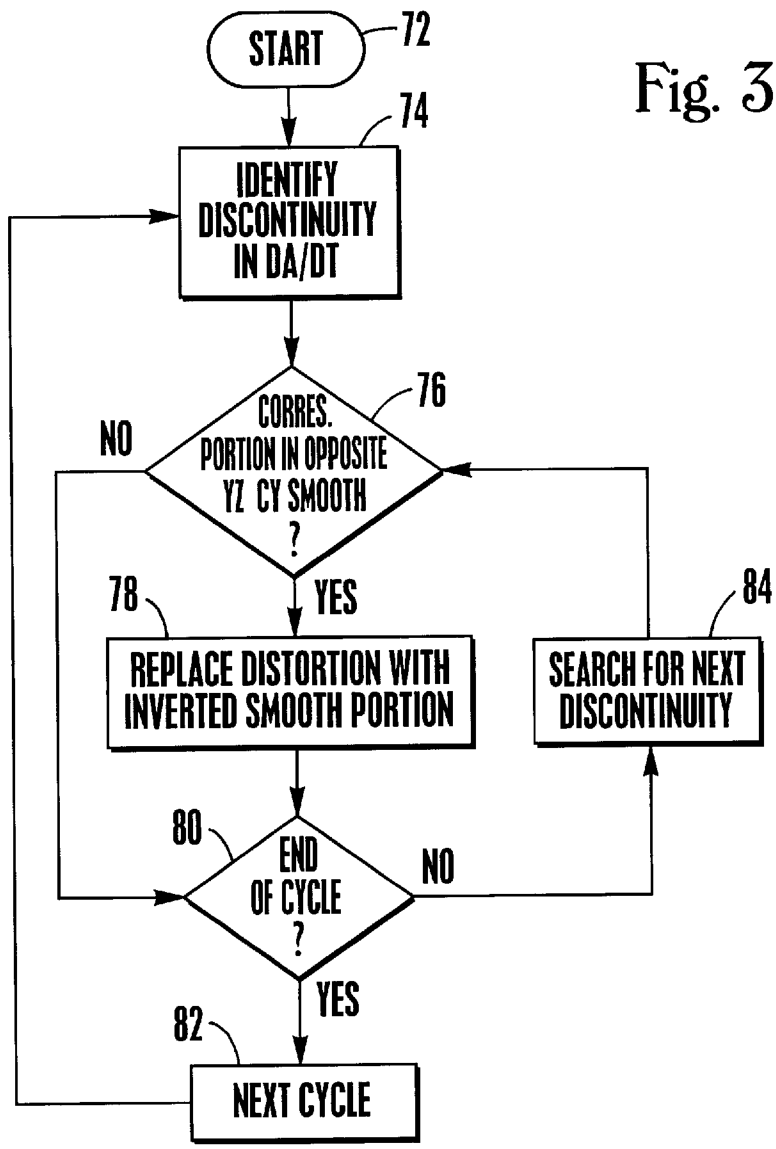
52
READ DIGITIZED RF SIGNAL
68
INCREASE GAIN FACTOR
YES
54
BELOW THRESHHOLD ?
YES
66
PASS FREQ.= SIGNAL FREQ. ?
NO
70
SET PASS FREQUENCY = SIGNAL FREQ.
56
NO
RECONSTRUCT SIGNAL
62
58
AMP-LIFICATION HIGH ?
YES
DECREASE GAIN FACTOR
60
NO
MIX SIGNAL TO GENERATE IF
64
DEMODULATE IF AND DISPLAY

Fig. 2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74
IDENTIFY DISCONTINUITY IN DA/DT
76
CORRES. PORTION IN OPPOSITE YZ CY SMOOTH ?
NO
YES
78
REPLACE DISTORTION WITH INVERTED SMOOTH PORTION
84
SEARCH FOR NEXT DISCONTINUITY
80
END OF CYCLE ?
NO
YES
82
NEXT CYCLE

Fig. 3

SYSTEM AND METHOD FOR RADIO SIGNAL RECONSTRUCTION USING SIGNAL PROCESSOR

FIELD OF THE INVENTION

The present invention relates generally to radio signal processing, and more particularly to systems and methods for reducing distortion in rf signals and thus enhancing the fidelity and sensitivity of radio receivers.

BACKGROUND

Conventional radio receivers function by receiving an rf signal and preamplifying it, and then processing the signal using a superheterodyne structure. The superheterodyne structure, in its simplest configuration, includes a mixer oscillator 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 "baseband") 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 transmission. Conventional superheterodyne structures attempt to correct for signal corruption by suppressing corruption-induced noise using filtering techniques. Unfortunately, such conventional filtering, whether using analog or digital techniques, 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 demodulates 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 discarded 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 the other half. Consequently, in instances wherein the negative 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 detector statistically can be expected to be the corrupt half 50% of the time.

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 accomplish 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 therefore precludes identification of some distortion and corruption in the "true" signal post-mixing. As still further recognized 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 electrically connectable to an antenna for receiving an analog electromagnetic 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 electrically connected to the DSP. Also, a preamplifier filter circuit (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 controller. Advantageously, the PFC includes a frequency bandpass 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 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** 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 focusses 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 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. 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-usable 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 ransom 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 tuning 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 Informational Theory*, vol. 38. no. 2, 1992 (IEEE); and Coifman et al., "Wavelet Analysis and Signal Processing", wavelets and their Applications, pp. 1–30 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 waveform reconstruction device, comprising:

an analog to digital converter (ADC) electrically connectable to an antenna for receiving an analog electromagnetic signal therefrom and outputting a digitized electromagnetic signal in response; and

a digital processor electrically connected to the ADC for receiving the digitized electromagnetic signal and in response outputting a reconstructed electromagnetic signal in accordance with a predetermined reconstruction paradigm, the digital processor being electrically associable with a mixer circuit for sending the reconstructed electromagnetic signal thereto, wherein the electromagnetic signal is an rf signal, and the device further comprises 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.

2. A waveform reconstruction device, comprising:

an analog to digital converter (ADC) electrically connectable to an antenna for receiving an analog electromagnetic signal therefrom and outputting a digitized electromagnetic signal in response; and

a digital processor electrically connected to the ADC for receiving the digitized electromagnetic signal and in response outputting a reconstructed electromagnetic signal in accordance with a predetermined reconstruction paradigm, the digital processor being electrically associable with a mixer circuit for sending the reconstructed electromagnetic signal thereto, wherein the electromagnetic signal is an rf signal, and wherein the digital processor digitally mixes the reconstructed rf signal and outputs an intermediate frequency (IF) signal in response.

3. A waveform reconstruction device, comprising:

an analog to digital converter (ADC) electrically connectable to an antenna for receiving an analog electromagnetic signal therefrom and outputting a digitized electromagnetic signal in response; and

a digital processor electrically connected to the ADC for receiving the digitized electromagnetic signal and in response outputting a reconstructed electromagnetic signal in accordance with a predetermined reconstruction paradigm, the digital processor being electrically associable with a mixer circuit for sending the reconstructed electromagnetic signal thereto, wherein the electromagnetic signal is an rf signal, and the digital processor includes reconstruction means for effecting method steps to implement the predetermined reconstruction paradigm, the method steps including:

(a) receiving both a positive half and a negative half of the digitized rf signal;

(b) analyzing the positive and negative halves to identify distorted portions and undistorted portions thereof; and

(c) removing at least some of the distorted portions and replacing each with a respective replacement portion to thereby produce the reconstructed rf signal, each replacement portion being based on at least some of the undistorted portions.

4. The device of claim **3**, further comprising a controller electrically connected to the DSP.

5. The device of claim **4**, further comprising a preamplifier filter circuit (PFC) electrically connectable to the antenna and ADC for amplifying and filtering the analog rf signal from the antenna prior to sending the analog rf signal to the ADC, the PFC also being electrically connected to the controller, wherein

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

6. The device of claim **5**, wherein the PFC includes an amplifier for increasing, by a gain factor, the amplitude of signals having the pass frequency, and wherein the controller establishes the gain factor.

7. The device of claim **6**, wherein 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 an amplitude range, and the controller dynamically establishes the gain factor based on the gain adjust signal.

8. The device of claim **7**, in combination with an rf receiver apparatus having a tuning control element for establishing a channel frequency, wherein the controller establishes the pass frequency based on at least one of: the channel frequency, and the gain adjust signal.

9. A waveform reconstruction device, comprising:

an analog to digital converter (ADC) electrically connectable to an antenna for receiving an analog electromagnetic signal therefrom and outputting a digitized electromagnetic signal in response;

a digital processor electrically connected to the ADC for receiving the digitized electromagnetic signal and in response outputting a reconstructed electromagnetic signal in accordance with a predetermined reconstruction paradigm, the digital processor being electrically associable with a mixer circuit for sending the reconstructed electromagnetic signal thereto wherein the electromagnetic signal is an RF signal, and the device further comprises 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; and

an electromagnetic signal transmitter.

10. An rf receiver, comprising:

an antenna;

a reconstruction circuit electrically connected to the antenna for receiving an analog rf signal from the antenna and generating a reconstructed waveform having substantially no distortions therein, wherein the reconstruction circuit includes:

an analog to digital converter (ADC) electrically connected to the antenna for receiving the analog rf signal therefrom and outputting a digitized rf signal in response;

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

11. The receiver of claim **10**, further comprising:

a mixer circuit electrically associated with the reconstruction circuit for generating an intermediate frequency (IF) signal based on the reconstructed waveform;

a demodulator for decoding useful information from the IF signal; and

a digital to analog converter (DAC) for converting the reconstructed waveform to an analog reconstructed waveform, prior to sending the reconstructed waveform to the mixer circuit.

12. The receiver of claim **10**, wherein the DSP includes a mixer circuit.

13. The receiver of claim **10**, wherein the DSP includes reconstruction means for effecting method steps to implement the predetermined reconstruction paradigm, the method steps including:

(a) receiving both a positive half and a negative half of the digitized rf signal;

(b) analyzing the positive and negative halves to identify distorted portions and undistorted portions thereof; and

(c) removing at least some of the distorted portions and replacing each with a respective replacement portion to thereby produce the reconstructed waveform, each replacement portion being based on at least some of the undistorted portions.

14. The receiver of claim **13**, further comprising a preamplifier filter circuit (PFC) electrically connected to the antenna and ADC for amplifying and filtering the analog rf signal from the antenna prior to sending the analog rf signal to the ADC, the PFC also being electrically connected to the controller, wherein the PFC includes:

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

an amplifier for increasing, by a gain factor, the amplitude of signals having the pass frequency, and wherein the controller establishes the gain factor.

15. The receiver of claim **14**, further comprising a tuning control element for establishing a channel frequency, wherein

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, and the controller changes the gain factor based on the gain adjust signal; and

the controller establishes the pass frequency based on at least one of: the channel frequency, and the gain adjust signal.

16. The receiver of claim **15**, in combination with an rf transmitter.

17. A computer-implemented method for processing a transmitted electromagnetic signal to extract useful information from the signal, comprising the steps of:

receiving the electromagnetic signal and reconstructing it in accordance with a predetermined reconstruction paradigm;

after reconstruction, mixing and demodulating the electromagnetic signal to extract useful information therefrom;

digitizing the electromagnetic signal, prior to reconstructing it, wherein the reconstruction steps include

receiving both a positive half and a negative half of the electromagnetic signal;

analyzing the positive and negative halves to identify distorted portions and undistorted portions thereof; and

removing at least some of the distorted portions and replacing each with a respective replacement portion to thereby produce a reconstructed electromagnetic signal, each replacement portion being based on at least some of the undistorted portions.

18. The method of claim **17**, further comprising the step of digitizing the electromagnetic signal, prior to reconstructing it.

19. The method of claim **18**, further comprising the step of digitally mixing the reconstructed electromagnetic signal.

20. The method of claim **17**, further comprising the steps of:

preamplifying, by a gain factor, the electromagnetic signal prior to the reconstructing step;

attenuating signals having a frequency not equal to a pass frequency prior to the reconstructing step; and

dynamically establishing the pass frequency and gain factor.

21. A computer program device comprising:

a computer program storage device readable by a digital processing system; and

a program means on the program storage device and including instructions 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 comprising:

(a) receiving both a positive half and a negative half of the rf signal;

(b) analyzing the positive and negative halves to identify distorted portions and undistorted portions thereof; and

(c) removing at least some of the distorted portions and replacing each with a respective replacement portion to thereby produce a reconstructed rf signal, each replacement portion being based on at least some of the undistorted portions.

22. The computer program device of claim **21**, wherein the method steps further include:

preamplifying, by a gain factor, the rf signal prior to the reconstructing step;

attenuating signals having a frequency not equal to a pass frequency prior to the reconstructing step; and

dynamically establishing the pass frequency and gain factor.

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UNITED STATES DISTRICT COURT
CENTRAL DISTRICT OF CALIFORNIA

AMERICAN RADIO LLC PLAINTIFF(S) v. QUALCOMM INCORPORATED DEFENDANT(S).	CASE NUMBER CV12-8507 -ODW(JEMx) **SUMMONS**

TO: DEFENDANT(S):

A lawsuit has been filed against you.

Within 21 days after service of this summons on you (not counting the day you received it), you must serve on the plaintiff an answer to the attached ☑ complaint ☐ ____________ amended complaint ☐ counterclaim ☐ cross-claim or a motion under Rule 12 of the Federal Rules of Civil Procedure. The answer or motion must be served on the plaintiff's attorney, Terry T. Tsai, whose address is 2121 Avenue of the Stars, Suite 2800, Los Angeles, CA 90067. If you fail to do so, judgment by default will be entered against you for the relief demanded in the complaint. You also must file your answer or motion with the court.

Clerk, U.S. District Court

Dated: OCT - 3 2012

By: [signature]
Deputy Clerk

(Seal of the Court)

[Use 60 days if the defendant is the United States or a United States agency, or is an officer or employee of the United States. Allowed 60 days by Rule 12(a)(3)].