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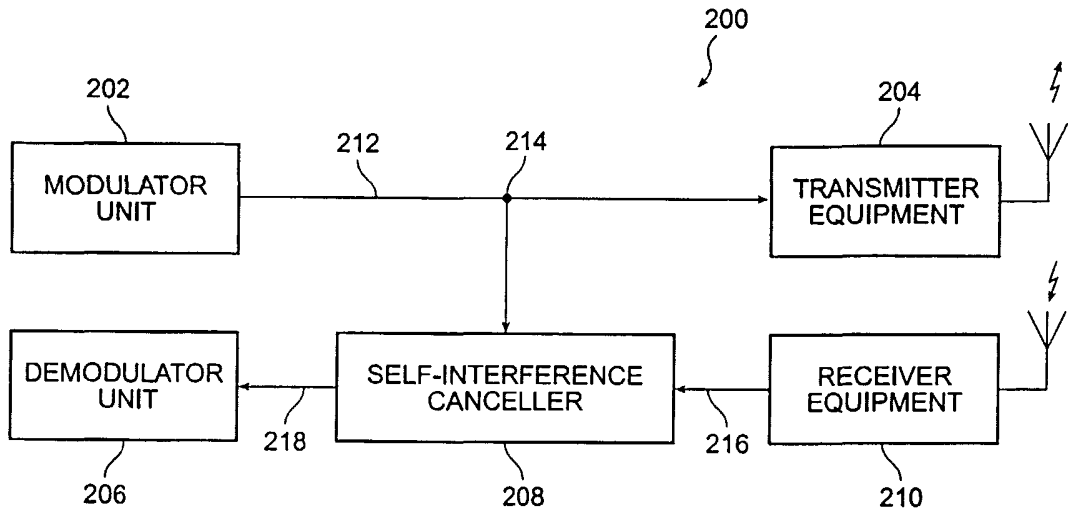
(54) Title: METHOD AND APPARATUS FOR RELAYED COMMUNICATION USING BAND-PASS SIGNALS FOR SELF-INTERFERENCE CANCELLATION



(57) Abstract: Self-interference cancellation is provided in RF communication. The system (200) comprises a modulator (202), a transmitter (204), a receiver (206), a self-interference canceller (208) and a demodulator (208). The RF signal in the transmitting side is fed to receiving side via the self-interference canceller (208) for cancelling interference in the communication system (200).

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Method and Apparatus for Relayed Communication Using Band-Pass Signals for Self-Interference Cancellation

CROSS-REFERENCES TO RELATED APPLICATIONS

[01] This application is related to U.S. Application No. 08/520/868 for SELF-INTERFERENCE CANCELLATION FOR TWO-PARTY RELAYED COMMUNICATION, filed August 1, 1995, now U.S. Patent No. 5,596,439, issued January 21, 1997 and U.S. Application No.09/009,573 for SELF-INTERFERENCE CANCELLATION FOR RELAYED COMMUNICATION NETWORKS, filed January 20, 1998, now U.S. Patent No. 6,011,952, issued January 4, 2000, both of which are owned by the Assignee of the present invention and are herein incorporated by reference for all purposes.

STATEMENT AS TO RIGHTS TO INVENTIONS MADE UNDER FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[02] NOT APPLICABLE

REFERENCE TO A "SEQUENCE LISTING," A TABLE, OR A COMPUTER PROGRAM LISTING APPENDIX SUBMITTED ON A COMPACT DISK

[03] NOT APPLICABLE

BACKGROUND OF THE INVENTION

[04] This invention relates to a radio frequency or optical communication system in which a relay station is used to aid communication among a network of parties, and more particularly to an improvement allowing more efficient use of the available channel resource.

[05] Self-interference cancellation is a theoretically efficient technique for relayed communication between two or more devices involving the transmission of different signals within the same frequency band at the same time. In the example of communication between two devices, such transmission results in a composite signal that includes two signals, one originating from each device. As each device attempts to receive the signal originating from the other device (far signal), it is hindered by interference caused by the signal originating from itself (near signal). Thus, self-interference cancellation works by generating a cancellation signal resembling the device's own near signal and using the cancellation signal to remove at least a portion of the near signal from the composite signal to obtain a signal closer to the desired far signal.

[06] A number of techniques have been developed for self-interference cancellation. However, these techniques have focused on structures which make it expensive and inconvenient to retrofit the large number of existing systems for the capability of self-interference cancellation. In addition, these techniques have failed to take into account various distortions introduced into the transmit signal. As a result, advantages of self-interference cancellation have not been fully realized.

[07] Figure 1 depicts an existing satellite communication facility with a transmitter system 100 and a receiver system 101 well known in the prior art with no self-interference cancellation capability. The transmitter system 100 comprises a modulator unit 102 and transmitter equipment 104, and the receiver system 101 comprises receiver equipment 108 and demodulator unit 106. Only one of each of these components is shown here for clarity of illustration. It should be understood that there may be more than one of each component in the satellite communication facility. Typically, the modulator unit 102 contains a modulator 112 receiving a transmit (TX) data signal 110 and producing a TX baseband modulated signal 114. An upconverter 116 receives the TX baseband modulated signal 114 and produces a TX interface signal 118 at or near its designated interface frequency. An interface signal as used herein is the signal at the point where a tap can be made in the signal path. The interface frequency, i.e., the frequency associated with the passband of the interface signal, can be any frequency above baseband, namely at a passband such as associated with an Intermediate Frequency (IF) (typically 70 MHz to 2 GHz) or a Radio Frequency (RF) (typically 400 MHz to 30 GHz). An RF frequency is the frequency of signal emission and the IF frequency is typically the frequency of a signal at some location between the baseband processing stage and the signal emission stage. The modulator 102 may produce the TX interface signal 118 using a different method, such as modulating and upconverting all in one step. (Modulating is the process of applying information to a signal.) Typically, the TX interface signal 118, operating at or near the interface frequency, is sent from the modulator unit 102 to a transmitter equipment 104 through a coaxial cable. The transmitter equipment 104 further processes the TX interface signal 118 before transmission to a satellite or other relay station (not shown).

[08] The radio receiver equipment 108 receives a signal from the satellite or other relay station and produces a receive (RX) interface signal 120 at or around an interface frequency. The interface frequency for the receive signal can be the same as or different than the TX interface frequency. Typically, the RX interface signal 120 is sent from the radio receive equipment 108 to the demodulator unit 106 through a coaxial cable. A downconverter 122 aboard the demodulator unit 106 receives the RX interface signal 120 and produces an RX baseband modulated signal 124. A demodulator 126 receives the RX baseband modulated signal 124 and produces an RX data signal 128.

[09] Retrofitting a facility such as an existing satellite communication facility for self-interference cancellation capability has been expensive and inconvenient because current techniques of self-interference cancellation have all focused on structures that require the construction of completely new systems or require tapping into existing systems at inconvenient and/or difficult-to-access locations. For example, a number of these techniques have relied on tapping into the transmit path at the data signal stage for purposes of generating the cancellation signal. Tapping the TX data signal 110 may be impracticable. The TX data signal 110 may be a signal internal to the modulator unit 102. Self-interference cancellation techniques that tap at the output of the modulated signal suffer the same problem. Here, TX baseband modulated signal 114 may also be internal to the modulator unit 102. Efforts to tap such signals may require modifications to circuit boards or other reconfigurations that, if possible at all, are costly and inefficient. Especially given the large amount of relayed communication facility equipment already in service around the world today and the prohibitive expense involved in replacing such equipment or modifying equipment in sealed or otherwise inaccessible enclosures, application of current techniques to retrofit existing equipment for self-interference cancellation capability may be impractical.

[10] In addition, current techniques for self-interference cancellation fail to take into account distortions introduced into the transmit signal. For example, current techniques that do not tap any signals sourced from the transmitter system 100 or tap either the TX data signal 110 or the TX baseband modulated signal 114 simply ignore certain induced distortions such as non-linearity or local oscillation (LO) feedthrough. As a result, the potential advantages of self-interference cancellation techniques and performance of self-interference cancellation systems have not been fully realized. The prior art approaches are illustrated by U.S. Patent No. 5,280,537 issued January 18, 1994 to Jugiyama et al. and assigned to Nippon Telegraph and Telephone Corporation, U.S. Patent No. 5,625,640 issued

April 29, 1997 to Palmer et al. and assigned to Hughes Electronics, and U.S. Patent No. 5,860,057 issued January 12, 1999 to Ishida et al. and assigned to Hitachi, Ltd.

BRIEF SUMMARY OF THE INVENTION

[11] Self-interference cancellation is provided in two-way relayed electromagnetic communication between a first device and a second device through a relay station wherein a representation of a relayed composite signal above baseband and a representation of a locally modulated interface signal above baseband interact to effect the self-interference cancellation. Specifically, the composite signal, which contains a relayed version of the locally modulated (near) signal from the first device and a relayed version of a modulated far signal from the second device, is received at the first device from the relay station. The composite signal is then provided in a representation as a first interface signal at a first frequency at or above baseband to a canceler module of the first device and a representation of the modulated near signal at a second frequency above baseband is provided as a second interface signal to the canceler module. Part of the relayed version of the modulated near signal is canceled from the representation of the composite signal using the representation of the modulated near signal as provided to the canceler module to produce a third interface signal as output at a third frequency at or above baseband. The first and second frequencies may or may not be the same.

[12] The invention provides a low cost, simple retrofit solution to existing relayed communication facilities for self-interference cancellation. The technique according to the invention takes into account distortion caused by transmission path components up to the last point in the signal path where the signal can be practically tapped and provided to a self-interference canceler before transmission into a communication channel.

[13] The invention will be better understood by reference to the following description in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[14] Figure 1 depicts known elements of a satellite communication facility with no self-interference capability;

[15] Figure 2 illustrates an embodiment of a versatile self-interference cancellation system of the present invention;

[16] Figure 3 is a functional diagram of a first example of the versatile self-interference cancellation system in Figure 2;

[17] Figure 4 is a functional diagram of a second example of the versatile self-interference cancellation system in Figure 2; and

[18] Figure 5 is a detailed block diagram of the self-interference canceler in Figure 3.

DETAILED DESCRIPTION OF THE INVENTION

[19] Figure 2 illustrates an embodiment of a versatile self-interference cancellation system 200 of the present invention. The self-interference cancellation system 200 comprises a modulator unit 202, transmitter equipment 204, a demodulator unit 206, a self-interference canceler 208, and receiver equipment 210.

[20] On the transmit side, the modulator unit 202 provides a TX interface signal 212 via an accessible feed line (typically coaxial) to the transmitter equipment 204. The TX interface signal 212 is a representation of the locally modulated signal which is also called the near signal. This representation is at or near an interface frequency that is not baseband. The transmitter equipment 204 can be any equipment along the transmit path, such as an up-converter, mixer, splitter, combiner, splitter/combiner, amplifier, antenna, or the like. A signal splitter 214 in the TX interface signal line allows the TX interface signal 212 to be easily tapped for purposes of self-interference cancellation according to the invention.

[21] On the receive side, the receiver equipment 210 provides an RX interface signal 216 to a self-interference canceler 208. The RX interface signal 216 is a representation of the composite signal, which is composed of two components, the relayed version of the near signal and the relayed version of the far signal. This representation is at or near an interface frequency that is not baseband. The frequency may differ from that of the TX interface signal 212. The receiver equipment 210 can be any equipment along the receive path, such as an up-converter, mixer, splitter, combiner, splitter/combiner, amplifier, antenna, or the like. The self-interface canceler 208 uses the TX interface signal 212 tapped from the TX interface signal line to perform self-interference cancellation on the RX interface signal 216 and provides a cancellation-processed RX interface signal 218 to the demodulation unit 206.

[22] This configuration allows convenient and cost-effective retrofitting of existing equipment for self-interference cancellation. Typically, an existing satellite communication facility that lacks self-interference capability, such as the one shown in Figure 1, already contains the modulator unit 202, the transmitter equipment 204, the demodulator unit 206, and the receiver equipment 210. According to the invention,

retrofitting of the existing facility for self-interference capability involves simple insertion of the self-interference canceler 208 along the path of the RX interface signal 216 between the receiver equipment 210 and the demodulator unit 206, and tapping the TX interface signal 212 using the splitter 214 and employing as the self-interference canceler 208 a function which is tailored to the signal characteristics to be canceled as hereinafter described.

[23] Figure 3 is a functional diagram of a first example 300 of the versatile self-interference cancellation system according to the invention. A modulator 302 receives a TX data signal and produces a TX baseband modulated signal, which is provided to a first upconverter (or mixer) 304. The first upconverter 304 produces a TX intermediate frequency (IF) bandpass signal at or near an IF frequency in a passband, which is provided to a second upconverter 306 (or mixer). The second upconverter 306 produces a TX radio frequency (RF) signal at or near an RF frequency. The TX RF signal is provided to a high power amplifier (HPA) 308, which produces a TX amplified RF signal that is provided to a transmit antenna 310 and transmitted toward the relay element (not shown). The transmit antenna 310 can be a parabolic reflector of other type of directional antenna.

[24] The signal received at the receive antenna 314 is provided to a low noise amplifier (LNA) 316. The receive antenna 314 may be the same device as the transmit antenna 310 or a different device, and likewise the receive antenna 314 may be a parabolic reflector or other type of antenna. The LNA 316 provides an amplified RX RF signal to a first downconverter (or mixer) 318. The downconverter 318 provides an RX IF signal in a passband to an interference canceler 312. The TX IF signal from the first upconverter 304 is also provided to the interference canceler 312. The interference canceler 312 provides a cancellation-processed RX IF signal in a passband to a second downconverter (or mixer) 320. The second downconverter 320 provides an RX baseband signal to a demodulator 322, which produces an RX data signal.

[25] In the example 300, the self-interference canceler 312 is able to take into account non-linearities, LO feed-through, and other distortions introduced by the modulator 302 and the first upconverter 304 because the interference canceler 312 takes as its input the TX IF signal that contains such distortions. In addition, retrofitting an existing facility for self-interference cancellation is made more convenient and practical. The cancellation signal is generated by tapping into the transmit path at the IF passband. Since the output of the upconverter 304 of a transmitter of interest has an easily accessible connector, and a self-interference canceler 312 of interest has readily accessible IF signal inputs and outputs (input from the first downconverter 318, input from the first upconverter

304, and output to the second downconverter 320), such retrofit is easily accomplished by adding a signal splitter 305 and coaxial connectors and cables to tap the existing IF signal paths. This is a task easily performed by a technician.

[26] Figure 4 is a functional diagram of a second example 400 of the self-interference cancellation system according to the invention. A modulator 402 receives a TX data signal and produces a TX baseband modulated signal, which is provided to a first upconverter (or mixer) 404. The first upconverter 404 produces a TX intermediate frequency (IF) bandpass signal at or near an IF frequency in a passband, which is provided to a second upconverter 406 (or mixer). The second upconverter 406 produces a TX radio frequency (RF) signal at or near an RF frequency. The TX RF signal is provided to a high power amplifier (HPA) 408, which produces a TX amplified RF signal that is provided to a transmit antenna 410 and transmitted toward the relay element.

[27] The signal received at the receive antenna 414 is provided to a low noise amplifier (LNA) 416. The receive antenna 414 can be the same device as the transmit antenna 410 or a different device. The LNA 416 provides an amplified RX RF signal to an interference canceler 412. The TX RF signal from the second upconverter 406 is also provided to the interference canceler 412. The interference canceler 412 provides a self-cancellation processed RX RF signal to a first downconverter (or mixer) 418. The first downconverter 418 provides an RX IF signal to a second downconverter (or mixer) 420. The second downconverter 420 provides an RX baseband modulated signal to a demodulator 422, which produces an RX data signal.

[28] In the example 400, the self-interference canceler 412 takes into account non-linearities, LO feed-through, and other distortions introduced by the modulator 402 and the first upconverter 404 and the second upconverter 406 because the interference canceler takes as its input the TX IF signal that contains such distortions. In addition, retrofitting an existing facility for self-interference cancellation is made more convenient and practical. The cancellation signal is generated by tapping into the transmit path at the IF passband. Since the output of the second upconverter 406 of a transmitter of interest has an easily accessible connector, and a self-interference canceler 412 of interest has readily accessible IF signal inputs and outputs (input from the second upconverter 406, input from the low-noise amplifier (LNA) 416, and output to the first downconverter 418), such retrofit is easily accomplished by adding a signal splitter 405 and coaxial connectors and cables to tap the existing RF signal paths. This is a task easily performed by a technician.

[29] Alternatively, the TX amplified RF signal produced by HPA 408, instead of the TX RF signal from the second upconverter 406, is provided to the self-interference canceler 412. By tapping the transmit signal after the HPA 408, the self-interference canceler 412 is able to also take into account non-linearities and other distortions introduced to the transmit signal by the HPA 408. Here, attention may be required to carefully attenuate the TX RF signal before providing it to the self-interference canceler 414, without disturbing the TX amplified RF signal provided to the transmit antenna 410.

[30] Figure 5 is a detailed block diagram of one possible embodiment of a self-interference canceler 312 of Figure 3. (The self-interference canceler 412 in Figure 4 may have a similar structure.) The composite received signal, in the form of the RX IF signal (or the RX RF signal in the case of the self-interference canceler 412), is down-converted to baseband at a downconverter block 502. The downconverter block 502 may be implemented in a variety of ways, such as in a single stage or in multiple stages and by analog or digital methods. This baseband signal is input to a time and phase detectors block 504. A time-delayed and phase-rotated local near signal is also input to the time and phase detector block 504. The time and phase detectors block 504, which may comprise a single device or separate devices, performs correlation function(s) on its inputs and produces outputs that drive a time tracking loop block 506 and a phase tracking loop block 508.

[31] The time-delayed and phase-rotated local near signal is generated from the local near signal as herein explained. The local near signal, in the form of the TX IF signal (or the TX RF signal in the case of the self-interference canceler 412), is down-converted at a downconverter block 514. The down-converted local near signal is time-delayed by the time delay block 510, which is under the control of the time tracking loop block 506. The time-delayed signal is then phase-rotated by the phase rotation block 512, which is under the control of the phase tracking loop block 508. The phase rotation is capable of removing frequency differences between the local near signal and the received near component of the composite received signal. The order of time delay and phase rotation can be changed with departing from the scope or spirit of the invention. However, phase rotation should preferably occur after time delay to mitigate against distortion.

[32] Once the local near signal has been aligned in frequency, time and phase to the received near signal, the resulting signal must still be adjusted to compensate for channel and relay effects. An adaptive filter 516 does this adjustment. The adaptive filter 516 can be as simple as a single tap finite impulse response filter to adjust the amplitude of the local near signal to the received near signal. On the other extreme, the adaptive filter 516

may be highly complex and non-linear, for example to mimic the effects of a saturated non-linear amplifier in a satellite transponder. The complexity of the filter will be determined by the combination of the complexity of the channel and the interference suppression requirement of the application. The order of adaptive filter, time delay, and phase rotation may be changed.

[33] The output of the adaptive filter 516 is an estimate of the received near component of the composite received signal. To remove the received near component, this estimate is subtracted from the baseband composite received signal at a subtraction block 518. The output of the subtraction block is provided as an error signal to the adaptive algorithm and is also up-converted back to the original IF frequency (or RF frequency in the case self-interference canceler 412) that was input to the canceler. Alternatively or additionally, this signal can be directly demodulated to extract the desired signal (or signals) using one or more demodulator(s).

[34] Although not shown in Figure 5, a delay block may be introduced in path 520 to introduce a delay in the baseband composite received signal to take into account time delay spread of the channel.

[35] Figure 5 is only one embodiment of a self-interference canceler. Other self-interference cancelers may be used if adapted to process signals in accordance with the invention. Other derivations of the present self-interference canceler may be made in which the local near signal may be modified by a variable delay, a phase rotator and an adaptive filter. This embodiment is generally preferable, since the local near signal does not carry the noise and additional signal components of the composite signal. Alternate embodiments, however, would include systems in which the composite received signal is variably delayed, phase rotated, and/or adaptively filtered.

[36] The self-interference cancellation system of the present invention is modulation independent and will correct a wide range of signal impairments, both linear and non-linear. The system is suited for a wide variety of implementations, including retrofit into existing satellite communication facilities.

[37] Although the present invention has been described in terms of specific embodiments, it should be apparent to those skilled in the art that the scope of the present invention is not limited to the described specific embodiments.

[38] The specification and drawings are, accordingly, to be regarded in an illustrative rather than a restrictive sense. It will, however, be evident that additions,

subtractions, substitutions, and other modifications may be made without departing from the broader spirit and scope of the invention as set forth in the claims.

WHAT IS CLAIMED IS:

1. A method for providing self-interference cancellation in two-way relayed electromagnetic communication between a first device and a second device through a relay station comprising the steps of:

generating at said first device a modulated near signal;

transmitting said modulated near signal from said first device to said relay station;

receiving at said first device a composite signal from said relay station, said composite signal containing a relayed version of said modulated near signal and a relayed version of a modulated far signal transmitted from said second device;

providing said composite signal in a representation as a first interface signal to a canceler module of said first device;

providing a representation of said modulated near signal as a second interface signal to said canceler module, said second interface signal being of a frequency centered at or near a second interface frequency not at baseband;

canceling at said canceler module a portion of said relayed version of said modulated near signal from said representation of said composite signal using said second interface signal to a produce a cancellation-processed signal; and

outputting said cancellation-processed signal as a third interface signal from said canceler module.

2. A method for retrofitting a first device for self-interference cancellation capability in two-way relayed electromagnetic communication between said first device and a second device through a relay station, said first device having an existing modulator unit, an existing transmitter equipment, an existing receiver equipment and an existing demodulator unit, said method comprising the steps of:

providing a composite signal in a representation as a first interface signal from said receiver equipment to a canceler module of said first device, said composite signal containing a relayed version of a modulated near signal transmitted from said first device and a relayed version of a modulated far signal transmitted from said second device;

providing a representation of said modulated near signal as a second interface signal from said modulator unit to said canceler module, said second interface signal also provided to said transmitter equipment, said second interface signal being of a frequency centered at or near a second interface frequency not at baseband;

canceling at said canceler module a portion of said relayed version of said modulated near signal from said representation of said composite signal using said second interface signal to produce a cancellation-processed signal; and

outputting said cancellation-processed signal as a third interface signal from said canceler module to said receiver equipment.

3. The method of claim 2 wherein said transmitter equipment includes an upconverter, a downconverter, or a mixer.

4. The method of claim 2 wherein said transmitter equipment includes an amplifier.

5. The method of claim 4 wherein said amplifier is a high power amplifier (HPA).

6. The method of claim 2 wherein said transmitter equipment includes an antenna.

7. The method of claim 2 wherein said transmitter equipment includes a splitter, combiner, or splitter/combiner.

8. The method of claim 2 wherein said receiver equipment includes an upconverter, a downconverter, or a mixer.

9. The method of claim 2 wherein said receiver equipment includes an amplifier.

10. The method of claim 9 wherein said amplifier is a low noise amplifier (LNA).

11. The method of claim 2 wherein said receiver equipment includes an antenna.

12. The method of claim 2 wherein said receiver equipment includes a splitter, combiner, or splitter/combiner.

13. The method of claim 1 or 2 wherein said first interface signal is of a frequency centered at or near a first interface frequency not at baseband.

14. The method of claim of claim 13 wherein said first interface frequency is an Intermediate Frequency (IF) or a Radio Frequency (RF).

15. The method of claim 1 or 2 wherein said second interface frequency is an IF or RF frequency.

16. The method of claim 1 or 2 wherein said third interface signal is of a frequency centered at or near a third interface frequency not at baseband.

17. The method of claim of claim 16 wherein said third interface frequency is an IF or RF frequency.

18. The method according to claim 1 or 2 wherein said first, second and third interface signals are provided or outputted at readily accessible locations.

19. The method according to claim 1 or 2 wherein said second interface signal is provided from a point in its signal path immediately preceding a signal emission stage.

20. The method according to claim 1 or 2 wherein said canceling step includes:

applying a time delay and phase rotation to a representation of said second interface signal to obtain a time-delayed and phase-rotated local near signal;

correlating said time-delayed and phase-rotated local near signal with at least a representation of said first interface signal to obtain correction signals for said time-delayed and phase-rotated local near signal;

adaptively filtering said time-delayed and phase-rotated local near signal to produce a filtered signal; and

applying said filtered signal with said at least said representation of said composite signal to yield said cancellation-processed signal.

21. The method according to claim 20 wherein said canceling step includes:

downconverting said first interface signal to produce said representation of said first interface signal;

downconverting said second interface signal to produce said representation of said second interface signal; and

upconverting said cancellation-processed signal to produce said third interface signal.

22. A method for providing self-interference cancellation in two-way relayed electromagnetic communication between a first device and a second device through a relay station comprising the steps of:

generating at said first device a modulated near signal;

transmitting said modulated near signal from said first device to said relay station;

receiving at said first device a composite signal from said relay station, said composite signal containing a relayed version of said modulated near signal and a relayed version of a modulated far signal transmitted from said second device;

providing said composite signal in a representation as a first interface signal to a canceler module of said first device;

providing a representation of said modulated near signal as a second interface signal to said canceler module, said second interface signal being of a frequency centered at or near a second interface frequency not at baseband;

canceling at said canceler module a portion of said relayed version of said modulated near signal from said representation of said composite signal using said second interface signal to a produce a cancellation-processed signal;

demodulating said cancellation-processed signal to produce at least one demodulated signal; and

outputting said at least one demodulated signal from said canceler module.

23. The method of claim 22 wherein said step demodulating step produces more than one demodulated signal using more than one demodulator.

24. A system for providing self-interference cancellation in two-way relayed electromagnetic communication between a first device and a second device through a relay station comprising:

means for generating at said first device a modulated near signal;

means for transmitting said modulated near signal from said first device to said relay station;

means for receiving at said first device a composite signal from said relay station, said composite signal containing a relayed version of said modulated near signal and a relayed version of a modulated far signal transmitted from said second device;

means for providing said composite signal in a representation as a first interface signal to a canceler module of said first device;

means for providing a representation of said modulated near signal as a second interface signal to said canceler module, said second interface signal being of a frequency centered at or near a second interface frequency not at baseband;

means for canceling at said canceler module a portion of said relayed version of said modulated near signal from said representation of said composite signal using said second interface signal to a produce a cancellation-processed signal; and

means for outputting said cancellation-processed signal as a third interface signal from said canceler module.

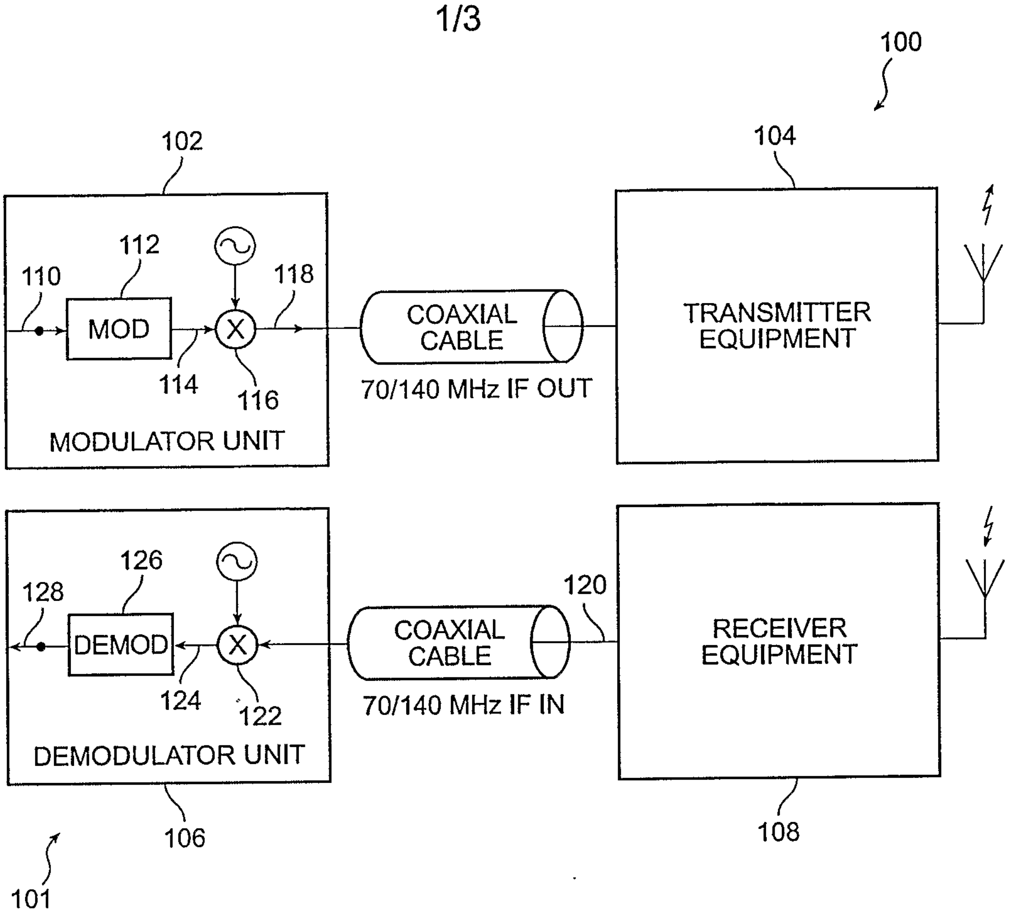


FIG. 1
(PRIOR ART)

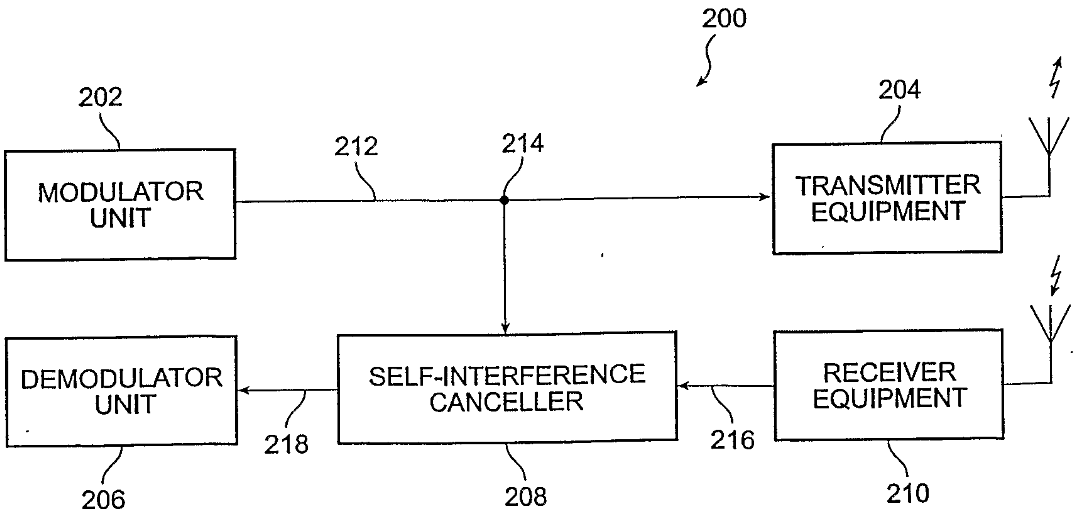
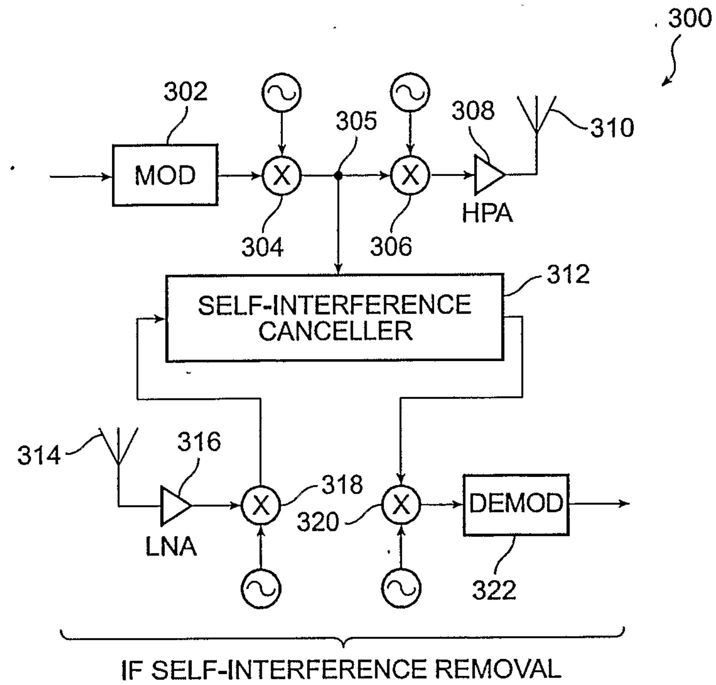


FIG. 2


300
302
MOD
304
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HPA
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SELF-INTERFERENCE CANCELLER
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DEMOD
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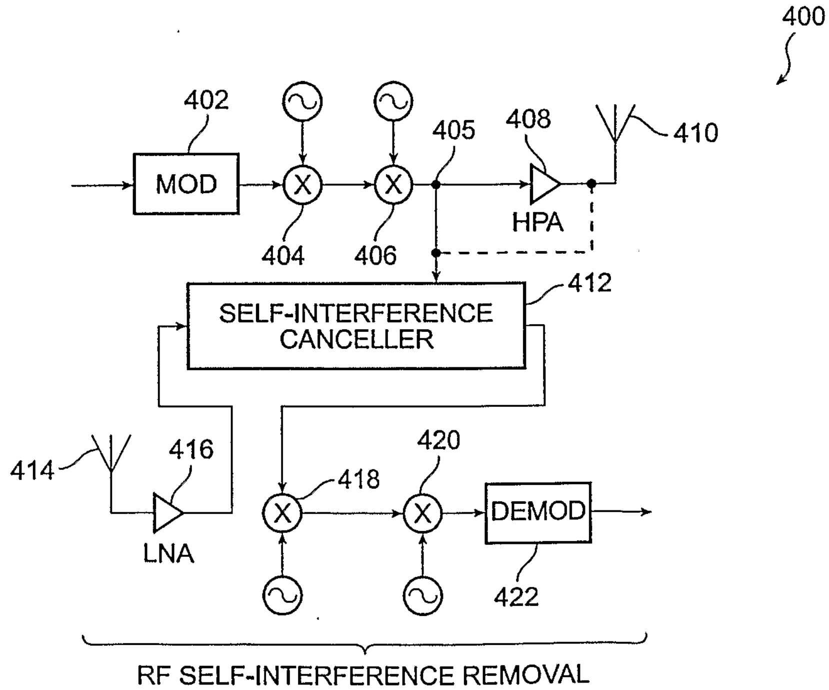
IF SELF-INTERFERENCE REMOVAL

FIG. 3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406
405
408
HPA
410
412
SELF-INTERFERENCE CANCELLER
414
416
LNA
418
420
DEMOD
422
RF SELF-INTERFERENCE REMOVAL

FIG. 4

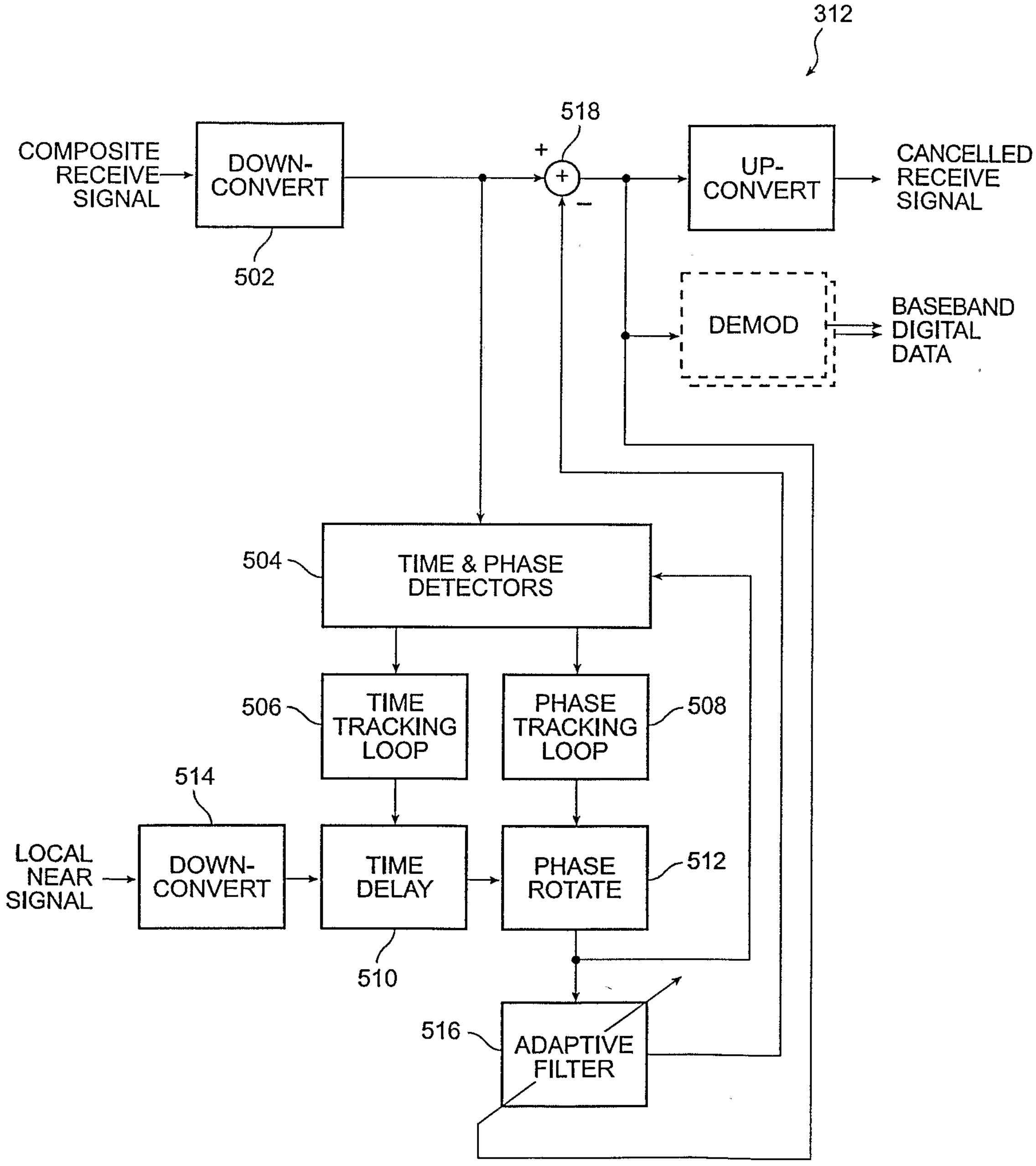
312
COMPOSITE RECEIVE SIGNAL
DOWN-CONVERT
502
518
+
−
UP-CONVERT
CANCELLED RECEIVE SIGNAL
DEMOD
BASEBAND DIGITAL DATA
504
TIME & PHASE DETECTORS
506
TIME TRACKING LOOP
PHASE TRACKING LOOP
508
514
LOCAL NEAR SIGNAL
DOWN-CONVERT
TIME DELAY
PHASE ROTATE
512
510
516
ADAPTIVE FILTER

FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US01/30223

A. CLASSIFICATION OF SUBJECT MATTER
IPC(7) : H04B 1/10
US CL : 25, 278.1
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 455/25, 272, 276.2, 277.1, 277.2, 278.1, 279.1, 280, 282, 283

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
NONE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,428,831 A (MONZELLO ET AL) 27 JUNE 1995, see figures 1-2, see column 8, line 10 to column 10, line 47.	1-24
X	US 5,140,699 A (KOZAK) 18 AUGUST 1992, see figures 1-2, see column 5, line 3 to column 6, line 66.	1-24

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

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Date of the actual completion of the international search 12 December 2001 (12.12.2001)	Date of mailing of the international search report 13 FEB 2002
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703)305-3230	Authorized officer Thanh C Le Telephone No. (703) 305-4819