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Kuo

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(54) **METHOD AND SYSTEM FOR REDUCING AMPLITUDE MODULATION (AM) NOISE IN AM BROADCAST SIGNALS**

(71) Applicant: **Yao H. Kuo**, West Bloomfield, MI (US)

(72) Inventor: **Yao H. Kuo**, West Bloomfield, MI (US)

(73) Assignee: **Visteon Global Technologies, Inc.**, Van Buren Township, MI (US)

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(51) **Int. Cl.**

H03D 1/04	(2006.01)
H04H 20/88	(2008.01)
H04B 1/10	(2006.01)
H04B 1/04	(2006.01)
G10K 11/178	(2006.01)

(52) **U.S. Cl.**

CPC ***H04H 20/88*** (2013.01); ***H04B 1/1027*** (2013.01); *G10K 11/178* (2013.01); *H04B 1/0475* (2013.01); *H04B 1/0483* (2013.01)

(58) **Field of Classification Search**

CPC H04H 20/88; H04H 60/12; H04H 40/72; H04B 1/10; H04B 1/16; H04B 17/00; H04B 1/1027; H04B 7/086; H04B 1/71075; H04B 1/1676; H04B 1/0475; H04B 1/0483; H03G 3/345; H03G 3/00; H03D 7/00; H04L 25/061; H04L 27/3863; G10K 2210/108; G10K 2210/3225; G10K 2210/00; G10K 2210/117; G10K 2210/1081; G10K 2210/1082; G10K 2210/50; G10K 2210/505; G10K 2210/511; G10K 2210/321; G10K 2210/3226; G10K 11/178

USPC 381/3, 94.4, 15, 94.8, 1, 10, 13, 94.1, 381/57; 455/226.1, 222, 223, 296, 3.01, 455/3.02, 277.2, 142, 143, 3.06, 67.13, 455/67.11, 67.7, 132, 135, 272, 502, 313; 375/227, 340, 341, 350, 232, 354, 308, 375/324, 343, 346, 326, 329; 342/174, 203, 342/601, 603, 613, 614, 159, 175, 89, 92; 379/399.01; 704/E21.004

See application file for complete search history.

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Primary Examiner — Vivian Chin

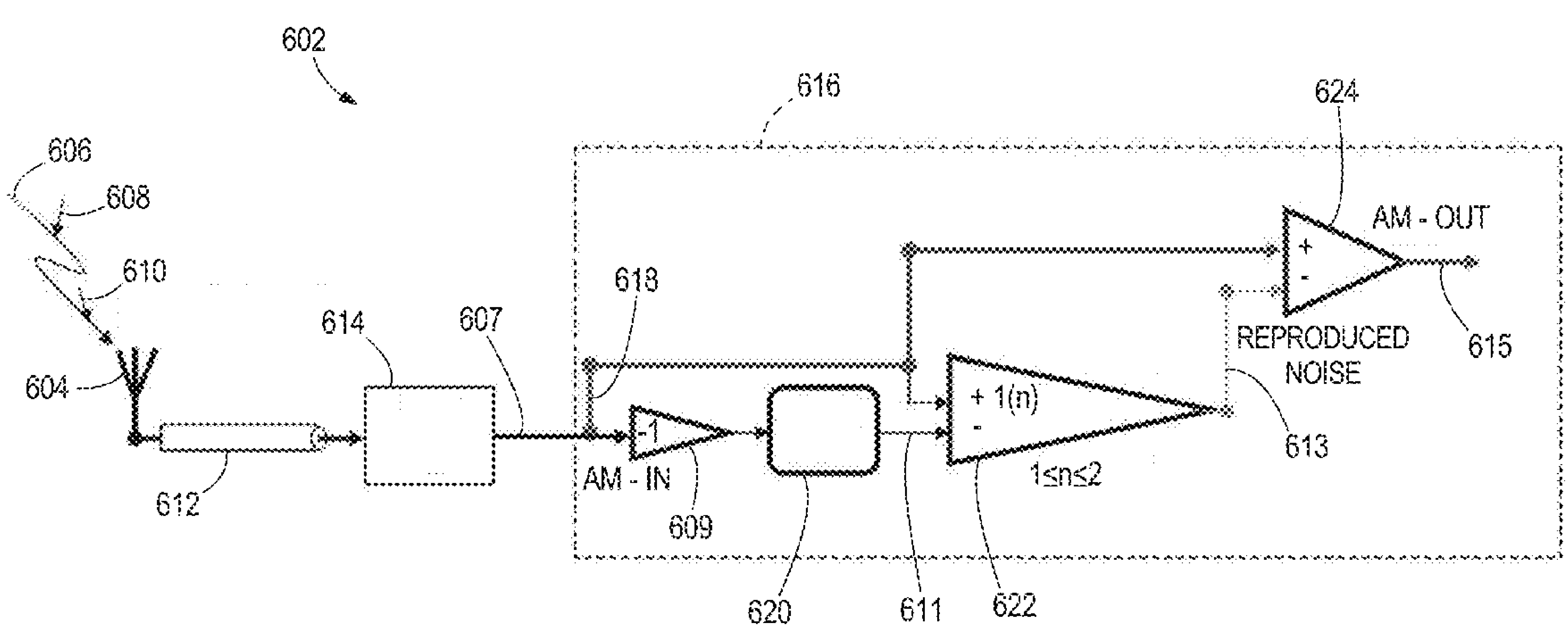
Assistant Examiner — Ubachukwu Odunukwe

(74) *Attorney, Agent, or Firm* — Klintworth & Rozenblat IP LLC

(57) **ABSTRACT**

A computer-implemented method for reducing a noise signal added to an amplitude modulated (AM) broadcast signal while travelling from a broadcasting antenna to a receiving antenna is provided. The method includes capturing a signal representative of the AM broadcast signal corrupted by the noise signal via the receiving antenna, inverting the captured signal, and determining a carrying frequency of the AM broadcast signal and delaying the inverted waveform by a fraction of a cycle of the carrying frequency. The method further includes generating a difference signal by subtractively combining the captured signal and the delayed inverted signal, generating an estimate noise signal by reducing an amplitude of the generated difference signal using a noise-reduction control multiplier, and minimizing the corrupting noise signal component of the captured signal by subtractively combining the captured signal and the generated estimate noise signal.

20 Claims, 25 Drawing Sheets



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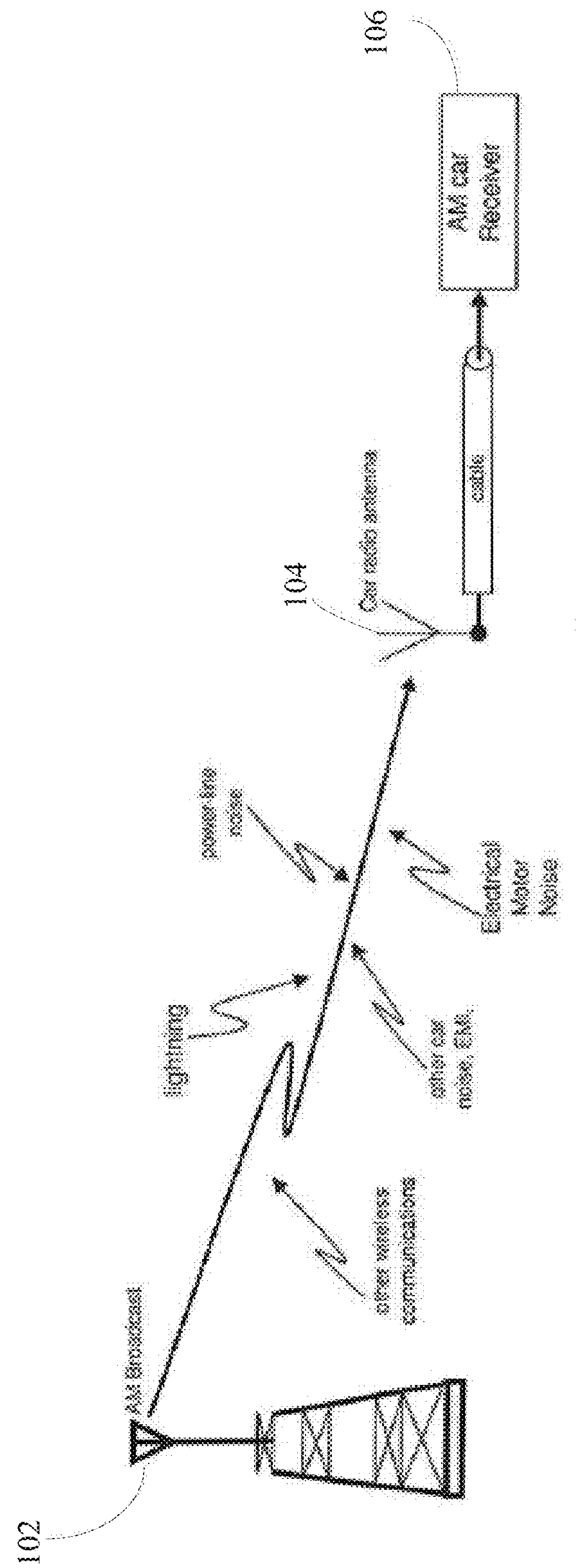
106
AM car Receiver
cable
104
Car radio antenna
power line noise
Electrical Motor Noise
lightning
other car noise, EMI
other wireless communications
AM Broadcast
102

Figure 1

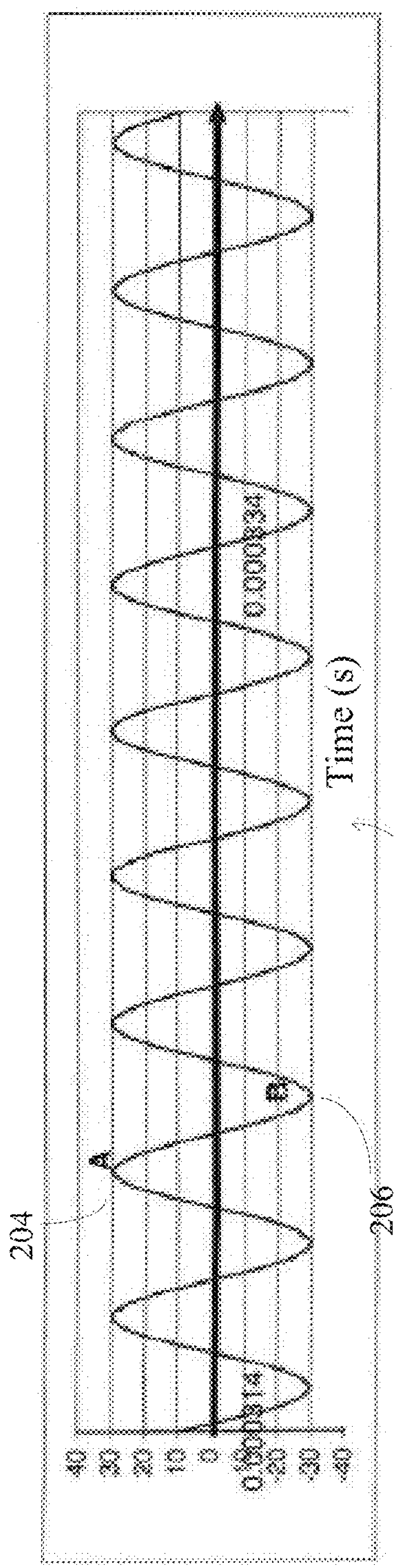

Figure 2A

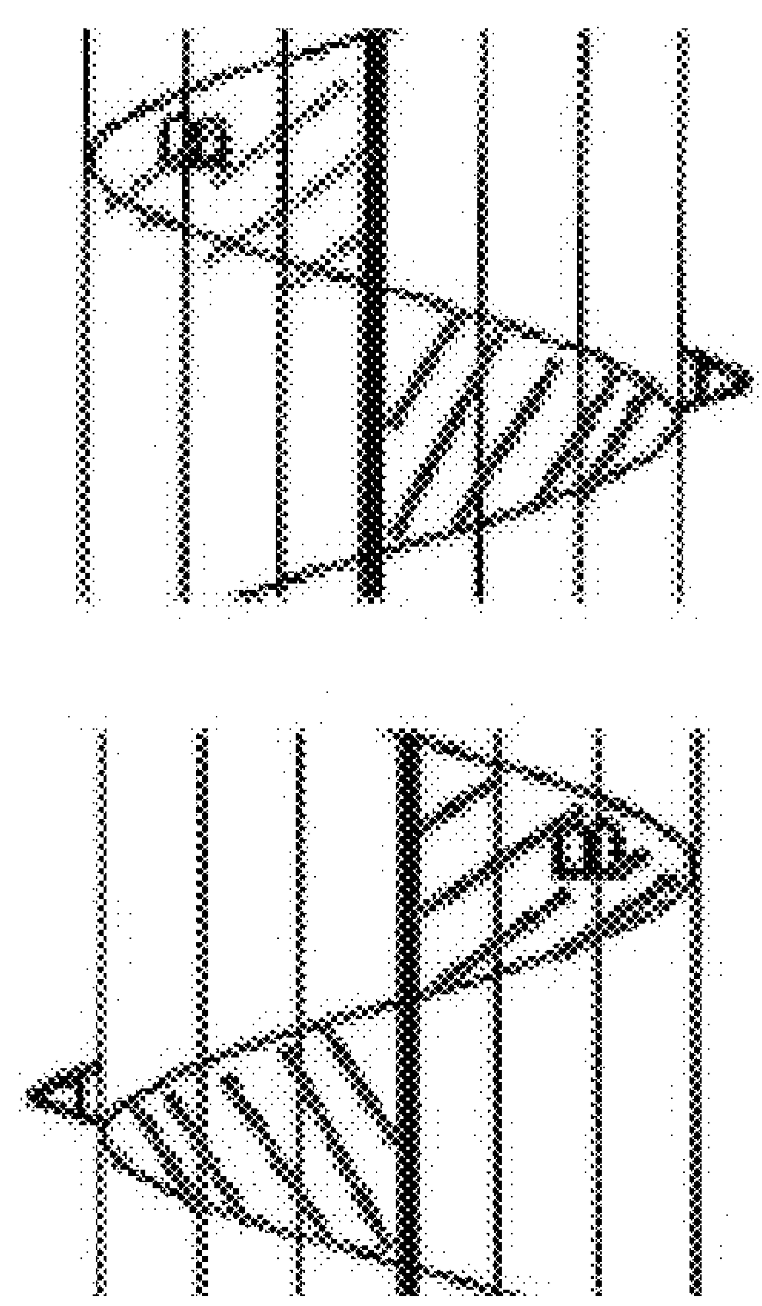

Figure 2B

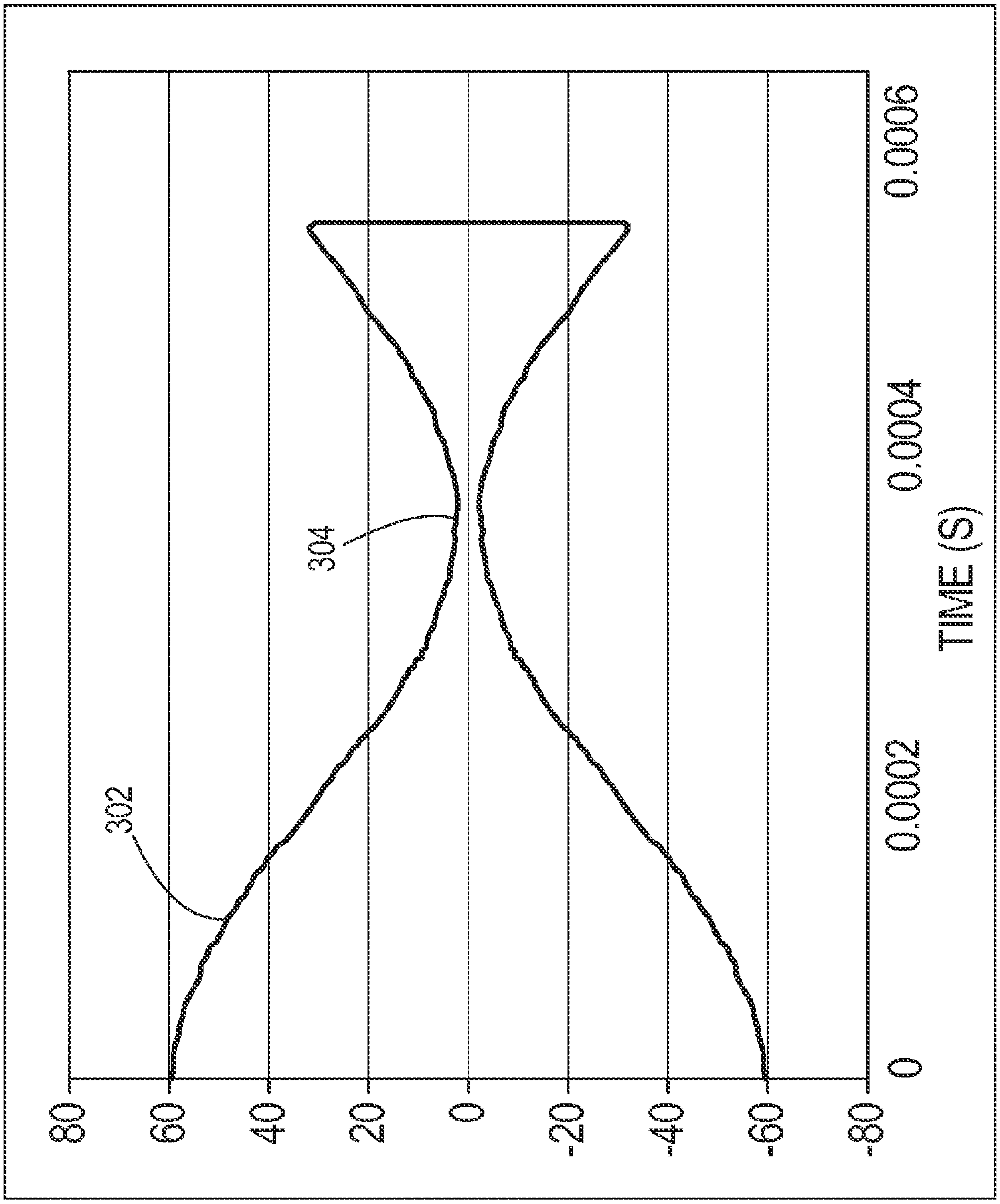

FIG. 3

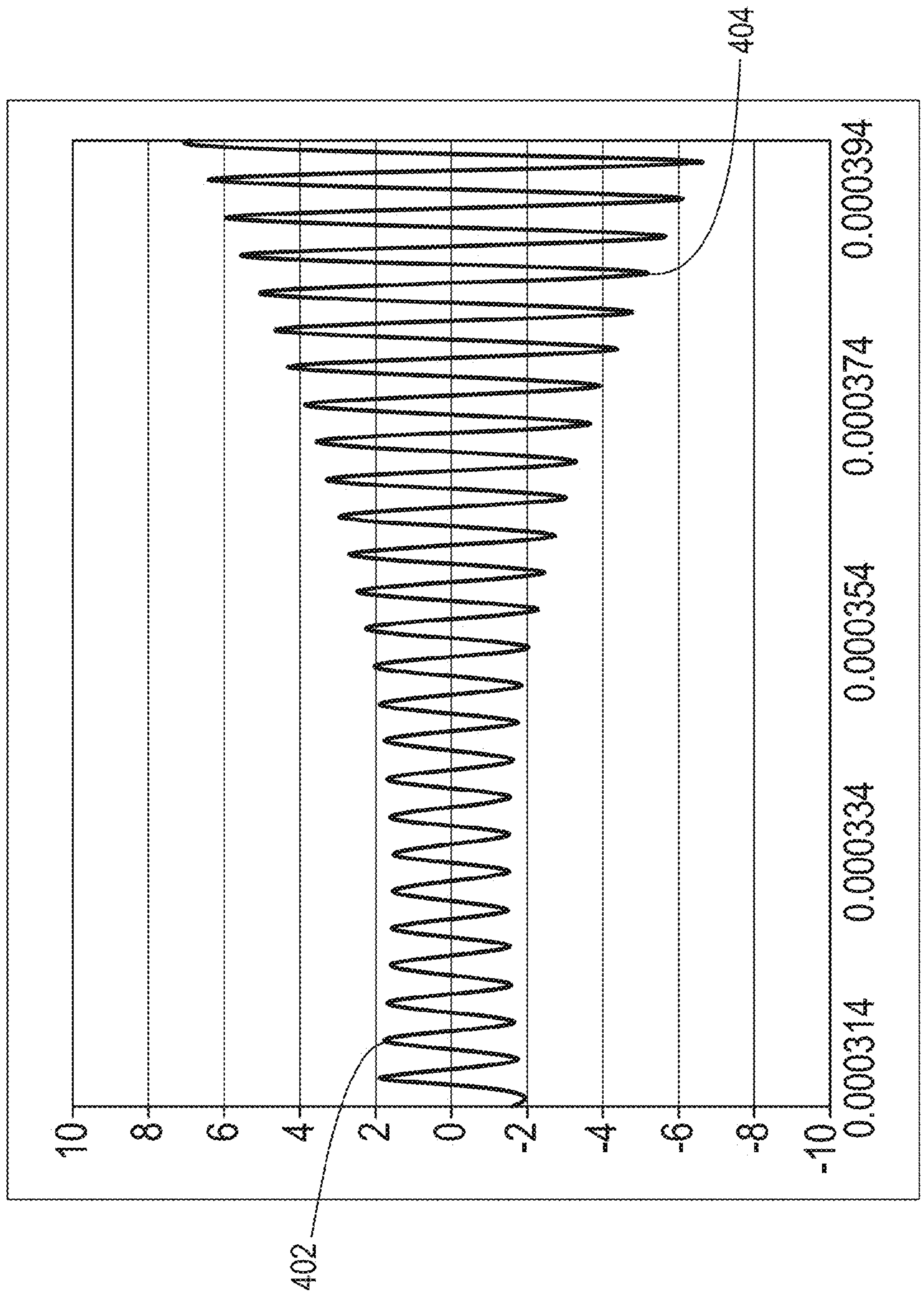
10
8
6
4
2
0
-2
-4
-6
-8
-10
0.000314
0.000334
0.000354
0.000374
0.000394
402
404

FIG. 4

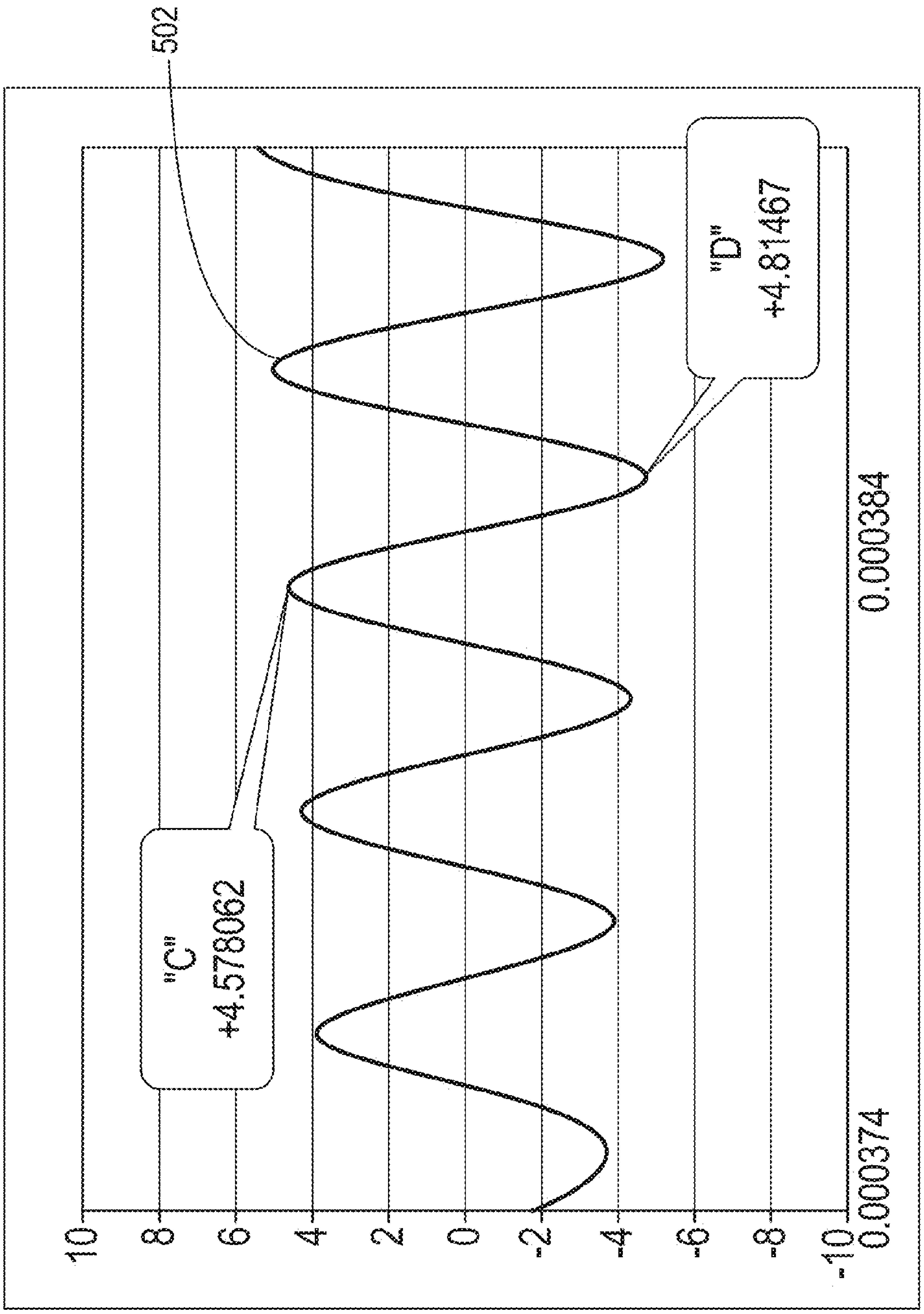

FIG. 5

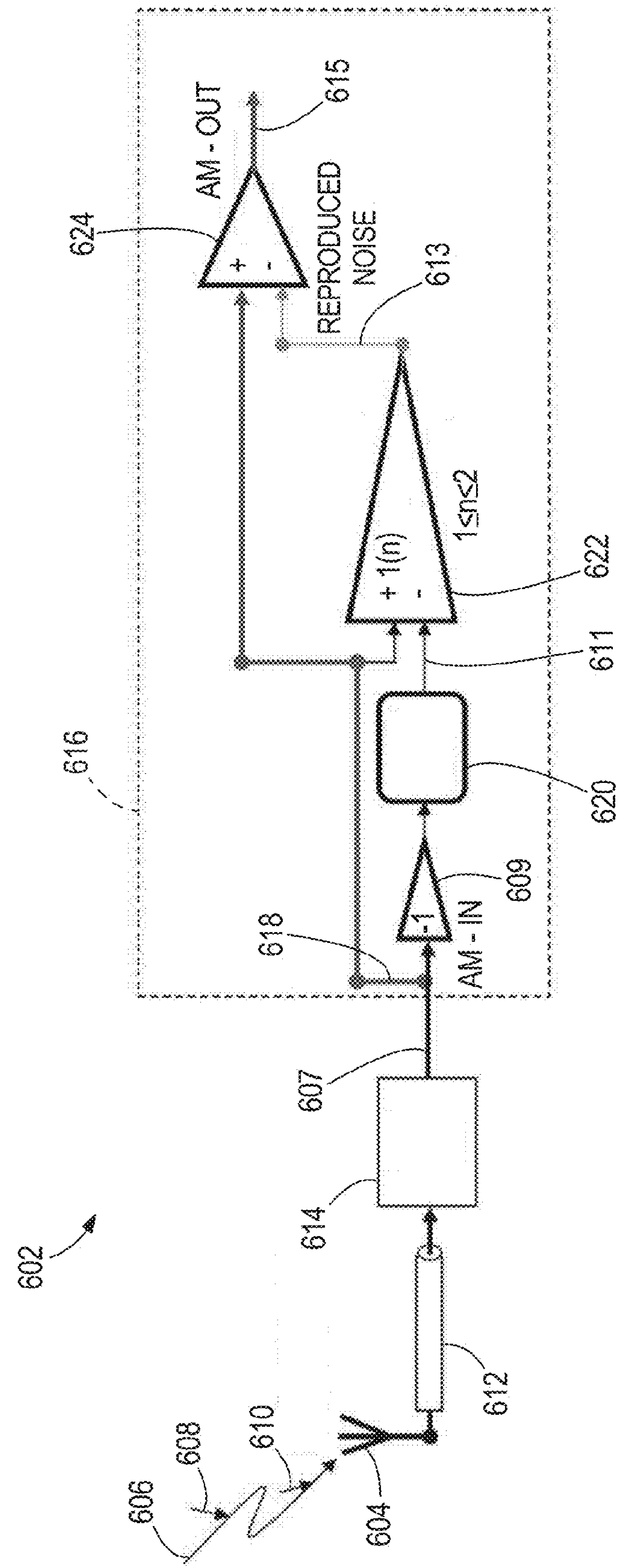
602
604
606
608
610
612
614
607
616
618
AM - IN
-1
609
620
611
+ 1(n)
-
1≤n≤2
622
613
REPRODUCED NOISE
+
-
624
AM - OUT
615

FIG. 6

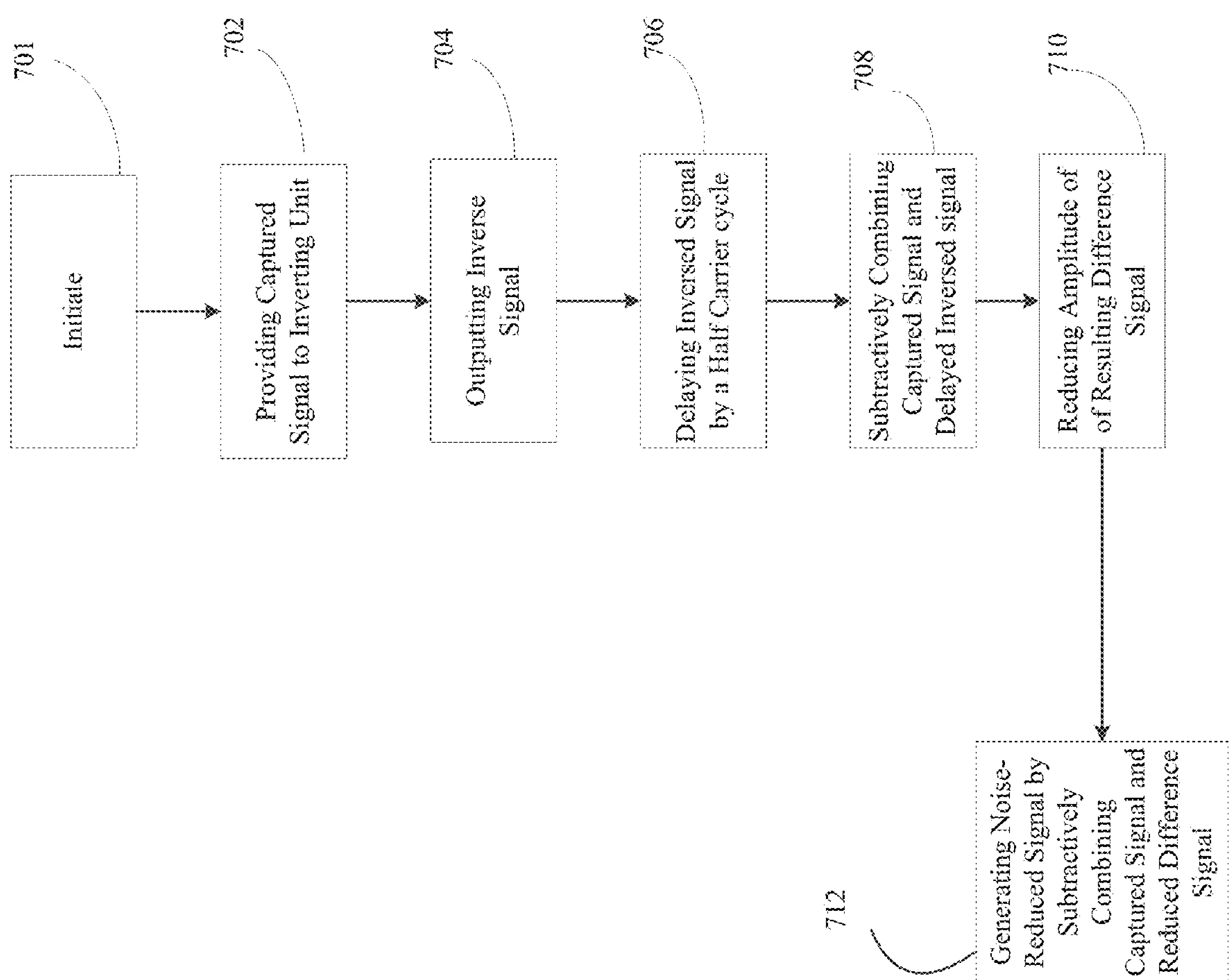
701
Initiate
702
Providing Captured Signal to Inverting Unit
704
Outputting Inverse Signal
706
Delaying Inversed Signal by a Half Carrier cycle
708
Subtractively Combining Captured Signal and Delayed Inversed signal
710
Reducing Amplitude of of Resulting Difference Signal
712
Generating Noise-Reduced Signal by Subtractively Combining Captured Signal and Reduced Difference Signal

Figure 7

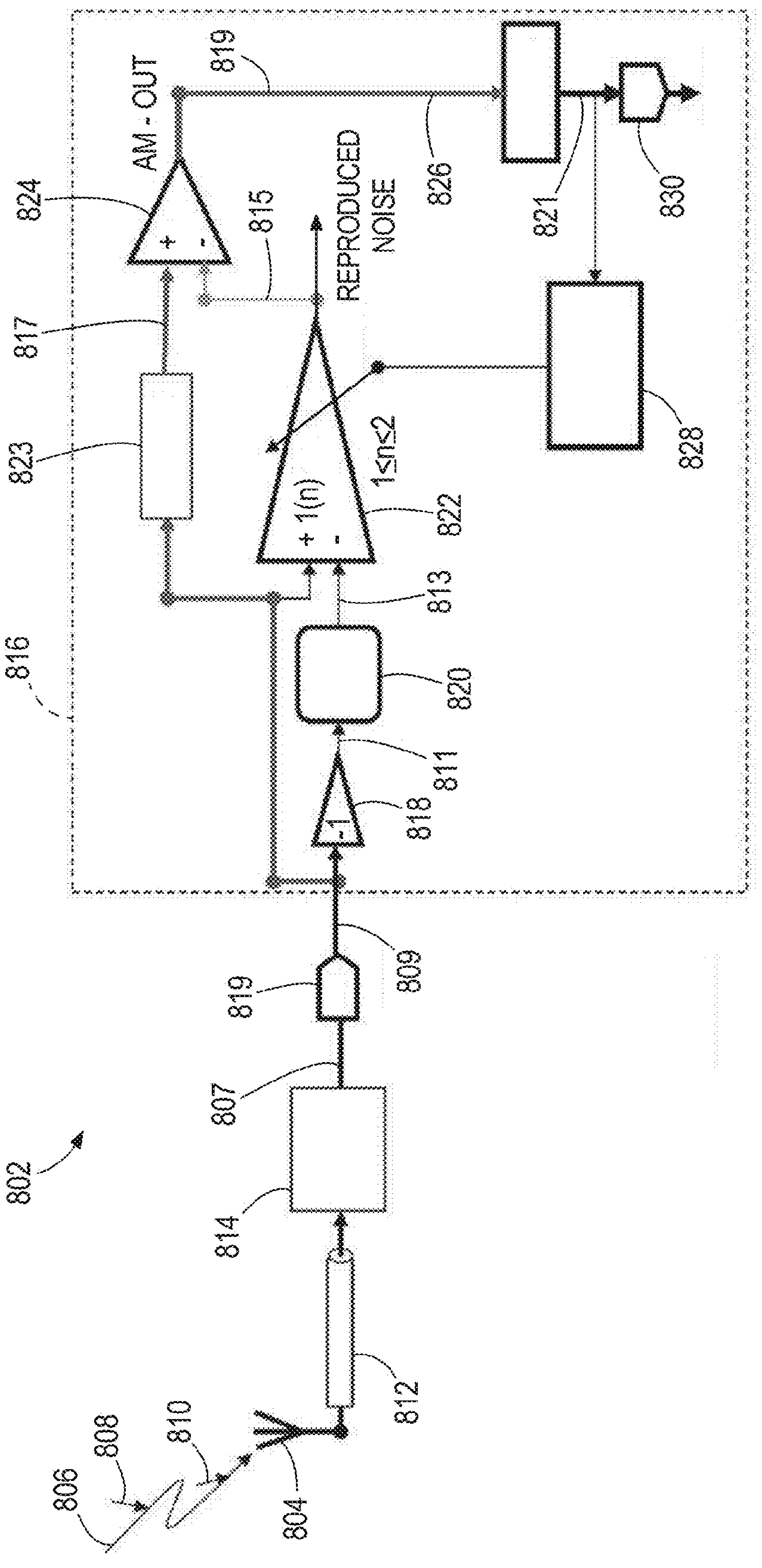
802
806
808
810
804
812
814
807
819
809
816
818
-1
811
820
813
822
+ 1(n)
-
1≤n≤2
823
817
828
824
+
-
AM - OUT
815
REPRODUCED
NOISE
819
826
821
830

FIG. 8

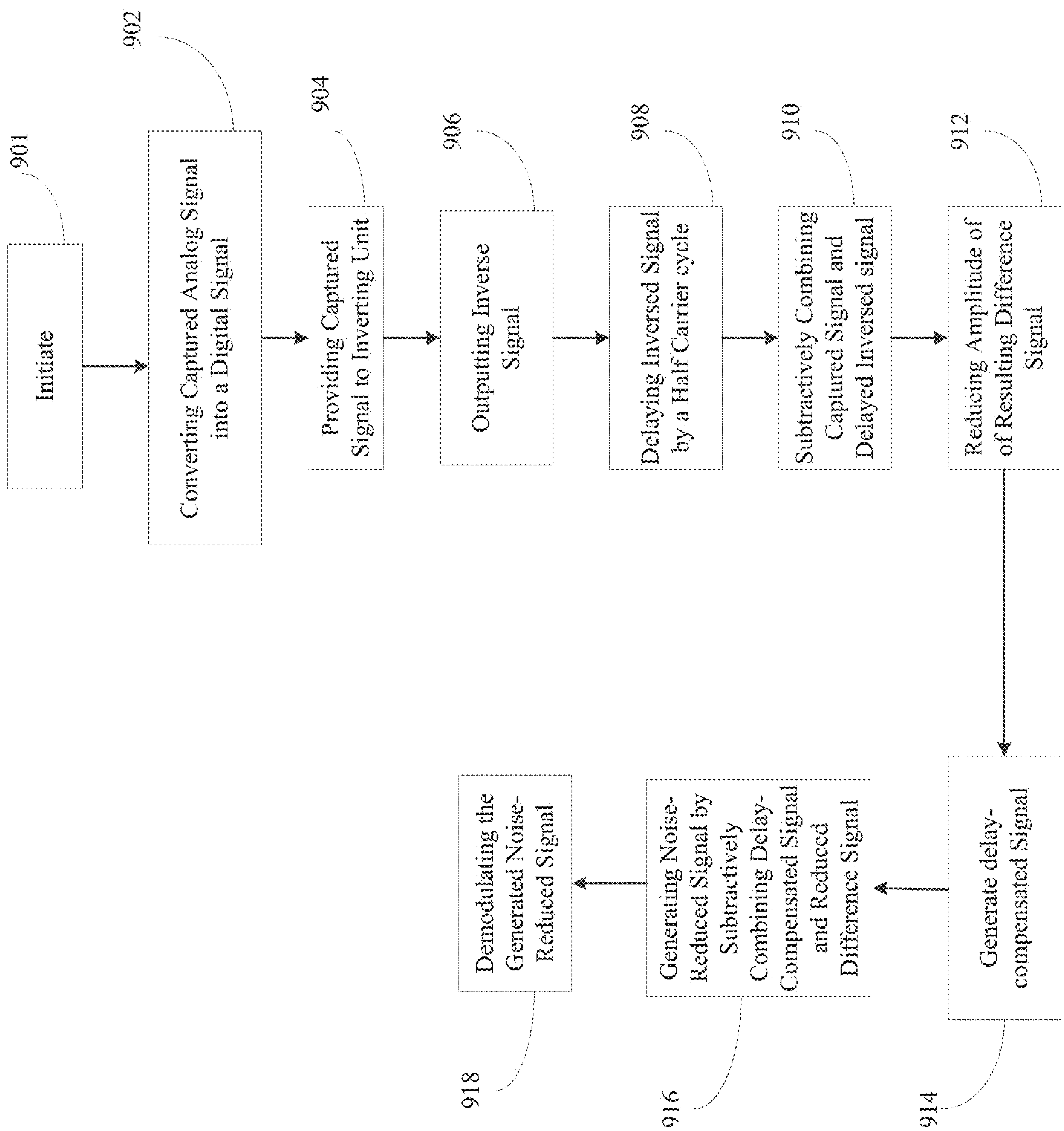
Initiate
901
Converting Captured Analog Signal into a Digital Signal
902
Providing Captured Signal to Inverting Unit
904
Outputting Inverse Signal
906
Delaying Inversed Signal by a Half Carrier cycle
908
Subtractively Combining Captured Signal and Delayed Inversed signal
910
Reducing Amplitude of of Resulting Difference Signal
912
Generate delay-compensated Signal
914
Generating Noise-Reduced Signal by Subtractively Combining Delay-Compensated Signal and Reduced Difference Signal
916
Demodulating the Generated Noise-Reduced Signal
918

Figure 9

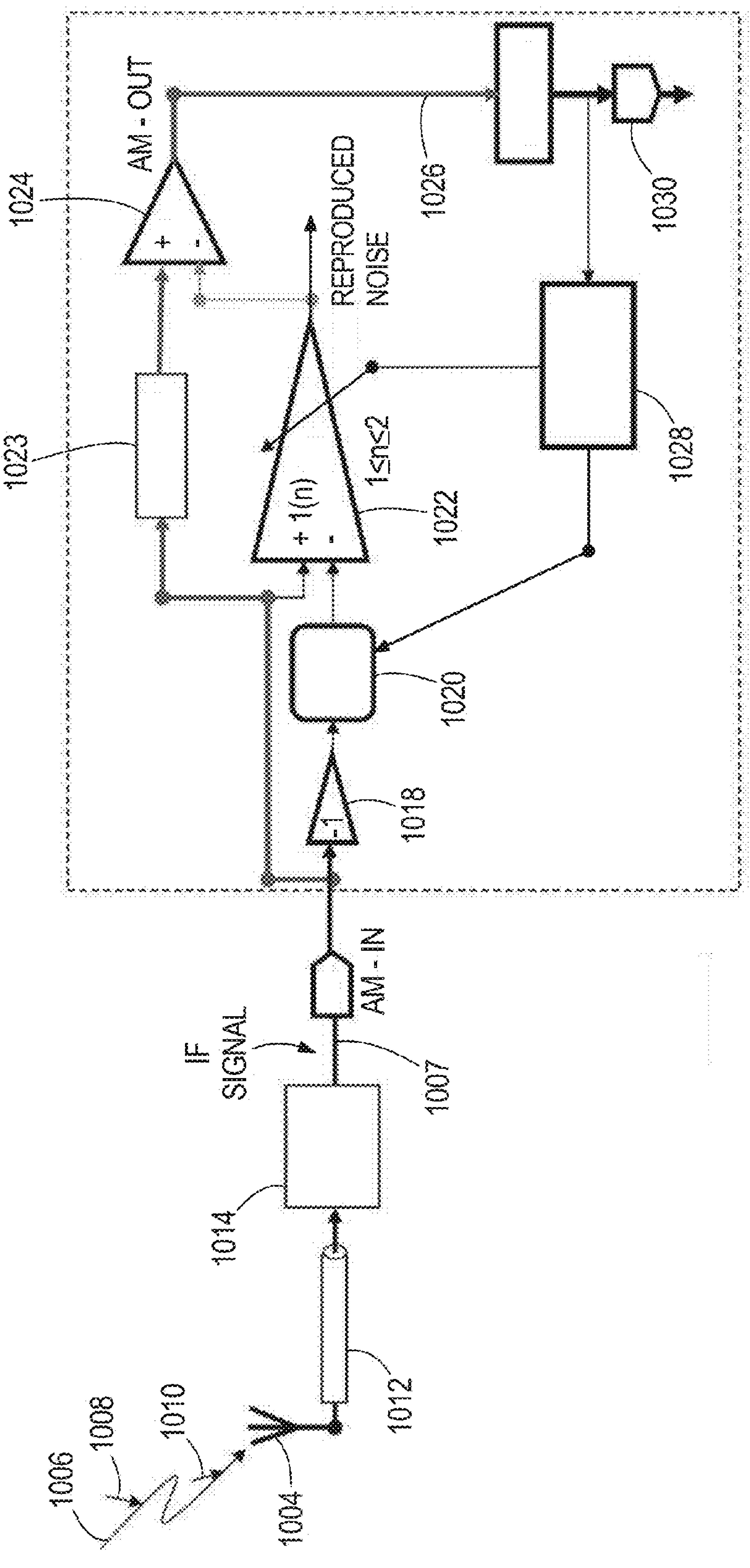
1006
1008
1010
1004
1012
1014
IF SIGNAL
1007
AM - IN
1018
-1
1020
1022
+ 1(n)
-
1≤n≤2
1023
1024
+
-
AM - OUT
REPRODUCED NOISE
1026
1028
1030

FIG. 10

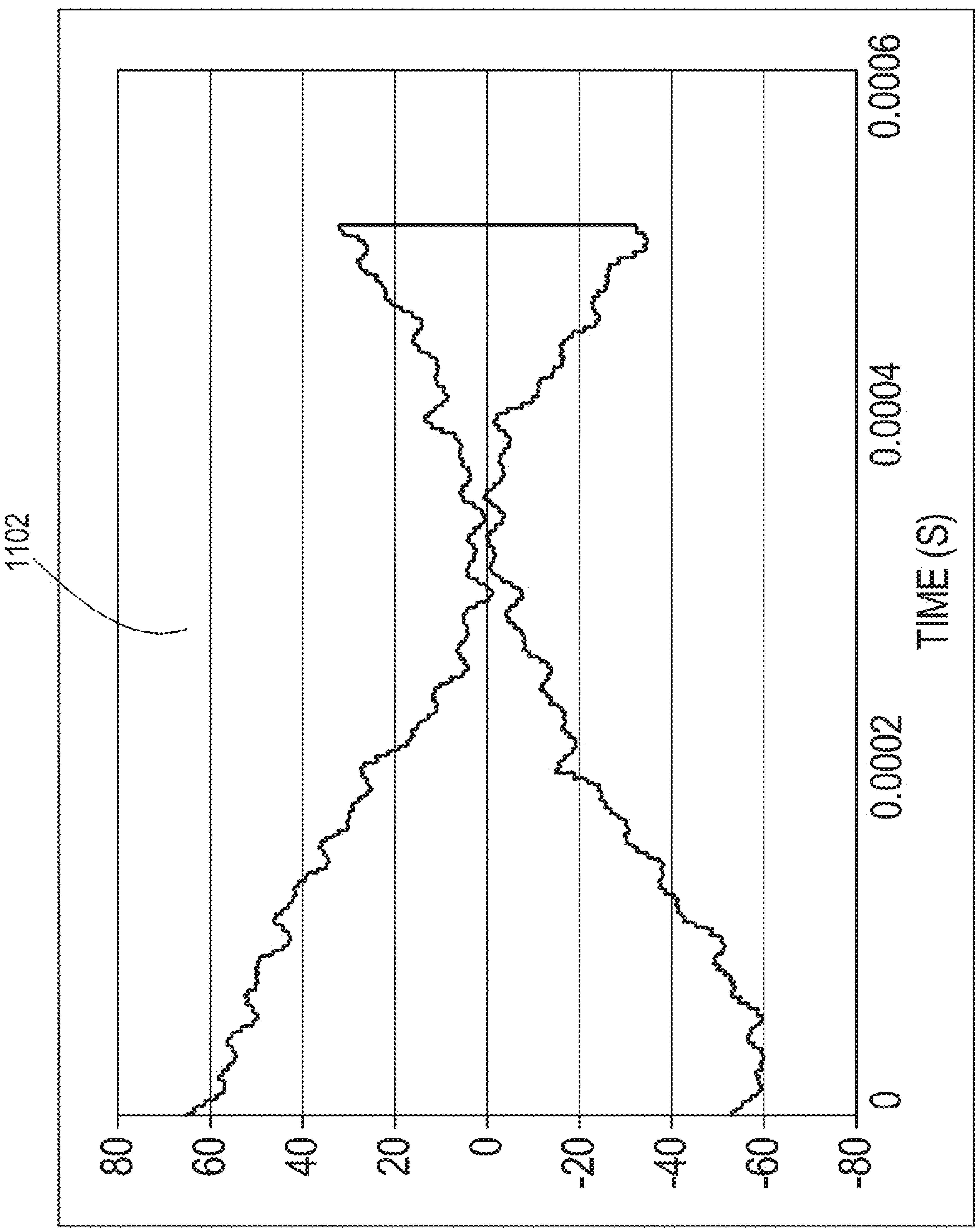

FIG. 11A

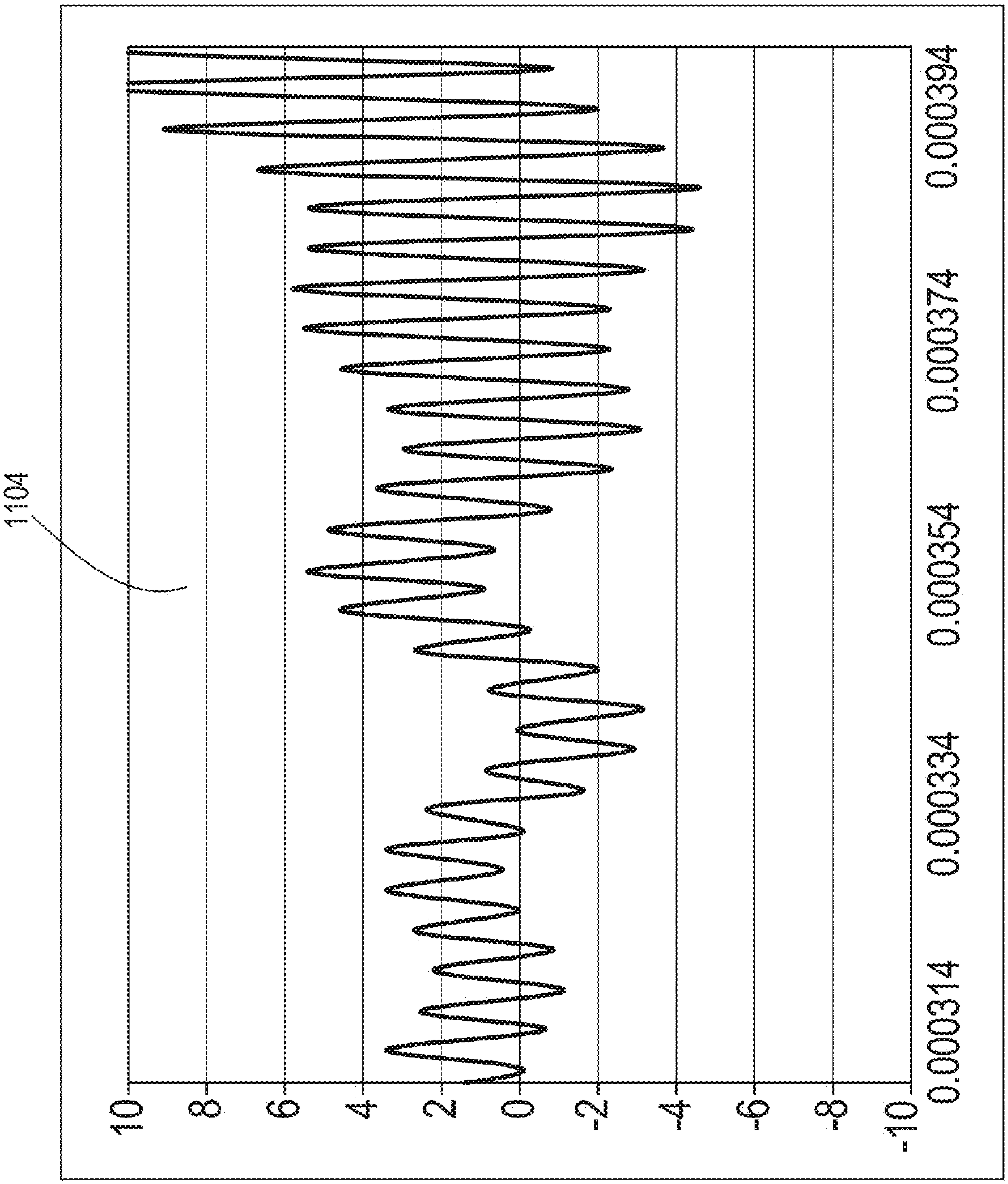
1104
10
8
6
4
2
0
-2
-4
-6
-8
-10
0.000314
0.000334
0.000354
0.000374
0.000394

FIG. 11B

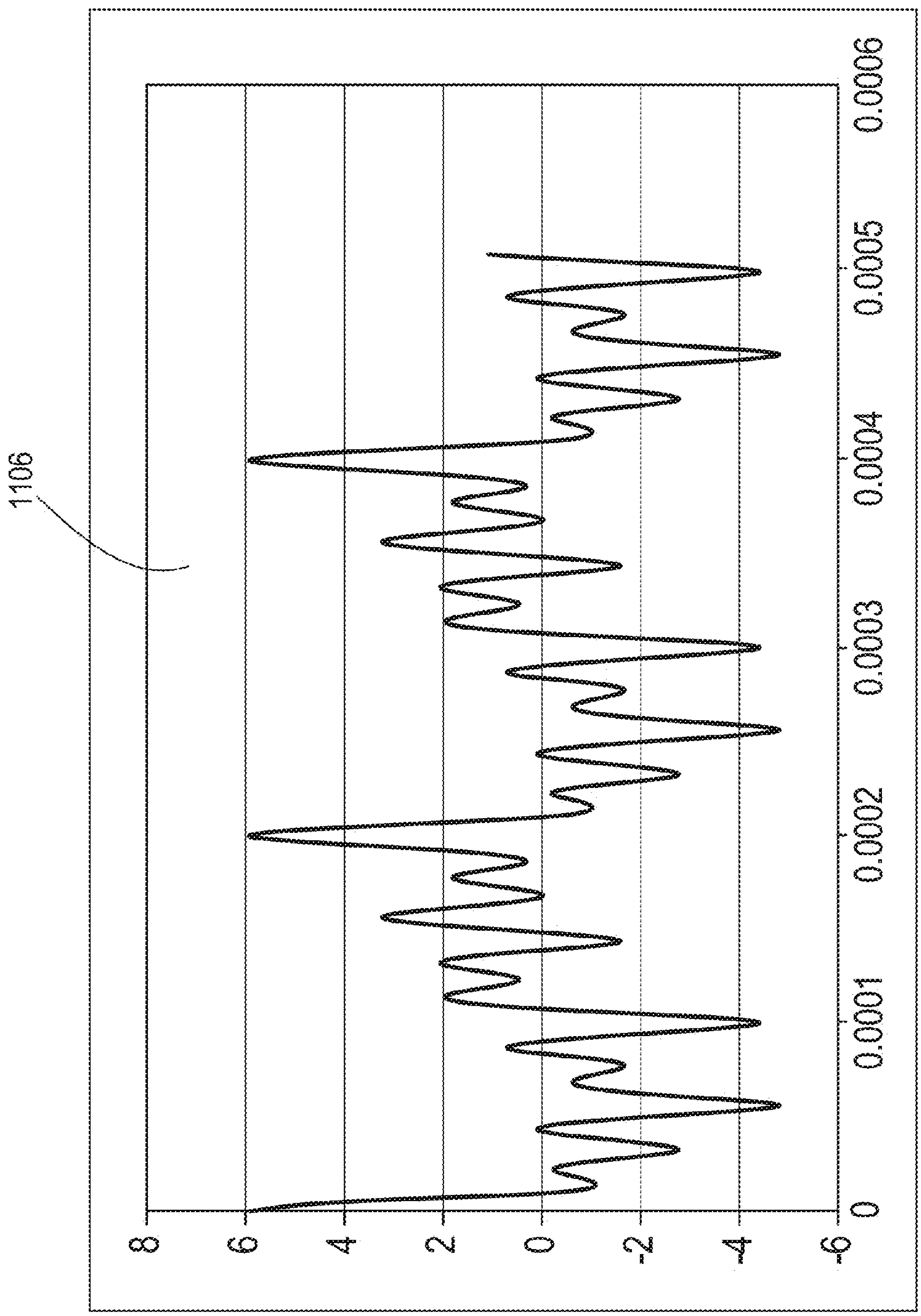

FIG. 11C

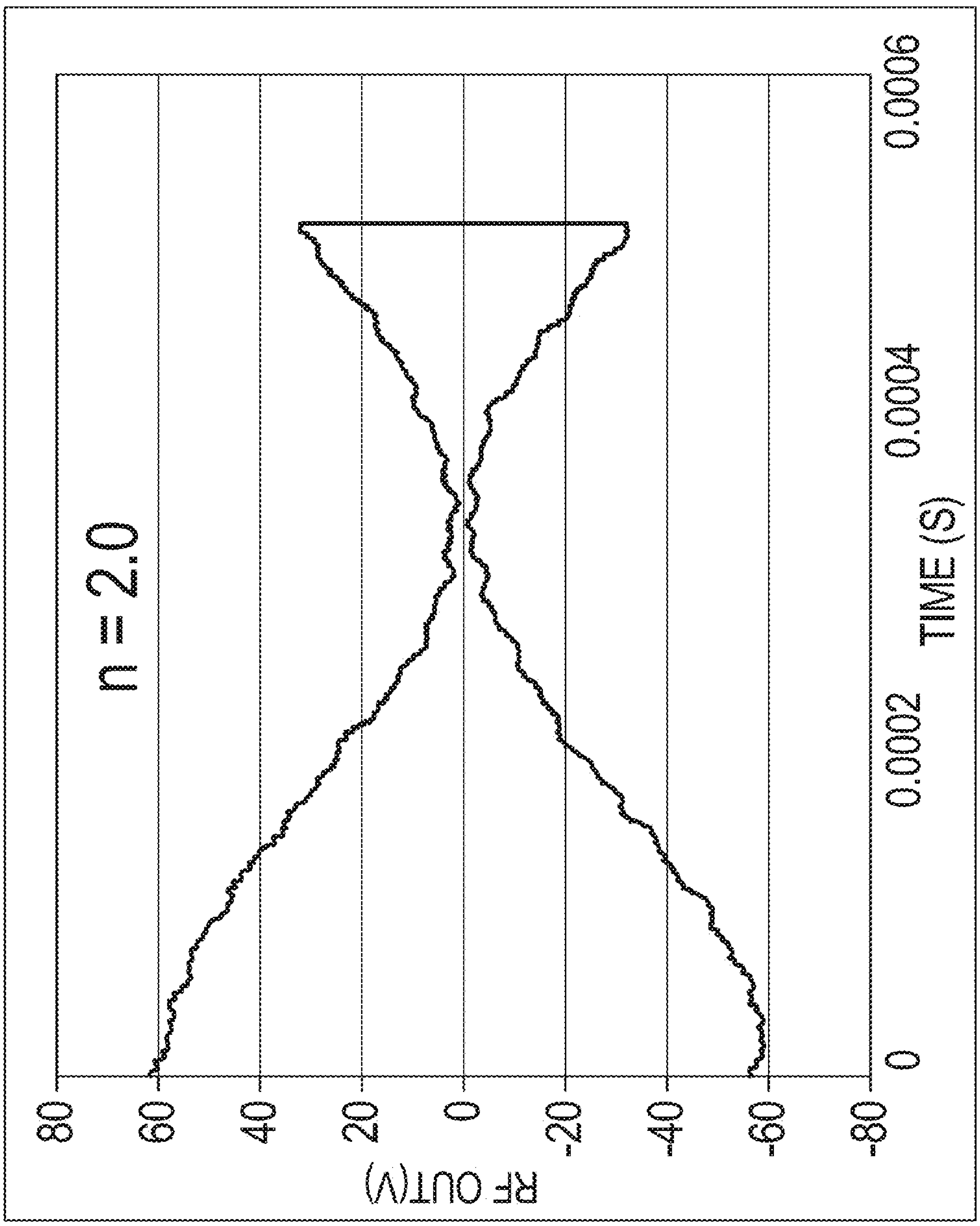

FIG. 12A

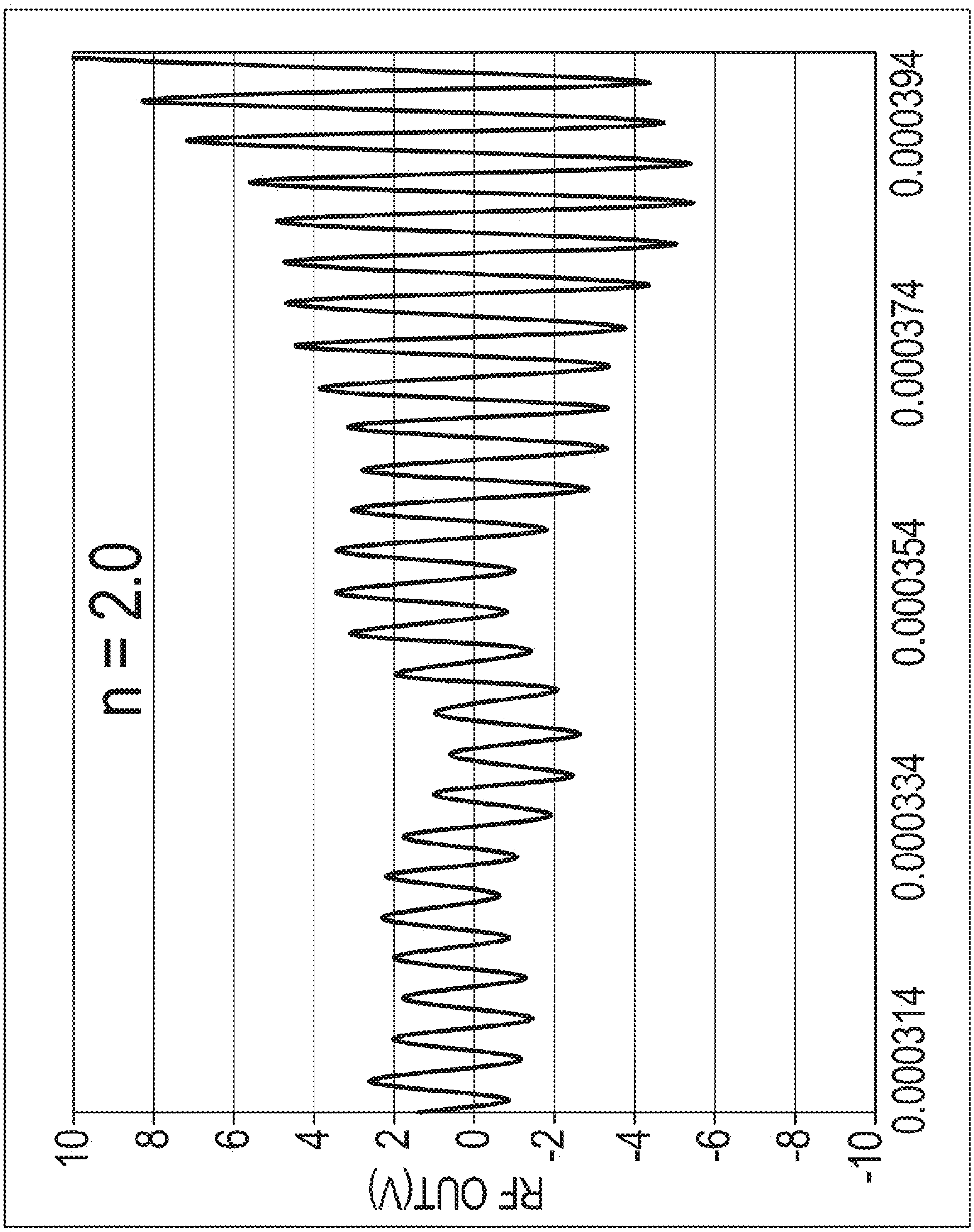
n = 2.0
RF OUT(V)
10
8
6
4
2
0
-2
-4
-6
-8
-10
0.000314
0.000334
0.000354
0.000374
0.000394

FIG. 12B

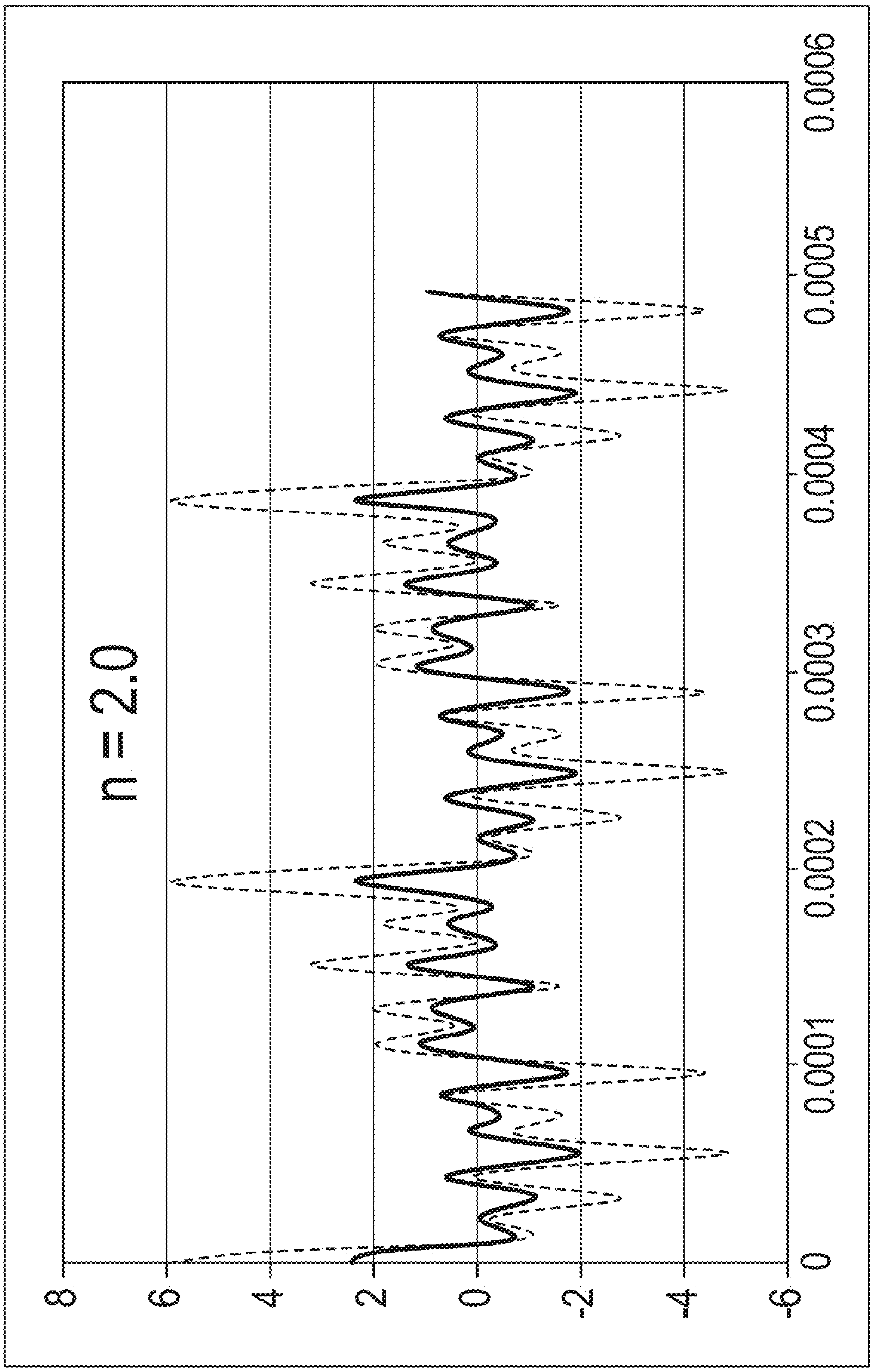

FIG. 12C

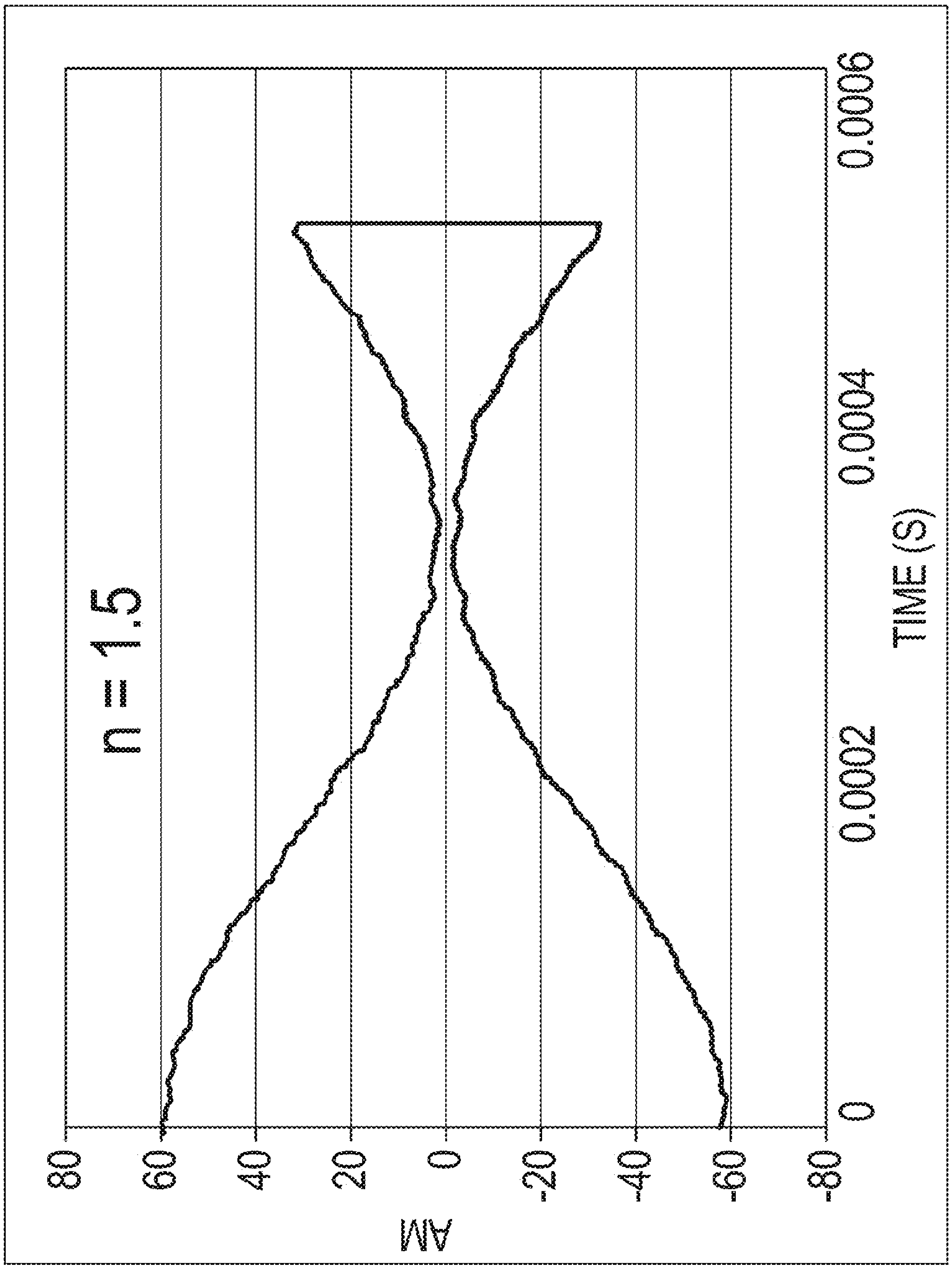

FIG. 13A

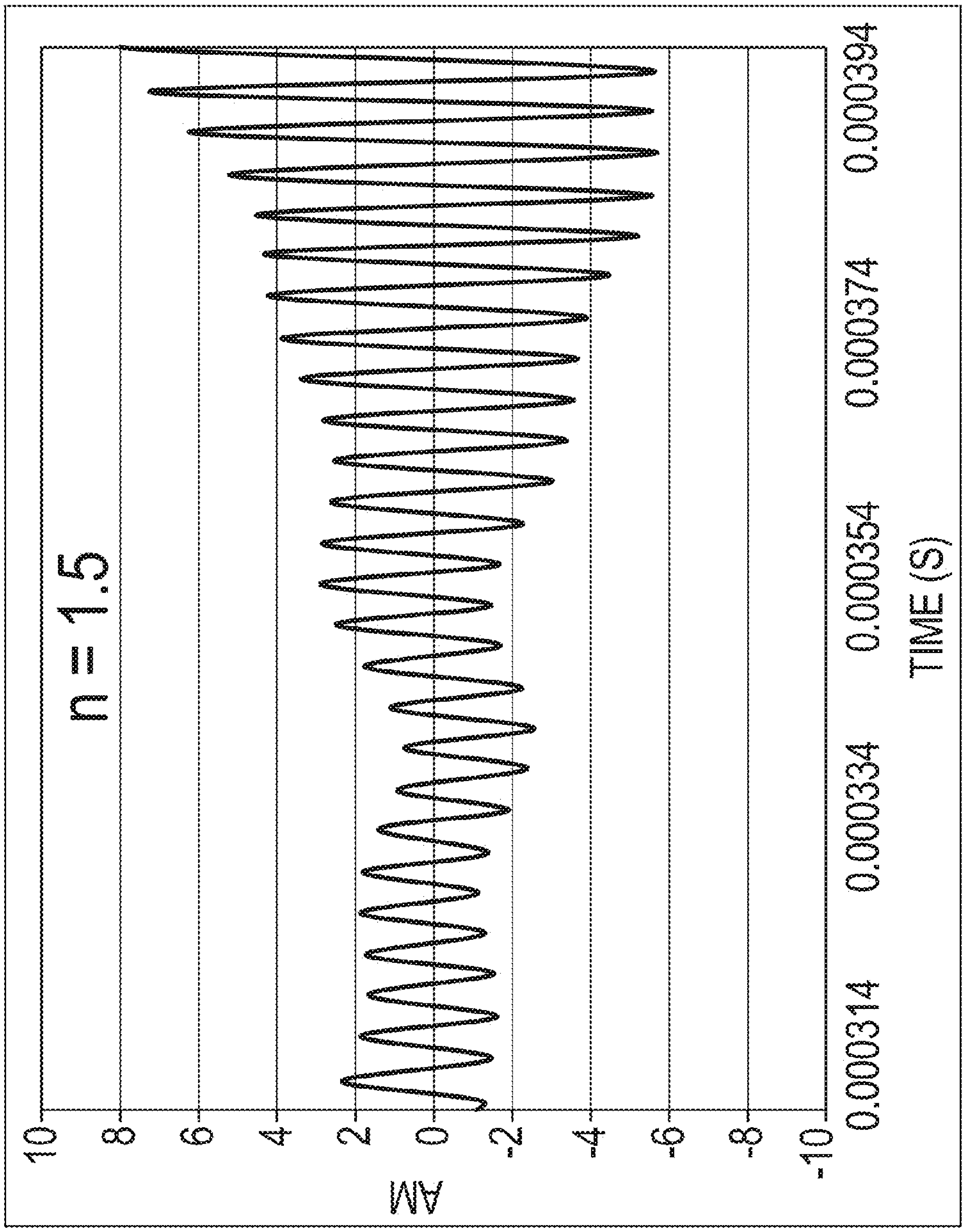
n = 1.5
AM
10
8
6
4
2
0
-2
-4
-6
-8
-10
0.000314
0.000334
0.000354
0.000374
0.000394
TIME (S)

FIG. 13B

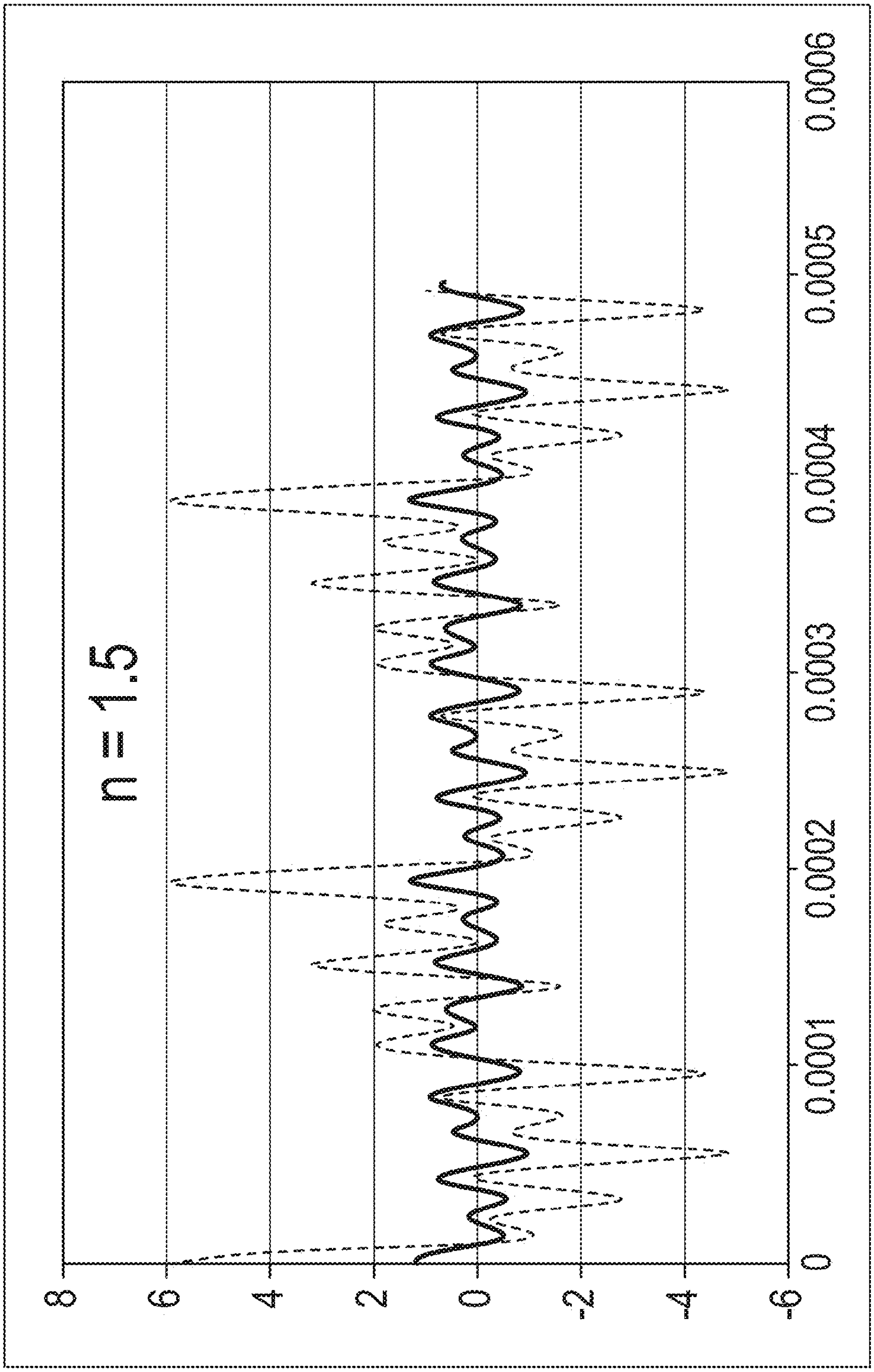

FIG. 13C

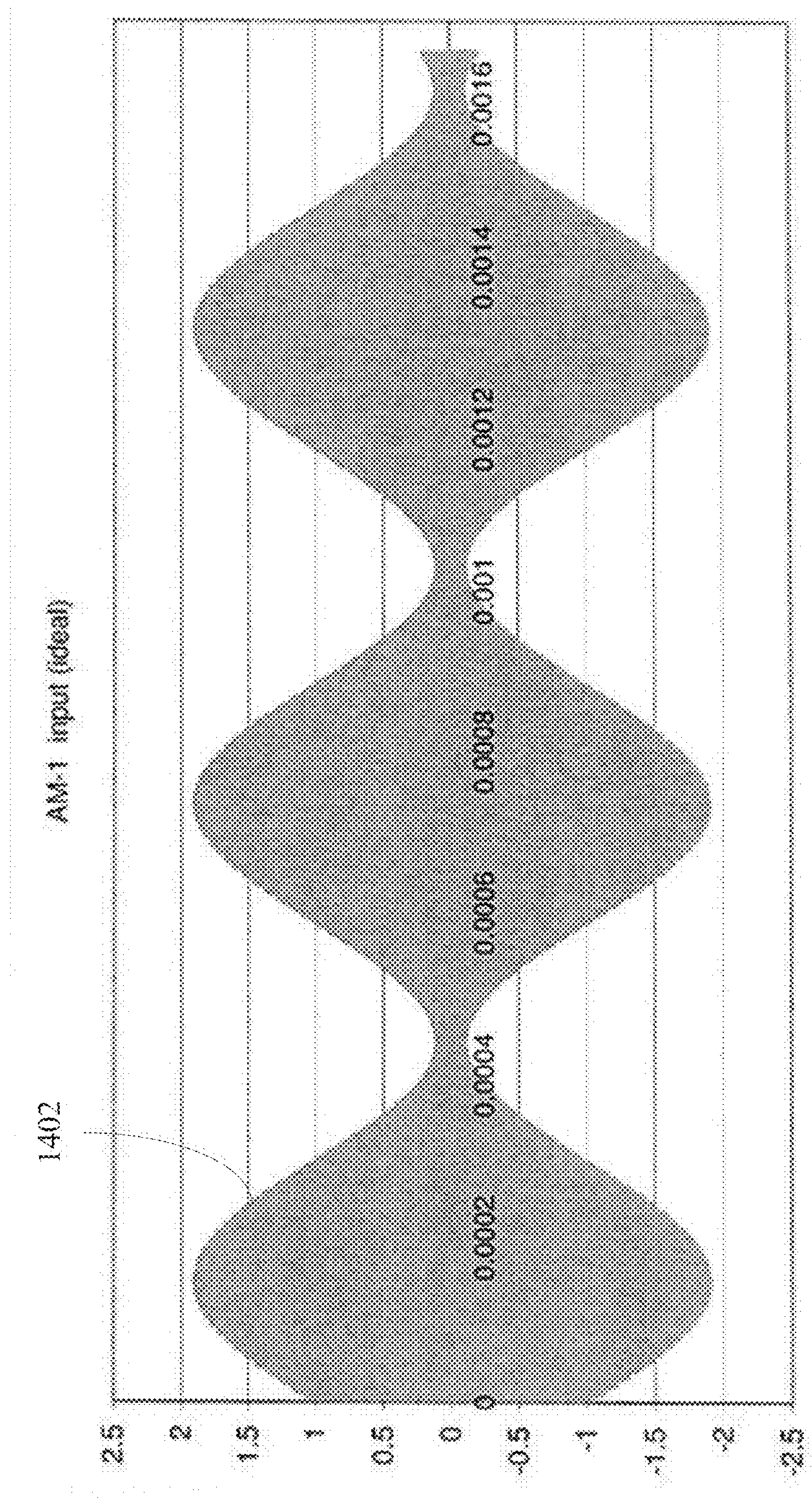
AM-1 input (ideal)
1402
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
0
0.0002
0.0004
0.0006
0.0008
0.001
0.0012
0.0014
0.0016

Figure 14

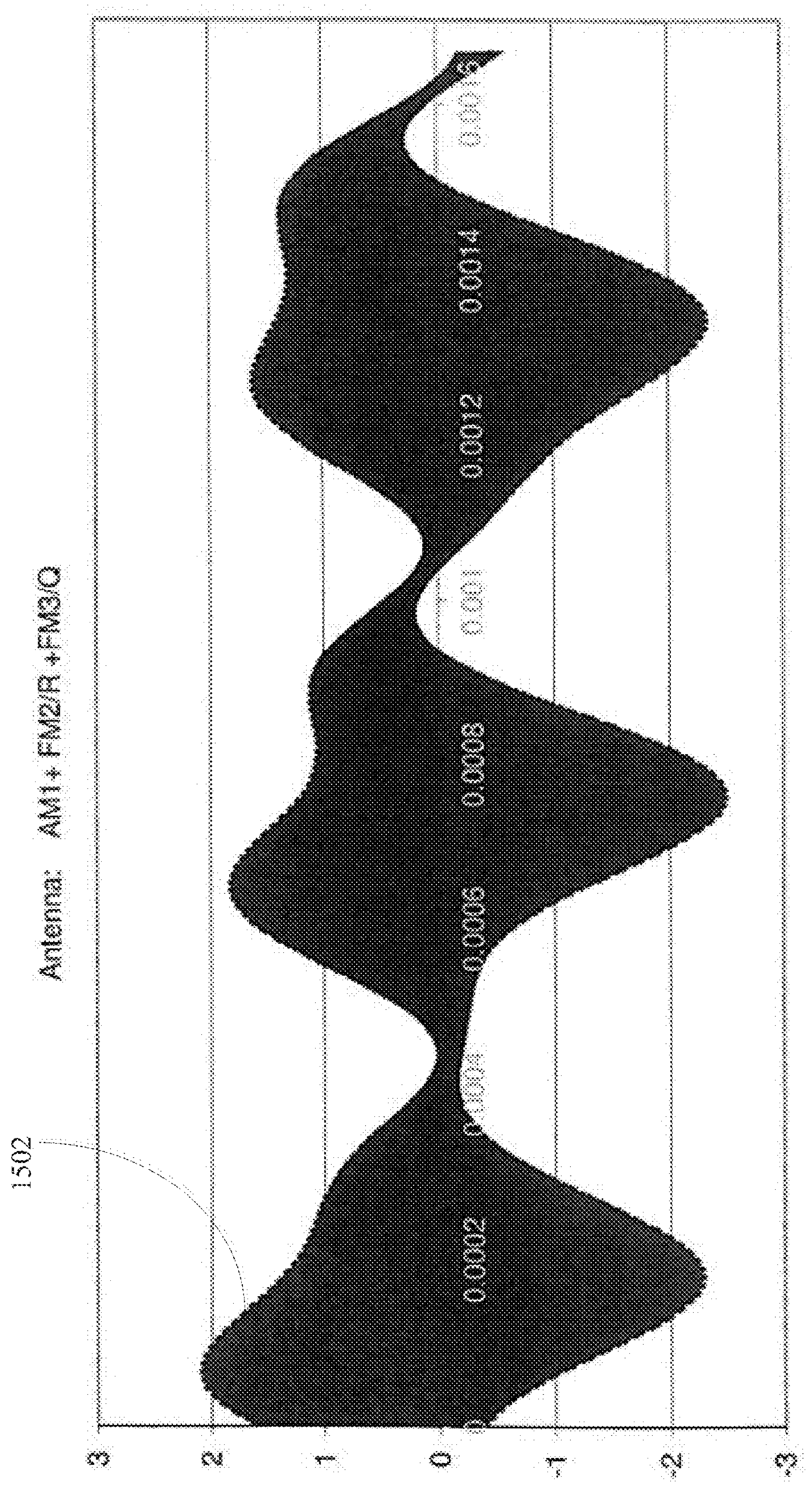
Antenna: AM1+ FM2/R +FM3/Q
1502
3
2
1
0
-1
-2
-3
0.0002
0.0006
0.0008
0.001
0.0012
0.0014

Figure 15

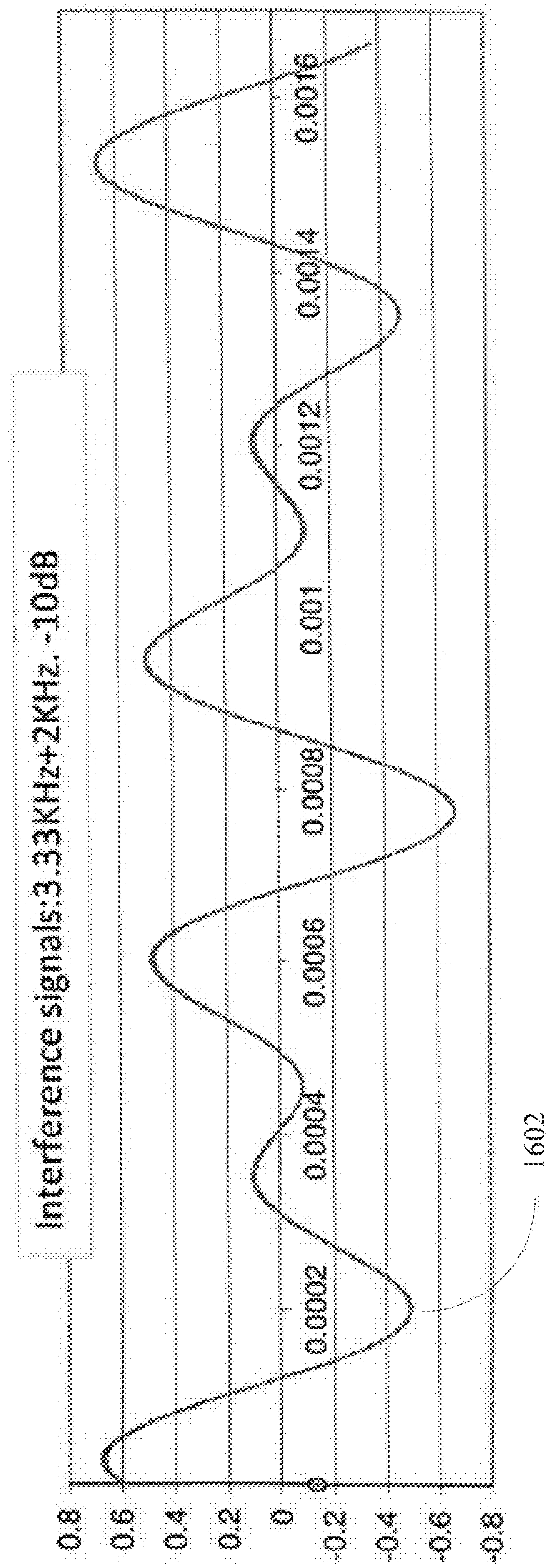
Interference signals:3.33KHz+2KHz, -10dB
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
0.0002
0.0004
0.0006
0.0008
0.001
0.0012
0.0014
0.0016
1602

Figure 16

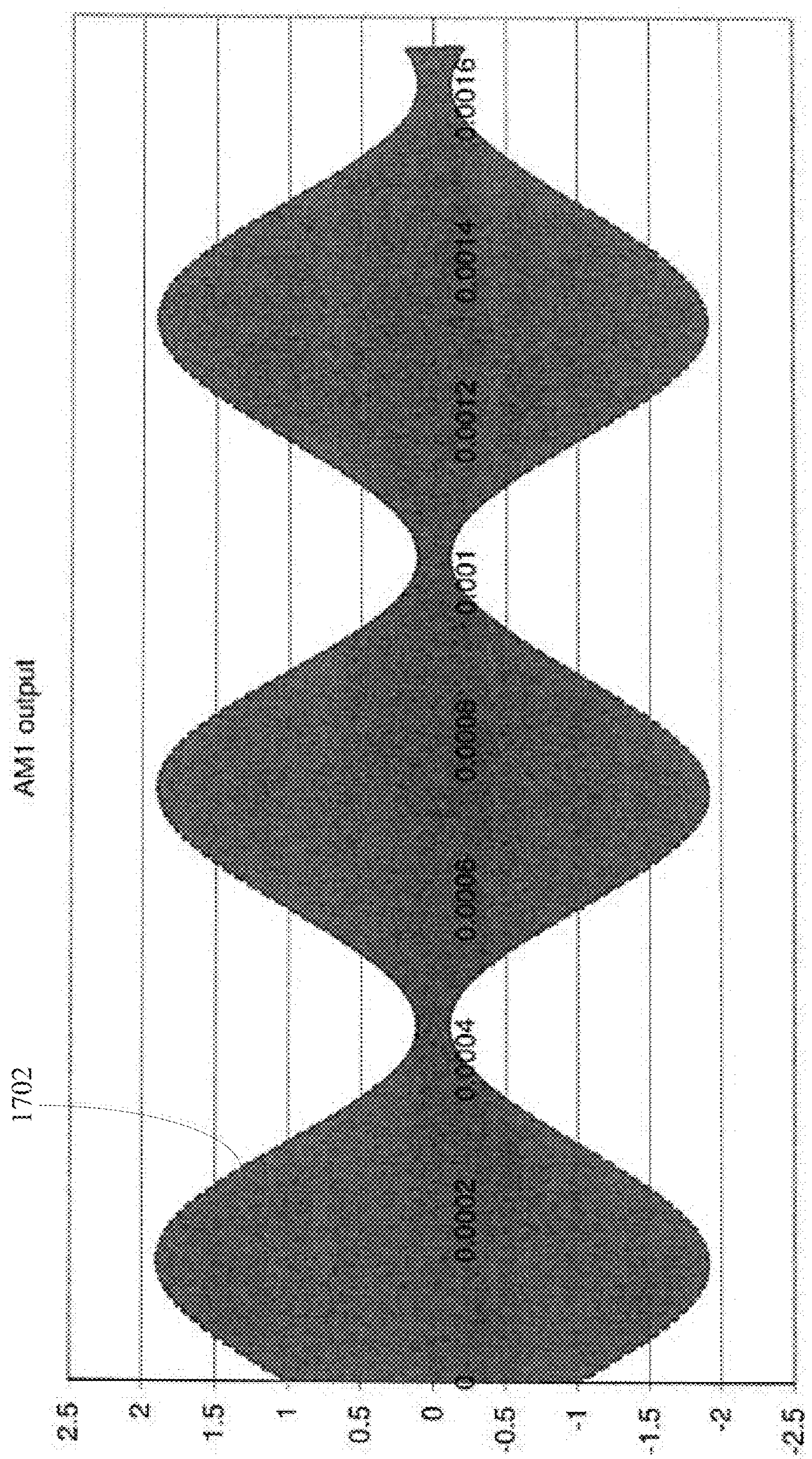
AM1 output
1702
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
0
0.0002
0.0004
0.0006
0.0008
0.001
0.0012
0.0014
0.0016

Figure 17

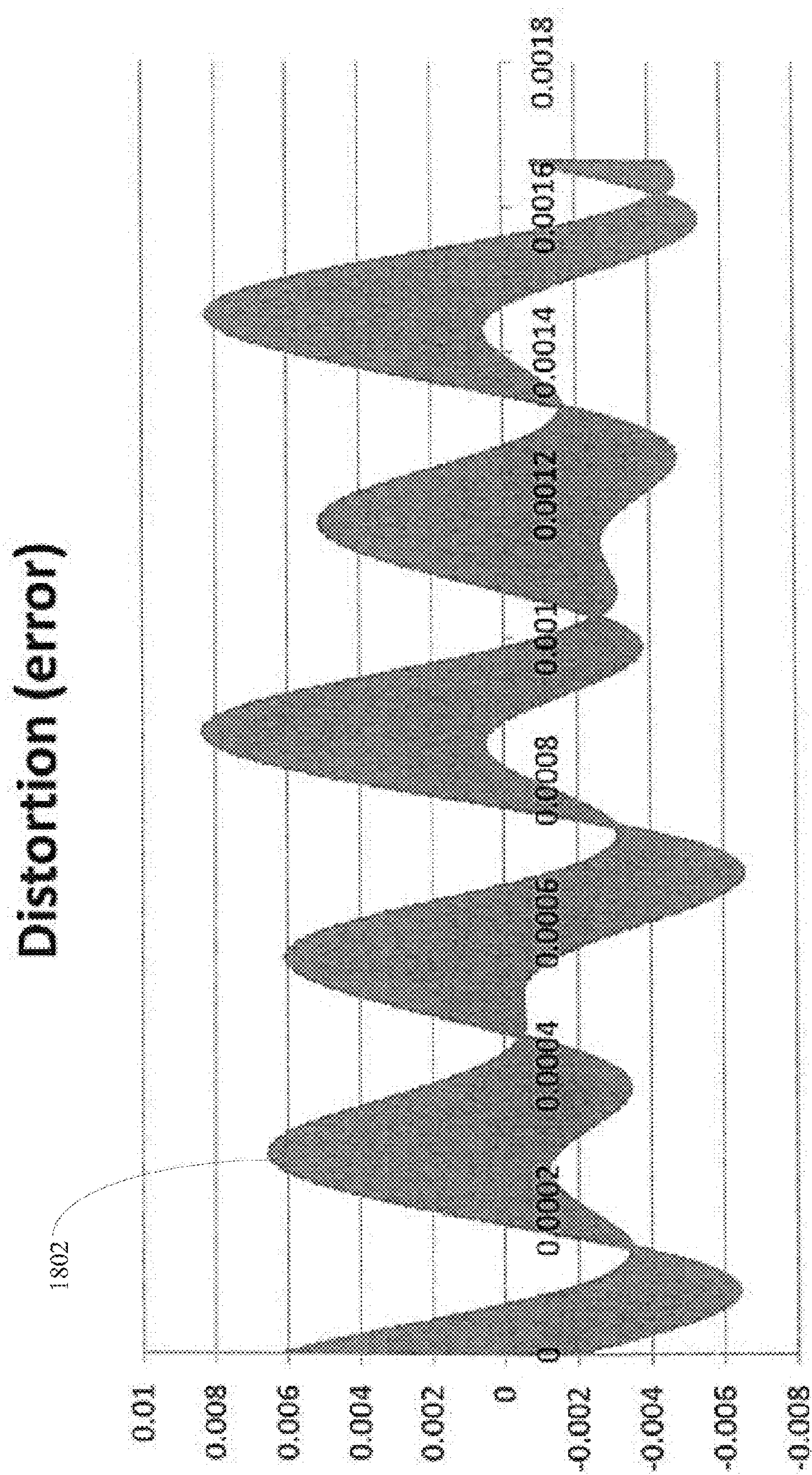
Distortion (error)
1802
0.01
0.008
0.006
0.004
0.002
0
-0.002
-0.004
-0.006
-0.008
0
0.0002
0.0004
0.0006
0.0008
0.001
0.0012
0.0014
0.0016
0.0018

Figure 18

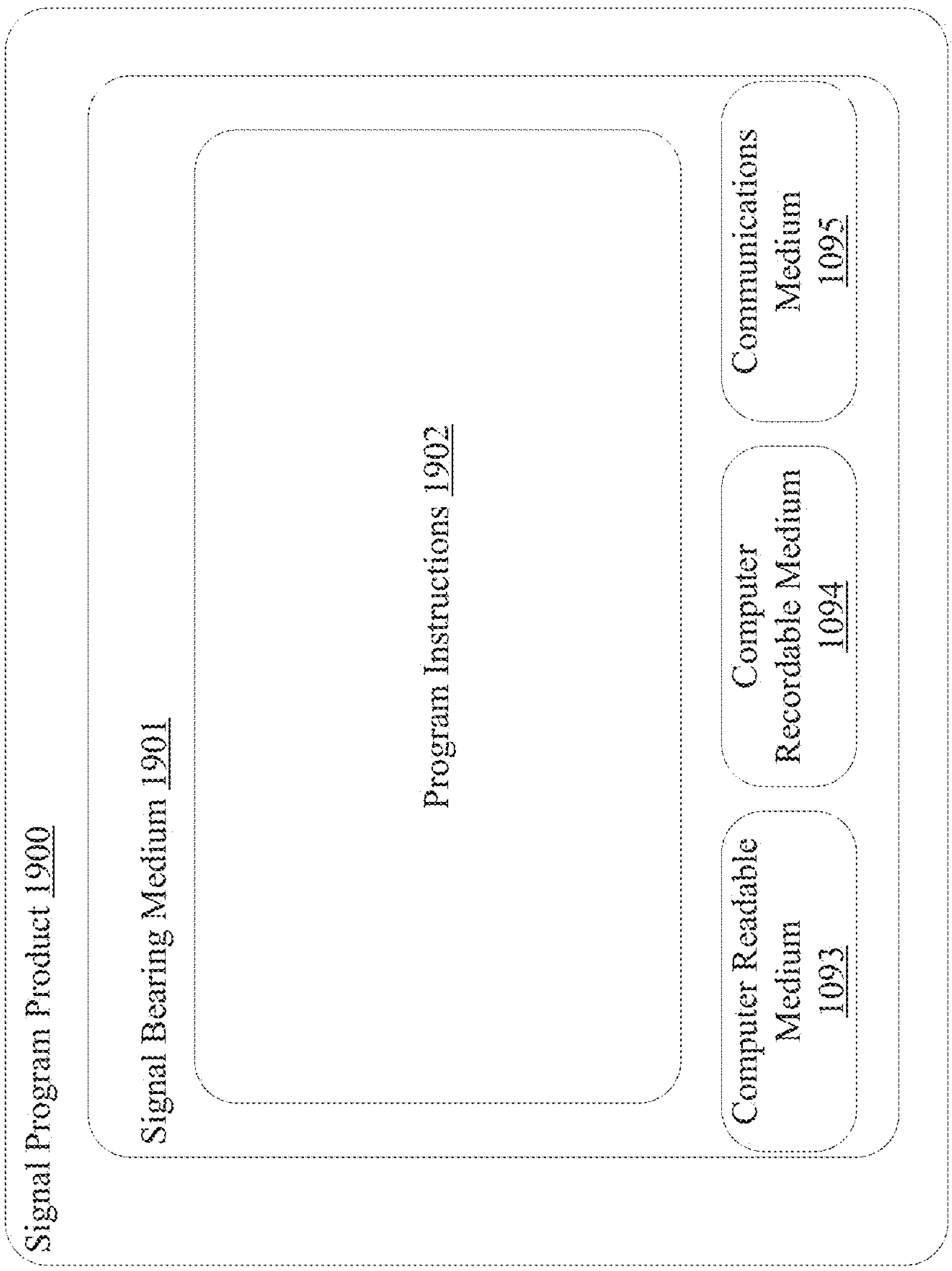
Signal Program Product 1900
Signal Bearing Medium 1901
Program Instructions 1902
Computer Readable Medium 1093
Computer Recordable Medium 1094
Communications Medium 1095

Figure 19

METHOD AND SYSTEM FOR REDUCING AMPLITUDE MODULATION (AM) NOISE IN AM BROADCAST SIGNALS

BACKGROUND

Unless otherwise indicated herein, the materials described in this section are not prior art to the claims in this application and are not admitted to be prior art by inclusion in this section.

Amplitude modulation (AM) broadcasting is a process of radio broadcasting that was the first method of impressing sound on a radio signal and is still widely used today. As known to one ordinary skill in the art, AM broadcasting signal has low immunity from interfering signals. As shown in FIG. **1**, during an AM signal travel from a broadcasting antenna tower **102** to an AM receiver antenna **104** coupled to an AM broadcast receiving device or apparatus **106**, many possible noise signals may become add-on or interference signals to the original AM signal. These interference noise signals can be generated by a number of sources, such as power-line noise, lightning, other wireless communications, etc. . . . . These interference noise signals are captured together with the AM broadcast signal by the receiver circuit to become an in-band noise.

In the case, for example, when AM broadcast receiving apparatus **106** is installed in a car, electrical motor noise and electromagnetic interferences generated by the car's electrical circuits/devices may increase the noise interference to the original AM broadcast signal.

Therefore, there is a need for a system and method that can help minimize AM broadcast interferences caused by noise signals.

SUMMARY

Disclosed herein are improved a method and system for reducing AM noise in AM broadcast signals.

In one aspect, a computer-implemented method for reducing a noise signal added to an amplitude modulated (AM) broadcast signal while travelling from a broadcasting antenna to a receiving antenna is provided. The method includes capturing a signal representative of the AM broadcast signal corrupted by the noise signal via the receiving antenna, inverting the captured signal, and determining a carrying frequency of the AM broadcast signal and delaying the inverted waveform by a fraction of a cycle of the carrying frequency. The method further includes generating a difference signal by subtractively combining the captured signal and the delayed inverted signal, generating an estimate noise signal by reducing an amplitude of the generated difference signal using a noise-reduction control multiplier, and minimizing the corrupting noise signal component of the captured signal by subtractively combining the captured signal and the generated estimate noise signal.

In another aspect, the computer-implemented method further includes filtering captured signal prior to the signal inversion.

In another aspect, the computer-implemented method further includes processing the captured signal through a low noise amplifying unit.

In another aspect, the computer-implemented method further includes processing the captured signal through an analog to digital converting unit to generate a digital version of the captured signal prior to the signal inversion.

In another aspect, the noise-reduction control multiplier is equal to a rational number 1/n with n being a number that is greater than a first value equal to about one (1) and is less than a second value equal to about two (2).

In another aspect, a computer readable storage medium having stored therein instructions executable by a computing element to cause the computing element to perform the above-introduced method.

These as well as other aspects, advantages, and alternatives will become apparent to those of ordinary skill in the art by reading the following detailed description, with reference where appropriate to the accompanying drawings. Further, it should be understood that the disclosure provided in this summary section and elsewhere in this document is intended to discuss the embodiments by way of example only and not by way of limitation.

BRIEF DESCRIPTION OF THE FIGURES

In the figures:

FIG. **1** is a schematic diagram illustrating an embodiment of an AM broadcast signal corrupted by a number of interfering signals and captured by a receiver antenna;

FIGS. **2**A-B are two graphs illustrating an uncorrupted AM broadcast signal and one of its period that has been inverted and delayed by a half-cycle;

FIG. **3** is a graph illustrating an AM broadcast signal with a predetermined amplitude modulation on a signal carrier;

FIG. **4** is a graph illustrating a zoomed section of the AM broadcast signal of FIG. **3**;

FIG. **5** is a graph illustrating a near-symmetrical characteristics of an upper half-cycle and of an inverted lower half-cycle of a waveform cycle of the zoomed signal section of FIG. **4**;

FIG. **6** is a block diagram illustrating an exemplary embodiment of a system, that includes an analog signal processing unit, for reducing AM noise captured by an AM receiver;

FIG. **7** is a flow chart illustrating an example embodiment of a method for reducing AM noise using the analog signal processing unit of FIG. **6**;

FIG. **8** is a block diagram illustrating an exemplary embodiment of a system, that includes a digital signal processing unit, for reducing an in-band AM noise signal captured by an AM receiver;

FIG. **9** is a flow chart illustrating an example embodiment of a method for reducing AM noise using the digital signal processing unit of FIG. **8**;

FIG. **10** is a block diagram illustrating another exemplary embodiment of a system, that includes another digital signal processing unit, for reducing an in-band AM noise signal captured by an AM receiver;

FIG. **11**A-C are three graphs that illustrate a corrupted AM broadcast signal, and a demodulated noise signal that corrupted the AM broadcast signal;

FIGS. **12**A-C are three graphs that illustrate the corrupted AM broadcast signal of FIG. **4**A after a reduction of the demodulated noise signal of FIG. **4**C, which has been achieved with a value of an adaptive control factor selected by one of the corresponding systems shown in FIGS. **2** and **3**;

FIGS. **13**A-C are three graphs that illustrate the corrupted AM broadcast signal of FIG. **4**A after another reduction of the demodulated noise signal of FIG. **4**C, which has been achieved with another value of the adaptive control factor selected by one of the corresponding systems shown in FIGS. **2** and **3**;

FIG. **14** is a graph illustrating an embodiment of another uncorrupted AM broadcast signal;

FIG. **15** is a graph illustrating the AM broadcast signal of FIG. **14** as corrupted by a couple of interfering signals;

FIG. **16** is a graph illustrating a composite of the signals interfering the AM broadcast signal of FIG. **15**;

FIG. **17** is a graph illustrating an embodiment of an AM broadcast signal output by one of systems of FIGS. **6**, **8**, and **10** after reduction of the interfering signals of FIG. **16**;

FIG. **18** is a graph illustrating an embodiment of an AM broadcast signal output by one of systems of FIGS. **6**, **8**, and **10** after reduction of the interfering signals of FIG. **16**; and

FIG. **19** is a schematic drawing illustrating a computing network system according to an exemplary embodiment.

DETAILED DESCRIPTION

In the following detailed description, reference is made to the accompanying figures, which form a part hereof. In the figures, similar symbols typically identify similar components, unless context dictates otherwise. The illustrative embodiments described in the detailed description, figures, and claims are not meant to be limiting. Other embodiments may be utilized, and other changes may be made, without departing from the spirit or scope of the subject matter presented herein. It will be readily understood that the aspects of the present disclosure, as generally described herein, and illustrated in the figures, can be arranged, substituted, combined, separated, and designed in a wide variety of different configurations, all of which are explicitly contemplated herein.

Overview

Some conventional noise suppression systems are known to use a noise generator coupled to a noise canceller. One such noise suppression system may include a tuner configured to selectively receive a radio wave signal and to transform it into an electric signal, a field information detector to detect electric field information of the radio wave signal received by the tuner, a noise data generator that generate a noise pattern on the basis of the detected electric field information, a noise canceler configured to remove a noise component from the signal outputted from the tuner on the basis of the noise pattern generated by the noise data generator. However, these noise data generators are known to lack the accuracy to generate a noise signal that can be considered a substantial reproduction of the captured noise signal.

Accordingly, an embodiment of the proposed noise reducing method is configured to process and analyze "near-symmetric" characteristics of a received AM broadcast signal. As such, the proposed method is configured to produce noise signals that are substantially similar to the original add-on noise signals. The reproduced noise signals are then used to cancel substantially all or at least the majority of the add-on noise signals before the AM de-modulation process of the received AM broadcast signal.

As known to one of ordinary skill in the art, in telecommunications, a carrier wave or carrier is a waveform (usually sinusoidal) that is modulated (modified) with an input signal for the purpose of conveying information. This carrier wave is usually a much higher frequency than the input signal. The purpose of the carrier is usually either to transmit the information through space as an electromagnetic wave (as in radio communication), or to allow several carriers at different frequencies to share a common physical transmission medium by frequency division multiplexing (as, for example, a cable television system).

Now referring to FIG. **2**A, an exemplary embodiment **200** of a perfect sinusoidal waveform **202** is illustrated. As an example, waveform **202** represents un-modulated AM carrier waveform at 300 KHz without interference. As shown, waveform **202** is a smooth repetitive oscillating waveform with a periodically constant amplitude, i.e., peak deviation from zero. As shown in FIG. **2**A, waveform **202** includes a positive peak A **204** and a negative peak B **206**. Because waveform **202** is a perfect sine wave, if a half cycle delay is applied to the waveform **202** then, as shown in FIG. **2**B, peak A becomes peak B and peak B becomes peak A, i.e., A=−B. That is, waveform **202** at peak A is the same as at inverted peak B with a half carrier cycle delay. Accordingly, peak A and peak B are considered to be symmetrical with respect to waveform **202**.

Now referring to FIG. **3**, an exemplary embodiment **300** of an AM broadcast signal waveform **302** with a predetermined amplitude modulation on a signal carrier waveform (not shown) is illustrated. As an example, AM broadcast waveform **302** has a frequency of 1.5 KHz and a 95% amplitude-modulation on the waveform carrier with a 300 KHz frequency.

Now referring to FIG. **4**, a waveform **402** representing a zoomed-in section **304** of the waveform carrier of FIG. **3** is shown. Zoomed-in section **304** corresponds to a waveform section associated with time points T1 and T2, which are close to about 3×10^{-4} seconds and about 4×10^{-4} seconds, respectively.

Now referring to FIG. **5**, a waveform **502** representing a zoomed-in section **404** of waveform **402** of FIG. **4** is shown. The zoomed section corresponds to a waveform section associated with time points T3 and T4, which are equal to about 374×10^{-6} seconds and about 390×10^{-4} seconds, respectively. As shown in FIG. **5**, waveform **502** includes an upper cycle peak "C" that has a magnitude equal to +4.578062, and an adjacent lower cycle peak "D" that has a magnitude equal to −4.81467. As such, upper cycle peak "C" is close to but not exactly the same as "inverted lower cycle peak "D." Thus, waveform **502** is a "Near Symmetrical" waveform. As known to one of ordinary skill in the art, a lower modulation index (%) leads to a more symmetrical waveform. Further, a higher audio and carrier frequency ratio leads to a more symmetrical waveform. Also, a lower modulation frequency leads to a more symmetrical waveform.

Now referring to FIG. **6**, a schematic diagram **600** illustrates an exemplary embodiment of an analog system **602** for reducing noise signals added to an AM broadcast signal. As shown, system **602** includes an antenna **604** for capturing an AM broadcast signal **606** augmented with add-on noise signals **608** and **610**. Captured AM broadcast signal **606** is a signal based on airwaves transmitted from a broadcasting station (not shown). System **602** further includes a cable unit **612** for communicating AM broadcast signal **606** to a filter and low-noise amplifier combination unit **614**, hereafter referred to as F&LNA unit **614**, and an analog signal processing unit **616** for AM noise reduction. In one embodiment, the filter of F&LNA unit **614** can be a two pole bandpass filter. As shown in FIG. **6**, analog signal processing unit **616**, hereafter referred to as analog AM noise reducing unit, includes a signal inverting unit **618**, a signal delaying unit **620**, a signal subtracting and reducing unit **622**, and a signal subtracting unit **624**.

Now referring to FIG. **7**, a flow chart **700** illustrates an example embodiment of a method for reducing/minimizing add-on noises using analog AM noise reducing unit **616**. During operation, upon initiation of the method at step **701**, F&LNA unit **614** processes AM broadcast signal **606** to output AM signal **607**. At step **702**, AM noise reducing unit **616** is configured to provide AM signal **607** to signal inverting unit **618**. Upon receipt of AM signal **607**, signal inverting unit **618** processes it to output inverse AM signal **609**, at step **704**.

Then at step **706**, AM noise reducing unit **616** provides AM signal **609** to signal delaying unit **620** that is configured to delay AM signal **609** by about a half carrier cycle and to output resulting AM signal **611**. Subsequently, AM noise reducing unit **616** provides both AM signal **607** and AM signal **611** to signal subtracting and reducing unit **622**, which proceeds to subtractively combine them, at step **708**, and to change an amplitude of the resulting difference signal by multiplying it with a rational number that is less than or equal to one (1), at step **710**. This rational number can be selected to be equal to about 1/n where n satisfies the following inequality: $1 \le n \le 2$. In accordance with one embodiment, the reduced difference signal **613** represents a generated or re-produced noise signal that is substantially similar to combined add-on noise signals **608** and **610**. Then, at step **712**, AM noise reducing unit **616** provides both AM signal **607** and reduced difference signal **613** to signal subtracting unit **624**, which is configured to subtractively combine them and output an AM noise-reduced signal **615**, which is desirably substantially similar to AM broadcast signal **606**.

Based on experimental results, AM noise reducing unit **616** substantially reduces add-on noise signals **608** and **610** when n is close to 2. Moreover, an optimal control value of n can be determined adaptively by this noise reduction approach during an on-going processing of AM broadcast signal **606**. This optimal control value of n represents a value that best minimizes add-on noise signals **608** and **610**.

Now referring to FIG. **8**, a schematic diagram **800** illustrates an exemplary embodiment of a digital system **802** for reducing noise signals added to an AM broadcast signal. As shown, system **802** includes an antenna **804** for capturing an AM broadcast signal **806** augmented with add-on noise signals **808** and **810**. System **802** further includes a cable unit **812** for communicating captured AM broadcast signal **806** to a filter and low-noise amplifier combination unit **814**, hereafter referred to as F&LNA unit **814**, an analog to digital (A/D) signal converting unit **819**, and a digital signal processing unit **816** for AM noise reduction. As discussed above, the filter of F&LNA unit **814** can be a two pole bandpass filter. As shown in FIG. **8**, analog signal processing unit **816**, hereafter referred to as digital AM noise reducing unit, includes a signal inverting unit **818**, a signal delaying unit **820**, a signal subtracting and reducing unit **822**, a delay compensation unit **823**, a signal subtracting unit **824**, an AM demodulating unit **826**, an error control calibration unit **828**, and a digital to analog (D/A) converting unit **830**.

Now referring to FIG. **9**, a flow chart **900** illustrates an example embodiment of a method for reducing/minimizing add-on noises using digital AM noise reducing unit **816**. During operation, upon initiation of the method at step **901**, F&LNA unit **814** processes AM broadcast signal **806** to output AM signal **807**. At step **902**, A/D signal converting unit **819** is configured to convert AM signal **807** to a digital signal **809**. AM noise reducing unit **816** is configured to provide AM digital signal **809** to signal inverting unit **818**, at step **904**. Upon receipt of AM digital signal **809**, signal inverting unit **818** processes it to output inverse AM digital signal **811**, at step **906**. Then, AM noise reducing unit **816** provides AM digital signal **811** to signal delaying unit **820** that is configured to delay AM digital signal **811** by about a half carrier cycle and to output resulting AM signal **813**, at step **908**. Subsequently, AM noise reducing unit **816** provides both AM signal **807** and AM signal **813** to signal subtracting and reducing unit **822**, which proceeds to subtractively combine them, at step **910**, and to change an amplitude of the resulting difference signal by multiplying it with a rational number that is less than or equal to one (1), at step **912**. As discussed above, alternatively, the rational number can be selected to be equal to 1/n where n satisfies the following inequality: $1 \le n \le 2$. In accordance with one embodiment, the reduced difference signal **815** represents a re-produced noise signal that is desirably substantially similar to combined add-on noise signals **808** and **810**. Then, at step **914**, AM noise reducing unit **816** provides AM signal **809** to delay compensation unit **823**, which is configured to apply a compensating time delay to AM signal **809**, and output AM delay-compensated signal **817**. Subsequently, at step **916**, AM noise reducing unit **816** is configured to provide both AM delay-compensated signal **817** and reduced difference signal **815** to signal subtracting unit **824**, which is configured to subtractively combine them and output an AM noise-reduced signal **819**, which is substantially similar to AM broadcast signal **806**. Further, at step **918**, AM noise-reduced signal **819** is demodulated by AM demodulating unit **826**, and the resulting demodulated signal **821** is provided to D/A converting unit **830** that converts it into an analog waveform prior to being outputted as an audio signal by a receiving speaker (not shown).

During this noise-reducing process, error control and calibration unit **828** is recruited to analyze demodulated signal **819** and use results of the analysis to adjust as needed the rational number 1/n that is used by signal subtracting and reducing unit **822** in order to improve on the minimization of add-on noise signals **808** and **810**.

Now referring to FIG. **10**, a schematic diagram **800** illustrates another exemplary embodiment of a digital system **1002** for reducing noise signals added to an AM broadcast signal. Digital system **1002** has substantially similar components as those of digital system **802**, except that F&LNA unit **1014** further includes a radio processing unit and error control and calibration unit **1028** is further coupled to signal delaying unit **1020**. In this configuration of Digital system **1002**, F&LNA unit **1014** is configured to identity an intermediate frequency (IF) of AM broadcast signal **1006**, to extract from it a signal, denoted IF signal **1007** having the identified intermediate frequency as its main frequency. In one embodiment, the coupling of error control and calibration unit **1028** to signal delaying unit **1020** serves to control the signal delaying process to further improve on the noise reduction process. That is, based on input received from error control and calibration unit **1028**, signal delaying unit **1020** adaptively adjusts an amount of signal delay that can be different from a half carrier cycle delay and still leads to a better minimization of add-on noise signals **808** and **810**.

Now referring to FIGS. **11**A-C, three graphs are shown that illustrate a corrupted AM broadcast signal **1102**, a zoomed section **1104** of AM broadcast signal **1102**, and an add-on noise signal **1106** that corrupted AM broadcast signal **1102**. FIG. **11**A illustrates AM broadcast signal **1102** that was selected to represent AM broadcast signal waveform **302** of FIG. **3** corrupted with add-on noise signals. A zoomed section of AM broadcast signal **1102** is illustrated in FIG. **11**B. Subsequent to processing AM broadcast signal **1102** using any one of noise reducing systems **602**, **802**, and **1002**, the add-noise signal **1106** corresponding to the zoomed **1104** section is substantially determined.

During a noise reduction process using any one of noise reducing systems **602**, **802**, and **1002**, and selecting adaptive control factor "n" to be equal to 2.0, FIG. **12**A illustrates a resulting AM broadcast signal **1202** that represents AM broadcast signal **1102** with the reduced add-on noise signal **1106**. FIG. **12**B illustrates the zoomed section of AM broadcast signal **1102** shown in FIG. **11**B after the noise reduction, and FIG. **12**C illustrates the reduced version of add-on noise signal **1106**.

To further reduce add-on noise signal **1106**, noise reducing systems **602**, **802**, and **1002** are configured to adaptively vary the value of adjusting control factor n. As such, based on a continuous analysis of outputted noise-reduced AM signals, adjusting control factor n was selected to be equal to 1.5, which lead to a further reduction of add-on noise signal **1106** as illustrated in a further smoother waveform of AM broadcast signal **1102**, and a further reduced amplitude-wise of add-on noise signal **1106**, shown in FIGS. **13**A and **13**C.

Now referring to FIG. **14**, a graph **1400** illustrates an embodiment of an uncorrupted AM broadcast signal **1402** provided with a substantially perfect signal modulation. As an example, AM broadcast signal **1402** has a frequency of 1.7 KHz and is amplitude-modulated by a 300 KHz waveform carrier (not shown). During its broadcast travel, AM broadcast signal **1402** is corrupted by a couple of add-on noise signals. These interfering noise signals are both frequency modulated (FM) signals having frequencies equal to 3.33 KHz and 2.0 KHz, respectively, whose composite signal is illustrated by waveform **1602** of FIG. **16**. The corrupted version of AM broadcast signal **1402** is illustrated by waveform **1502** of FIG. **15**. By processing the corrupted version of AM broadcast signal **1402** using any one of noise reducing systems **602**, **802**, and **1002**, a noise-reduced signal version of AM broadcast signal **1402** is generated as illustrated by waveform **1702**, shown in FIG. **17**. The removed distorting component of waveform **1502** is illustrated by waveform **1802** of FIG. **18**.

In one embodiment, each of noise reducing systems **602**, **802**, and **1002** include a processing unit and a memory unit. Each of the processing units can be implemented on a single-chip. For example, various architectures can be used including dedicated or embedded microprocessor (μP), a microcontroller (μC), or any combination thereof. Each of the memory units may be of any type of memory now known or later developed including but not limited to volatile memory (such as RAM), non-volatile memory (such as ROM, flash memory, etc.) or any combination thereof, which may store software that can be accessed and executed by the processing units, for example. Each of the memory units are configured to store instructions that correspond to the processing functions of the above discussed noise reducing systems.

In some embodiments, the disclosed method may be implemented as computer program instructions encoded on a non-transitory computer-readable storage media in a machine-readable format. FIG. **19** is a schematic illustrating a conceptual partial view of an example computer program product **1900** that includes a computer program for executing a computer process on a computing device, arranged according to at least some embodiments presented herein. In one embodiment, the example computer program product **1900** is provided using a signal bearing medium **1901**. The signal bearing medium **1301** may include one or more programming instructions **1902** that, when executed by one or more processors may provide functionality or portions of the functionality described above with respect to FIGS. **7** and **9**. Thus, for example, referring the embodiments shown in FIGS. **7** and **9**, one or more features of blocks **702**, **704**, **706**, **708** and/or **710** and **902**, **904**, **906**, **908**, **910** and/or **912**, respectively, may be undertaken by one or more instructions associated with the signal bearing medium **1901**.

In some examples, the signal bearing medium **1901** may encompass a non-transitory computer-readable medium **1903**, such as, but not limited to, a hard disk drive, a Compact Disc (CD), a Digital Video Disk (DVD), a digital tape, memory, etc. In some implementations, the signal bearing medium **1901** may encompass a computer recordable medium **1904**, such as, but not limited to, memory, read/write (R/W) CDs, R/W DVDs, etc. In some implementations, the signal bearing medium **1901** may encompass a communications medium **1905**, such as, but not limited to, a digital and/or an analog communication medium (e.g., a fiber optic cable, a waveguide, a wired communications link, a wireless communication link, etc.).

While various aspects and embodiments have been disclosed herein, other aspects and embodiments will be apparent to those skilled in the art. The various aspects and embodiments disclosed herein are for purposes of illustration and are not intended to be limiting, with the true scope and spirit being indicated by the following claims, along with the full scope of equivalents to which such claims are entitled. It is also to be understood that the terminology used herein is for the purpose of describing particular embodiments only, and is not intended to be limiting.

What is claimed is:

1. A computer-implemented method for reducing an externally generated noise signal imposed on an amplitude modulated (AM) broadcast signal, the AM broadcast signal travelling from a broadcasting antenna to a receiving antenna, the method comprising:

capturing, via the receiving antenna, a signal representative of the AM broadcast signal corrupted by the externally generated noise signal;

shifting the phase of the captured signal by 180 degrees;

determining a carrying frequency of the AM broadcast signal and delaying the phase-shifted waveform by a fraction of a cycle of the carrying frequency, the delaying of the waveform occurring after the phase shifting of the captured signal;

generating a difference signal by combining the captured signal and the delayed phase-shift signal;

generating an estimate noise signal by reducing an amplitude of the generated difference signal using a noise amplifier control multiplier, wherein the generated estimate noise signal represents an estimate of the corrupting noise signal;

minimizing the corrupting noise signal component of the captured signal by combining the captured signal and the generated estimate noise signal so as to compensate for the externally generated noise signal imposed on the AM broadcast signal; and

wherein shifting the phase, determining the carrier frequency, generating a difference signal, generating an estimate noise signal, and minimizing the corrupting noise signal component, are performed on a continuous basis operating on complete cycles of the captured signal and without down-conversion of the signal.

2. The computer-implemented method of claim **1**, wherein a fraction of a cycle is equal to about a half cycle.

3. The computer-implemented method of claim **1**, further comprising filtering captured signal prior to the signal inversion.

4. The computer-implemented method of claim **1**, further comprising processing the captured signal through a low noise amplifying unit.

5. The computer-implemented method of claim **1**, further comprising processing the captured signal through an analog to digital converting unit to generate a digital version of the captured signal prior to the signal inversion.

6. The computer-implemented method of claim **1**, wherein the noise amplifier control multiplier is equal to a rational number 1/n with n being a number that is greater than a first value equal to one (1) and is less than a second value equal to two (2).

7. A system for reducing an externally generated noise signal imposed on an amplitude modulated (AM) broadcast signal, the AM broadcast signal travelling from a broadcasting antenna to a receiving antenna, the system comprising:
- a receiving unit for capturing, by the receiving antenna, a signal representative of the AM broadcast signal corrupted by the externally generated noise signal;
- a signal inverting unit for shifting the phase of the captured signal by 180 degrees;
- a signal frequency determining unit for determining a carrying frequency of the AM broadcast signal and delaying the phase-shifted waveform, using a delay circuit, by a fraction of a cycle of the carrying frequency, the signal inverting unit disposed in a signal processing path before the delay circuit;
- a first signal differentiating unit for generating a difference signal by combining the captured signal and the delayed phase-shifted signal;
- a signal amplitude reducing unit for reducing an amplitude of the generated difference signal using a noise amplifier control multiplier to generate an estimate noise signal, wherein the generated estimate noise signal represents an estimate of the corrupting noise signal;
- a second signal differentiating unit for minimizing the corrupting noise signal component of the captured signal by combining the captured signal and the generated estimate noise signal so as to compensate for the externally generated noise signal imposed on the AM broadcast signal; and
- wherein the signal inverting unit for shifting the phase, the signal frequency determining unit for determining the carrier frequency, the first signal differentiating unit for generating the difference signal, the signal amplitude reducing unit for generating an estimate noise signal, and the second signal differentiating unit for minimizing the corrupting noise signal component, continuously operate on complete cycles of the captured signal and without down-conversion of the signal.

8. The system of claim 7, wherein a fraction of a cycle is equal to about a half cycle.

9. The system of claim 7, further comprising a filtering unit for filtering captured signal prior to the signal inversion.

10. The system of claim 7, further comprising a low noise amplifying unit for amplifying a low noise component of the captured signal.

11. The system of claim 7, further comprising an analog to digital converting unit for generating a digital version of the captured signal prior to the signal inversion.

12. The system of claim 7, wherein the noise-reduction control multiplier is equal to a rational number 1/n with n being a number that is greater than a first value equal to one (1) and is less than a second value equal to two (2).

13. A non-transitory computer readable storage medium having stored therein instructions executable by a computing element to cause the computing element to perform functions to reduce an externally generated noise signal imposed on an amplitude modulated (AM) broadcast signal, the AM broadcast signal travelling from a broadcasting antenna to a receiving antenna, the functions comprising:
- capturing, by the receiving antenna, a signal representative of the AM broadcast signal corrupted by the externally generated noise signal;
- shifting the phase of the captured signal by 180 degrees;
- determining a carrying frequency of the AM broadcast signal and delaying the phase-shifted waveform by a fraction of a cycle of the carrying frequency, the delaying of the waveform occurring after the phase-shifted of the captured signal;
- generating a difference signal by combining the captured signal and the delayed phase-shifted signal;
- generating an estimate noise signal by reducing an amplitude of the generated difference signal using a noise-reduction control multiplier, wherein the generated estimate noise signal represents an estimate of the corrupting noise signal;
- minimizing the corrupting noise signal component of the captured signal by subtractively combining the captured signal and the generated estimate noise signal so as to compensate for the externally generated noise signal imposed on the AM broadcast signal; and
- wherein shifting the phase, determining the carrier frequency, generating a difference signal, generating an estimate noise signal, and minimizing the corrupting noise signal component, are performed on a continuous basis operating on complete cycles of the captured signal and without down-conversion of the signal.

14. The non-transitory computer readable storage medium of claim 13, wherein a fraction of a cycle is equal to about a half cycle.

15. The non-transitory computer readable storage medium of claim 13, further comprising filtering captured signal prior to the signal inversion.

16. The non-transitory computer readable storage medium of claim 13, further comprising processing the captured signal through a low noise amplifying unit.

17. The non-transitory computer readable storage medium of claim 13, further comprising processing the captured signal through an analog to digital converting unit to generate a digital version of the captured signal prior to the signal inversion.

18. A computing system comprising:
- at least one memory unit for storing program instructions for reducing a noise signal imposed on an amplitude modulated (AM) broadcast signal, the AM broadcast signal travelling from a broadcasting antenna to a receiving antenna, and
- at least one processing unit for executing the program instructions; and
- wherein the program instructions comprise:
  - capturing, via the receiving antenna, a signal representative of the AM broadcast signal corrupted by the externally generated noise signal;
  - shifting the phase of the captured signal by 180 degrees;
  - determining a carrying frequency of the AM broadcast signal and delaying the phase-shifted waveform by a fraction of a cycle of the carrying frequency, the delaying of the waveform occurring after the inverting of the captured signal;
  - generating a difference signal by subtractively combining the captured signal and the delayed inverted signal;
  - generating an estimate noise signal by reducing an amplitude of the generated difference signal using a noise-reduction control multiplier, wherein the generated estimate noise signal represents an estimate of the corrupting noise signal;
  - minimizing the corrupting noise signal component of the captured signal by subtractively combining the captured signal and the generated estimate noise signal so as to compensate for the externally generated noise signal imposed on the AM broadcast signal; and

wherein shifting the phase, determining the carrier frequency, generating a difference signal, generating an estimate noise signal, and minimizing the corrupting noise signal component, are performed on a continuous basis operating on complete cycles of the captured signal and without down-conversion of the signal.

19. The computing system of claim **18**, wherein a fraction of a cycle is equal to about a half cycle.

20. The computing system of claim **18**, further comprising filtering captured signal prior to the signal inversion.

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