US009680435B1

(12) **United States Patent**
Huang et al.

(10) **Patent No.: US 9,680,435 B1**
(45) **Date of Patent: Jun. 13, 2017**

(54) **METHOD AND DEVICE FOR IMPROVING ACOUSTICS OF AN AM DEMODULATION OUTPUT SIGNAL**

(71) Applicant: **Beken Corporation**, Shanghai (CN)

(72) Inventors: **Yiming Huang**, Shanghai (CN); **Weifeng Wang**, Shanghai (CN)

(73) Assignee: **Beken Corporation**, Shanghai (CN)

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

(21) Appl. No.: **15/257,418**

(22) Filed: **Sep. 6, 2016**

(30) **Foreign Application Priority Data**

Aug. 22, 2016 (CN) 2016 1 0702026

(51) **Int. Cl.**
H04H 20/49 (2008.01)
H03G 3/30 (2006.01)
H03M 1/12 (2006.01)

(52) **U.S. Cl.**
CPC ***H03G 3/3005*** (2013.01); ***H03M 1/124*** (2013.01); *H03G 3/3052* (2013.01); *H03G 3/3068* (2013.01)

(58) **Field of Classification Search**
CPC H03G 3/005; H03G 3/3052; H03G 3/3068
USPC 381/119, 1–3, 15
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2007/0049223 A1* 3/2007 Nishizawa H04H 20/30 455/182.3
2013/0029621 A1* 1/2013 Nakata H04B 1/109 455/161.3

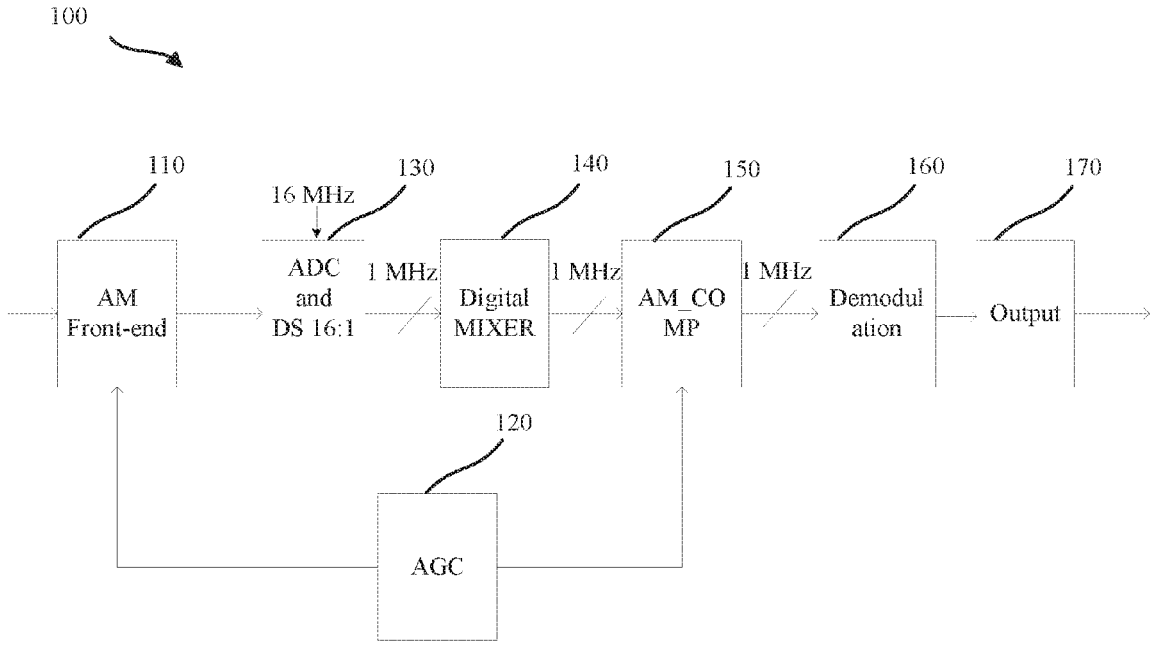
* cited by examiner

Primary Examiner — Disler Paul
(74) *Attorney, Agent, or Firm* — Perkins Coie LLP

(57) **ABSTRACT**

A method for improving acoustics of amplitude modulation (AM) audio signal, comprising: amplifying and mixing, with an amplitude modulation (AM) front-end module, an analog AM signal and an automatic gain control (AGC) signal from an AGC module; converting and sampling, with an analog-digital converter and down-sampling module, the amplified and mixed signal to generate a digital AM signal; digitally mixing, with a digital mixer module, the digital AM signal to generate a first digital AM envelope signal; compensating, with an AM compensator module, the first digital AM envelope signal by an AM compensating AGC signal from the AM compensator module to generate a second digital AM envelope signal; demodulating, with a demodulation module, the second digital AM envelope signal; and outputting, with an output module, a demodulated AM audio signal.

10 Claims, 5 Drawing Sheets



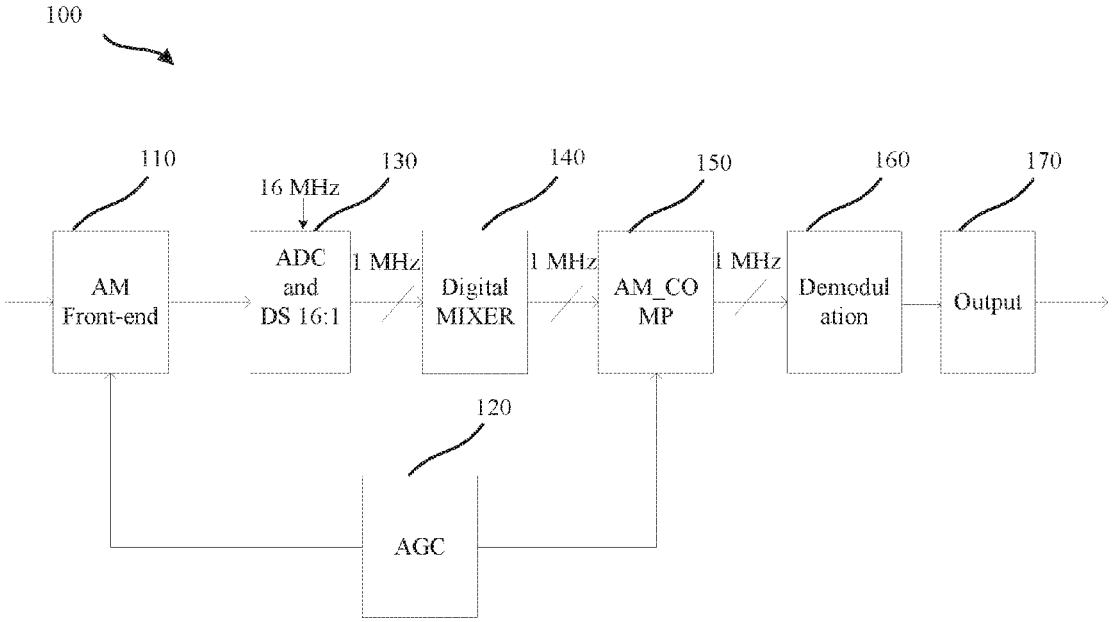

100
110
130
140
150
160
170
16 MHz
AM Front-end
ADC and DS 16:1
1 MHz
Digital MIXER
1 MHz
AM_COMP
1 MHz
Demodulation
Output
120
AGC

FIG. 1

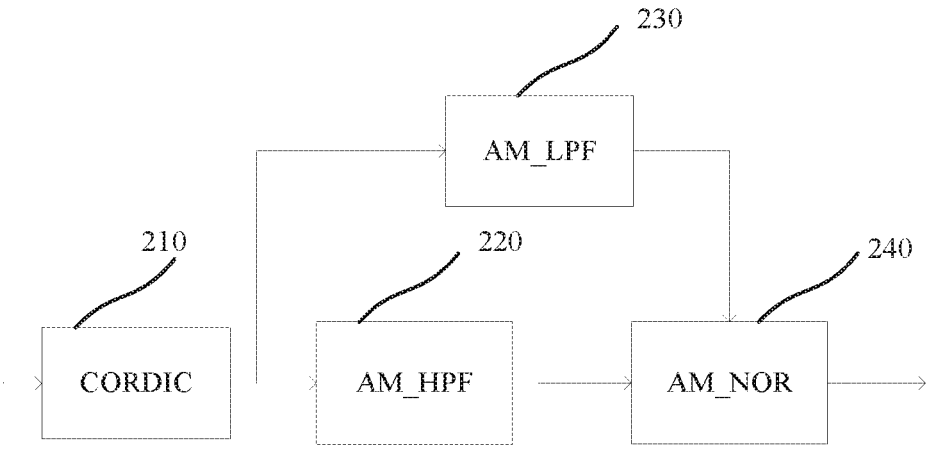


FIG. 2

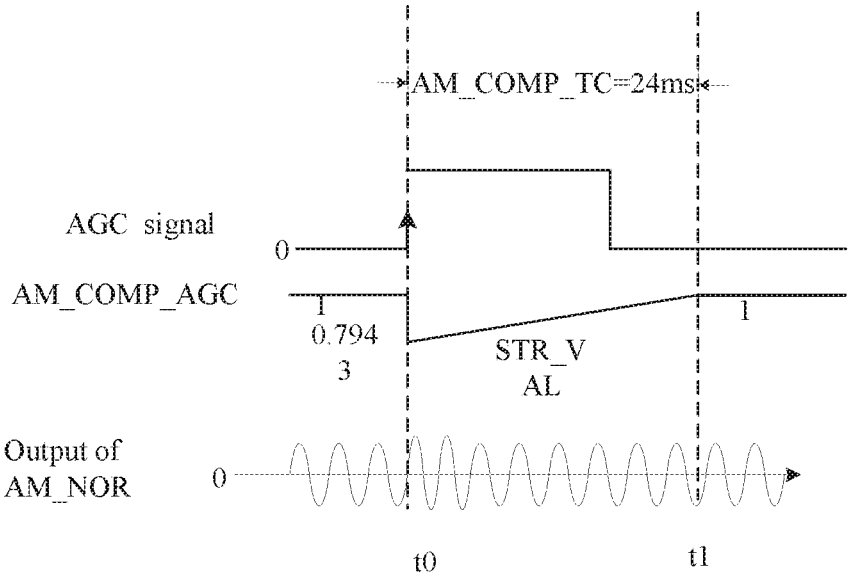

AM_COMP_TC=24ms
AGC signal
0
AM_COMP_AGC
1
0.794
3
STR_V
AL
1
Output of
AM_NOR
0
t0
t1

FIG. 3A

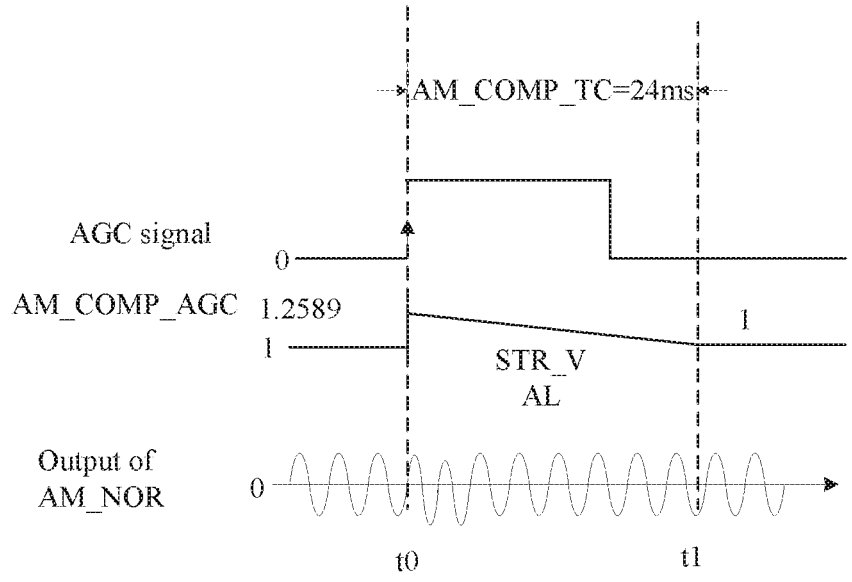

AM_COMP_TC=24ms
AGC signal
0
AM_COMP_AGC
1.2589
1
STR_V
AL
1
Output of
AM_NOR
0
t0
t1

FIG. 3B

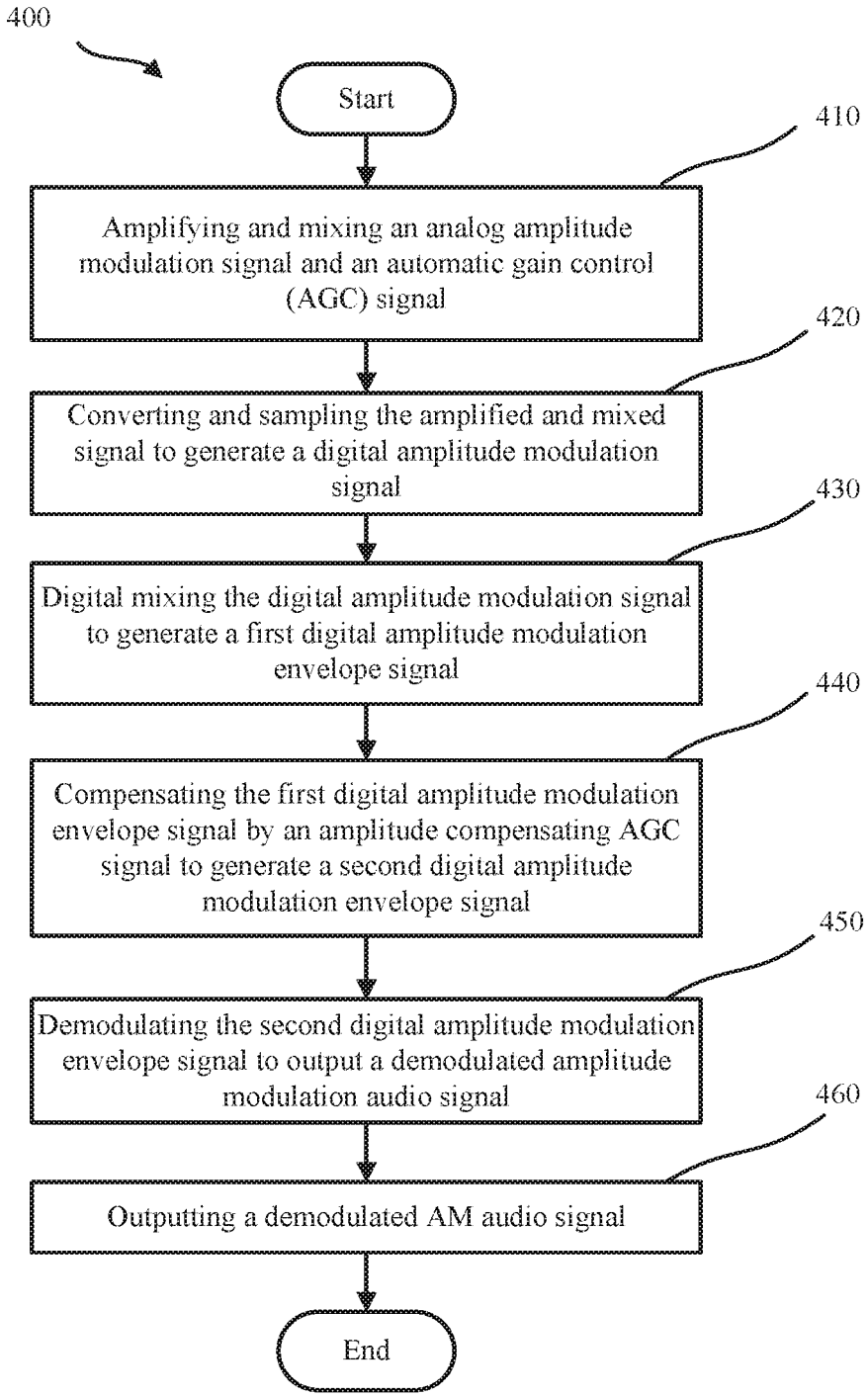

400
Start
410
Amplifying and mixing an analog amplitude modulation signal and an automatic gain control (AGC) signal
420
Converting and sampling the amplified and mixed signal to generate a digital amplitude modulation signal
430
Digital mixing the digital amplitude modulation signal to generate a first digital amplitude modulation envelope signal
440
Compensating the first digital amplitude modulation envelope signal by an amplitude compensating AGC signal to generate a second digital amplitude modulation envelope signal
450
Demodulating the second digital amplitude modulation envelope signal to output a demodulated amplitude modulation audio signal
460
Outputting a demodulated AM audio signal
End

FIG. 4

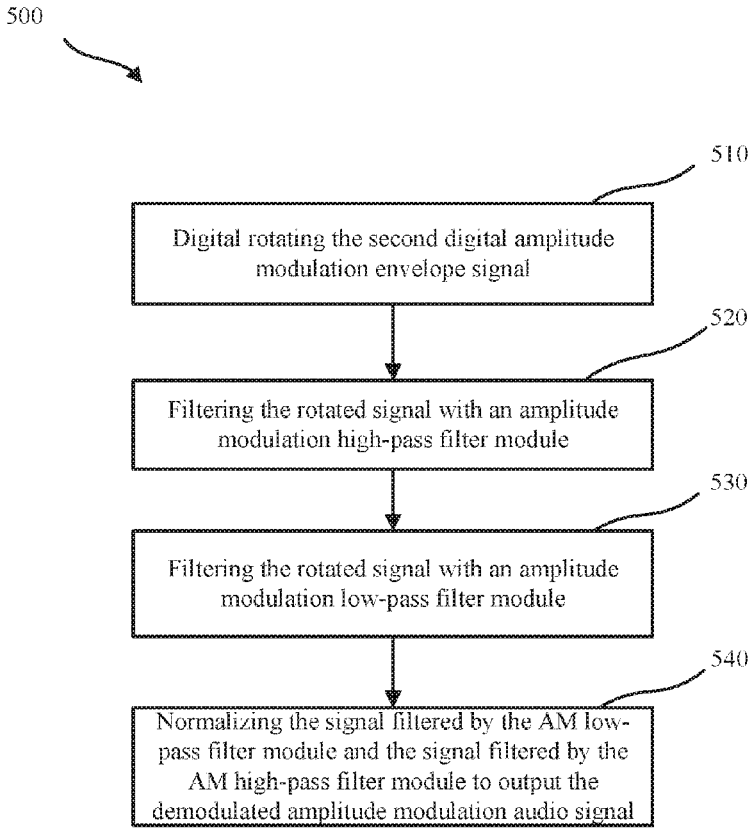

500
510
Digital rotating the second digital amplitude modulation envelope signal
520
Filtering the rotated signal with an amplitude modulation high-pass filter module
530
Filtering the rotated signal with an amplitude modulation low-pass filter module
540
Normalizing the signal filtered by the AM low-pass filter module and the signal filtered by the AM high-pass filter module to output the demodulated amplitude modulation audio signal

FIG. 5

METHOD AND DEVICE FOR IMPROVING ACOUSTICS OF AN AM DEMODULATION OUTPUT SIGNAL

CLAIM OF PRIORITY

This application claims priority to Chinese Application number 201610702026.X, entitled "Method and Device for Improving Acoustics of an AM Demodulation Output Signal," filed on Aug. 22, 2016 by Beken Corporation, which is incorporated herein by reference.

TECHNICAL FIELD

The present application relates to an amplitude modulation (AM) receiver and more particularly, but not exclusively, to a method and device for improving acoustics of an AM demodulation output signal.

BACKGROUND OF THE INVENTION

In a traditional AM receiver, there are abrupt changes in direct current (DC) and amplitude of the output signal and thus affects the sound quality of the output signal. The abrupt changes can be caused by the gain from an automatic gain control (AGC) module, an effect of $(1-e^{-\omega_{HPFt}})$ in an AM high-pass filter module and an effect of $(1-e^{-\omega_{LPFt}})$ in the AM low-pass filter module in the receiver. For example, if an amplitude value of an input signal changes from A to B due to the gain change from the AGC module, the output signal of the AM receiver can have an abrupt change

$$\frac{B-A}{A}$$

in DC of the output signal and an abrupt change B/A in amplitude of the output signal.

To eliminate these abrupt changes, a new method and device for improving acoustics of AM demodulation output signal may be necessary.

BRIEF DESCRIPTION OF THE INVENTION

According to an embodiment of the invention, a method and device use an AM compensator module to reduce the abrupt changes in DC and amplitude of the output signal and improve the sound quality of the output signal.

In an embodiment, a method comprises: amplifying and mixing, with an amplitude modulation (AM) front-end module, an analog AM signal and an automatic gain control (AGC) signal from an AGC module; converting and sampling, with an analog-digital converter and down-sampling module, the amplified and mixed signal to generate a digital AM signal; digitally mixing, with a digital mixer module, the digital AM signal to generate a first digital AM envelope signal; compensating, with an AM compensator module, the first digital AM envelope signal by an AM compensating AGC signal from the AM compensator module to generate a second digital AM envelope signal; demodulating, with a demodulation module, the second digital AM envelope signal to output a demodulated AM audio signal; and outputting, with an output module, a demodulated AM audio signal.

In another embodiment, the method further comprises: digitally rotating, with a cordic (coordinated rotation digital computer) module, the second digital AM envelope signal; filtering, with an AM high-pass filter module, the rotated signal; filtering, with an AM low-pass filter module, the rotated signal; and normalizing, with an AM normalization module, the signal filtered by the AM low-pass filter module and the signal filtered by the AM high-pass filter module to output the demodulated AM audio signal.

In another embodiment, a device comprises: an automatic gain control (AGC) module configured to generate an AGC signal for adjusting the gain; an amplitude modulation (AM) front-end module connected to the AGC module and configured to amplify and mix an analog AM signal and the AGC signal; an analog-digital converter (ADC) and down-sampling module connected to the AM front-end module and configured to convert and sample the amplified and mixed signal to generate a digital AM signal; a digital mixer module connected to the ADC and down-sampling module and configured to digitally mix the digital AM signal to generate a first digital AM envelope signal; an AM compensator module connected to the digital mixer module and to the AGC module and configured to compensate the first digital AM envelope signal by an AM compensating AGC signal from the AM compensator module to generate a second digital AM envelope signal; a demodulation module connected to the AM compensator module and configured to demodulate the second digital AM envelope signal to output a demodulated AM audio signal; and an output module connected to the demodulation module and configured to output a demodulated AM audio signal.

In still another embodiment, the device further comprises: a cordic module connected to the AM compensator module and configured to digitally rotate the second digital AM envelope signal; an AM high-pass filter module connected to the cordic module and configured to filter the rotated signal; an AM low-pass filter module connected to the cordic module and configured to filter the rotated signal; and an AM normalization module connected to the AM high-pass filter module and to the AM low-pass filter module and configured to normalize the signal filtered by the AM low-pass filter module and the signal filtered by the AM high-pass filter module to output the demodulated AM audio signal.

BRIEF DESCRIPTION OF THE DRAWINGS

Non-limiting and non-exhaustive embodiments of the present invention are described with reference to the following figures, wherein like reference numerals refer to like parts throughout the various views unless otherwise specified.

FIG. **1** is a block diagram illustrating an AM receiver for reducing abrupt changes in DC and amplitude of the output signal according to an embodiment of the invention.

FIG. **2** is a block diagram illustrating a demodulation module of the AM receiver shown in FIG. **1**.

FIGS. **3**A and **3**B are sequence diagrams illustrating the output of the AM receiver shown in FIG. **1**.

FIG. **4** is a flowchart illustrating a method for reducing abrupt changes in DC and amplitude of the output signal according to an embodiment of the invention.

FIG. **5** is a continuation of the method illustrated in FIG. **4**.

DETAILED DESCRIPTION OF THE ILLUSTRATED EMBODIMENTS

Various aspects and examples of the invention will now be described. The following description provides specific details for a thorough understanding and enabling descrip-

tion of these examples. Those skilled in the art will understand, however, that the invention may be practiced without many of these details. Additionally, some well-known structures or functions may not be shown or described in detail, so as to avoid unnecessarily obscuring the relevant description.

The terminology used in the description presented below is intended to be interpreted in its broadest reasonable manner, even though it is being used in conjunction with a detailed description of certain specific examples of the invention. Certain terms may even be emphasized below, however, any terminology intended to be interpreted in any restricted manner will be overtly and specifically defined as such in this Detailed Description section.

FIG. **1** is a block diagram illustrating an AM receiver **100** for reducing abrupt changes in DC and amplitude of the output signal according to an embodiment of the invention. The AM receiver **100** comprises an AM front-end module **110**, an automatic gain control (AGC) module **120** connected to the AM front-end module **110**, an analog-digital converter (ADC) and down-sampling (DS) module **130** connected to the AGC module **120**, a digital mixer module **140** connected to the ADC and DS module **130**, an AM compensator module **150** connected to the digital mixer module **140** and to the AGC module **120**, a demodulation module **160** connected to the AM compensator module **150** and an output module **170** connected to the demodulation module **160**.

In an embodiment, the AM front-end module **110** that is connected to the AGC module **120** receives an AM signal and an AGC signal from the AGC module **120**. The AM signal is amplified and mixed in the AM front-end module **110** to output an analog AM signal with a frequency, for example, 125 KHz. The analog AM signal is $A\cdot(1+m\cos(\Omega t))\cdot\cos(\omega t+\sigma t)$. Wherein, the A is amplitude value of an amplitude modulation carrier wave, m is a degree of modulation, Ω is an angular frequency of an amplitude modulation audio signal, ω is an angular frequency of the amplitude modulation carrier wave, for example, 2*π*125K, and σ is an offset angular frequency of the carrier wave due to the frequency deviation of crystal. In the embodiment, the AGC signal is provided from the AGC module **120** to control the gain of the AM front-end module **110**, that is, to control the size of A, and the A will quickly changes to B after the AGC signal is input into the AM front-end module. Wherein, the $B=A\cdot 10^{(0.05*\delta)}$, and the value of gain change is δ dB ($\delta>0$ represents the gain increases and $\delta<0$ represents the gain decreases).

Then the analog AM signal with 125 KHz is input into the ADC and DS module **130**. In the embodiment, the sampling clock of the ADC module is 16 MHz. The analog AM signal is first converted to a digital signal by sampling at 16 MHz, then the digital signal is down sampled by 16 times in the DS module. The ADC and DS module **130** outputs a digital AM signal, which is also $A\cdot(1+m\cos(\Omega t))\cdot\cos(\omega t+\sigma t)$ but with 1 MHz sampling rate. In the embodiment, the output of the module **130** changes from $A\cdot(1+m\cos(\Omega t))\cdot\cos(\omega t+\sigma t)$ to $B\cdot(1+m\cos(\Omega t))\cdot\cos(\omega t+\sigma t)$ due to the gain control from the AGC module **120**.

The digital AM signal with 1 MHz sampling rate is input into the digital mixer module **140**. Then the module **140** outputs an digital AM envelope signal, which is $A\cdot(1+m\cos(\Omega t))\cdot\cos(\sigma t)$ and with 1 MHz sampling rate. In the embodiment, the output of the module **140** changes from $A\cdot(1+m\cos(\Omega t))\cdot\cos(\sigma t)$ to $B\cdot(1+m\cos(\Omega t))\cdot\cos(\sigma t)$ due to the gain control from the AGC module **120**.

In the embodiment, the AM compensator module **150** then receives the signal $A\cdot(1+m\cos(\Omega t))\cdot\cos(\sigma t)$ from the digital mixer module **140** and compensates the signal by an AM compensating AGC signal, i.e., multiplies the signal by the AM compensating AGC signal according to the AGC signal (the AGC signal is valid during the rising edge), the value of gain change δ, and a time of duration for gain change (AM_COMP_TC), and wherein a starting value of the AM compensating AGC signal is A/B and $A/B=10^{(-0.05*\delta)}$.

Still in the embodiment, due to the gain control from the AGC module **120**, after the signal received from the digital mixer module **140** changes from $A\cdot(1+m\cos(\Omega t))\cdot\cos(\omega t)$ to $B\cdot(1+m\cos(\Omega t))\cdot\cos(\omega t)$, a starting value of the output of the AM compensator module **150** is

$$B\bullet(1+m\cos(\Omega t))\bullet\cos(\sigma t)\bullet\frac{A}{B}=A\bullet(1+m\cos(\Omega t))\bullet\cos(\sigma t)$$

Then the starting output $A\cdot(1+m\cos(\Omega t))\cdot\cos(\sigma t)$ is transmitted to the demodulation module **160**. As shown in FIG. **2**, the demodulation module **160** connected to the AM compensator module **150** further comprises: a cordic module **210**, an AM high-pass filter module **220** connected to the cordic module, an AM low-pass filter module **230** connected to the cordic module, and an AM normalization module **240** connected to the AM high-pass filter module and to the AM low-pass filter module.

In one embodiment, the cordic module **210** receives and rotates the signal $A\cdot(1+m\cos(\Omega t))\cdot\cos(\sigma t)$ from the AM compensator module **150** and outputs a starting value $A\cdot(1+m\cos(\Omega t))$. Then the AM high-pass filter module **220** receives the rotated signal $A\cdot(1+m\cos(\Omega t))$ from the cordic module **210** and wherein the passband of the high-pass filter module **220** is −3 dB and the corner frequency is ω_{HPF}, for example, 2*π*100. Thus, the AM high-pass filter module **220** can remove the DC component from the signal $A\cdot(1+m\cos(\Omega t))$ and output $A\cdot m\cos(\Omega t)$. At the same time, the AM low-pass filter module **230** also receives the rotated signal from the cordic module **210** and wherein the passband of the low-pass filter module **230** is −3 dB and the corner frequency is ω_{LPF}, for example, 2*π*20. Thus, the low-pass filter module **230** can obtain the DC component from the signal $A\cdot(1+m\cos(\Omega t))$ and output A. Then the AM normalization module **240** receives $A\cdot m\cos(\Omega t)$ and A from the AM high-pass filter module **220** and AM low-pass filter module **230** respectively and outputs in $m\cos(\Omega t)$, i.e.,

$$\frac{A\bullet m\cos(\Omega t)}{A}=m\cos(\Omega t).$$

Still in the embodiment, after the time of duration for gain change,

$$\text{AM_COMP_TC}=\frac{3}{\omega_{LPF}},$$

the value of the AM compensating AGC signal is 1, and an effect $(1-e^{-\omega_{HPF}t})$ of an AM high-pass filter module **220** and an effect $(1-e^{-\omega_{LPF}t})$ of an AM low-pass filter module **230** mostly disappeared. That is, the output of the AM compensator module **150** now is $B\cdot(1+m\cos(\Omega t))\cdot\cos(\sigma t)\cdot 1=B\cdot(1+m\cos(\Omega t))\cdot\cos(\sigma t)$. Then, this output signal $B\cdot(1+m\cos(\Omega t))$

·cos(σt) is also transmitted to the cordic module **210** of the demodulation module **160**. The cordic module **210** then outputs a signal B·(1+m cos(Ωt)). The AM high-pass filter module **220** receives the signal B·(1+m cos(Ωt)), removes the DC component from the signal B·(1+m cos(Ωt)) and outputs B·m cos(Ωt). The low-pass filter module **230** also receives the signal B·(1+m cos(Ωt)), obtains the DC component from the signal B·(1+m cos(Ωt)) and output B. The output of the AM normalization module **240** is also m cos(Ωt). Finally, the output module outputs the demodulated signal without abrupt changes

$$\frac{B-A}{A}$$

and B/A.

FIGS. **3**A and **3**B are sequence diagrams illustrating the output of the demodulation module **160** shown in FIG. **1**. In one embodiment, as shown in FIG. **3**A, wherein δ=2 dB, and the AM compensating AGC signal changes from the value $A/B=10^{(-0.05*\delta)}=0.7943$ to the value 1 after the time of duration for gain change, i.e.,

$$\text{AM_COMP_TC} = \frac{3}{\omega_{LPF}} \approx 24 \text{ ms.}$$

In another embodiment, as shown in FIG. **3**B, wherein δ=−2 dB, and the AM compensating AGC signal changes from the value $A/B=10^{(-0.05*\delta)}=1.2589$ to the value 1 after the time of duration for gain change, i.e.,

$$\text{AM_COMP_TC} = \frac{3}{\omega_{LPF}} \approx 24 \text{ ms.}$$

As shown in FIGS. **3**A and **3**B, there are no abrupt changes in the output of the AM receiver **100**.

FIG. **4** is a flowchart illustrating a method **400** for reducing abrupt changes in DC and amplitude of the output signal according to an embodiment of the invention. As shown in FIG. **4**, the method **400** comprises amplifying and mixing (**410**), with an amplitude modulation (AM) front-end module, an analog AM signal and an automatic gain control (AGC) signal from an AGC module; converting and sampling (**420**), with an analog-digital converter and down-sampling module, the amplified and mixed signal to generate a digital AM signal; digital mixing (**430**), with a digital mixer module, the digital AM signal to generate a first digital AM envelope signal; compensating (**440**), with an AM compensator module, the first digital AM envelope signal by an AM compensating AGC signal from the AM compensator module to generate a second digital AM envelope signal; demodulating (**450**), with a demodulation module, the second digital AM envelope signal to output a demodulated AM audio signal; and outputting (**460**), with an output module, a demodulated AM audio signal.

In the embodiment, the analog AM signal in step **410** is A·(1+m cos(Ωt))·cos(ωt+σt), wherein the A is amplitude value of an AM carrier wave, m is a degree of modulation, Ω is an angular frequency of an AM audio signal, w is an angular frequency of the AM carrier wave, and σ is an offset angular frequency of the carrier wave, and wherein the A is changed to B after the AGC signal is input into the AM front-end module. The first digital AM envelope signal generated in step **430** is A·(1+m cos(Ωt))·cos(σt).

In further embodiment, compensating the first digital AM envelope signal A·(1+m cos(Ωt))·cos(σt) by the AM compensating AGC signal in step **440** comprises multiplying the first digital AM envelope A·(1+m cos(Ωt))·cos(σt) by the AM compensating AGC signal according to the AGC signal (the AGC signal is valid during the rising edge), a value of gain change δ, and a time of duration for gain change (AM_COMP_TC). Wherein, a starting value of the AM compensating AGC signal is A/B, and $A/B=10^{(-0.05*\delta)}$. Thus, a starting value of the output of the AM compensator module is

$$B\bullet(1+m\cos(\Omega t))\bullet\cos(\sigma t)\bullet\frac{A}{B}=A\bullet(1+m\cos(\Omega t))\bullet\cos(\sigma t).$$

FIG. **5** is a continuation of the method **500** illustrated in FIG. **4**. As shown in FIG. **5**, demodulating the second digital AM envelope signal in step **450** further comprises digitally rotating (**510**), with a cordic module, the second digital AM envelope signal; filtering (**520**), with an AM high-pass filter module, the rotated signal, wherein the passband of the high-pass filter module is −3 dB and the corner frequency is ω_{HPF}, for example, 2*π*100; filtering (**530**), with an AM low-pass filter module, the rotated signal, wherein the passband of the low-pass filter module is −3 dB and the corner frequency is ω_{LPF}, for example, 2*π*20; and normalizing (**440**), with an AM normalization module, the signal filtered by the AM low-pass filter module and the signal filtered by the AM high-pass filter module to output the demodulated AM audio signal.

In the embodiment, the starting signal A·(1+m cos(Ωt))·cos(σt) of the AM compensator module is input to the cordic module. Then the cordic module outputs A·(1+m cos(Ωt)). The AM high-pass filter module receives the signal A·(1+m cos(Ωt)), removes the DC component from the signal A·(1+m cos(Ωt)) and output A·m cos(Ωt)). At the same time, the AM low-pass filter module also receives the signal A·(1+m cos(Ωt)) from the cordic module, obtains the DC component from the signal A·(1+m cos(Ωt)) and output A. Then, the AM normalization module receives A·m cos (Ωt) and A from the AM high-pass filter module and AM low-pass filter module respectively and outputs a starting value in cos(Ωt), i.e.,

$$\frac{A\bullet m\cos(\Omega t)}{A}=m\cos(\Omega t).$$

After the time of duration for gain change, i.e.,

$$\text{AM_COMP_TC} = \frac{3}{\omega_{LPF}},$$

the value of the AM compensating AGC signal is 1, and an effect $(1-e^{-\omega_{HPF}t})$ of the AM high-pass filter module and an effect $(1-e^{-\omega_{LPF}t})$ of the AM low-pass filter module mostly disappeared. That is, the output of the AM compensator module now is B·(1+m cos(Ωt))·cos(σt)·1=B·(1+m cos(Ωt))·cos(σt). Then this output signal B·(1+m cos(Ωt))·cos(σt) is also transmitted to the cordic module. The cordic module receives the signal B·(1+m cos(Ωt))·cos(σt) and outputs B·(1+m cos(Ωt)). The signal B·(1+m cos(Ωt)) then is trans-

mitted to the AM high-pass filter module and the low-pass filter module. The high-pass filter module removes the DC component from the signal B·(1+m cos(Ωt)) and outputs B·m cos(Ωt). The low-pass filter module obtains the DC component from the signal B·(1+m cos(Ωt)) and output B. Finally, the output of the AM normalization module is also m cos(Ωt).

For example, when δ=2 dB, the AM compensating AGC signal changes from the value $A/B=10^{(-0.05*\delta)}=0.7943$ to the value 1 after the time of duration for gain change, i.e.,

$$\text{AM_COMP_TC} = \frac{3}{\omega_{LPF}} \approx 24 \text{ ms},$$

as shown in FIG. **5**A. And when δ=−2 dB, the AM compensating AGC signal changes from the value $A/B=10^{(-0.05*\delta)}=1.2589$ to the value 1 after the time of duration for gain change, i.e.,

$$\text{AM_COMP_TC} = \frac{3}{\omega_{LPF}} \approx 24 \text{ ms}.$$

As shown in FIGS. **3**A and **3**B, there are no abrupt changes in the output of the demodulation module.

This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural components that do not differ from the literal language of the claims, or if they include equivalent structural components with insubstantial differences from the literal languages of the claims.

What is claimed is:

1. A method, comprising:

amplifying and mixing, with an amplitude modulation (AM) front-end module, an analog AM signal and an automatic gain control (AGC) signal from an AGC module;

converting and sampling, with an analog-digital converter and down-sampling module, the amplified and mixed signal to generate a digital AM signal;

digitally mixing, with a digital mixer module, the digital AM signal to generate a first digital AM envelope signal;

compensating, with an AM compensator module, the first digital AM envelope signal by an AM compensating AGC signal from the AM compensator module to generate a second digital AM envelope signal;

demodulating, with a demodulation module, the second digital AM envelope signal; and

outputting, with an output module, a demodulated AM audio signal;

wherein the analog AM signal is A·(1+m cos(Ωt))·cos(ωt+σt), wherein the A is amplitude value of an AM carrier wave, m is a degree of modulation, Ω is an angular frequency of an AM audio signal, ω is an angular frequency of the AM carrier wave, and σ is an offset angular frequency of the carrier wave, and wherein the A is changed to B after the AGC signal is input into the AM front-end module;

wherein the first digital AM envelope signal is A·(1+m cos(Ωt))·cos(σt)

wherein compensating the first digital AM envelope signal by the AM compensating AGC signal further comprises:

multiplying the first digital AM envelope by the AM compensating AGC signal according to the AGC signal, a value of gain change, and a time of duration for gain change.

2. The method of claim **1**, the value of gain change is δ and a starting value of the AM compensating AGC signal is A/B, wherein the A/B is $10^{(-0.05*\delta)}$.

3. The method of claim **2**, wherein demodulating the second digital AM envelope signal further comprises:

digitally rotating, with a cordic module, the second digital AM envelope signal;

filtering, with an AM high-pass filter module, the rotated signal;

filtering, with an AM low-pass filter module, the rotated signal; and

normalizing, with an AM normalization module, the signal filtered by the AM low-pass filter module and the signal filtered by the AM high-pass filter module.

4. The method of claim **3**, wherein an angular frequency of the AM low-pass filter module is ω_{LPF} and the time of duration for gain change is

$$\frac{3}{\omega_{LPF}}.$$

5. The method of claim **4**, wherein the value of the AM compensating AGC signal is 1, the value of the rotated signal is B·(1+m cos(Ωt)), and the value of the demodulated AM audio signal is m cos(Ωt) when the time of duration for gain change is

$$\frac{3}{\omega_{LPF}}.$$

6. A device, comprising:

an automatic gain control (AGC) module configured to generate an AGC signal for adjusting the gain;

an amplitude modulation (AM) front-end module connected to the AGC module and configured to amplify and mix an analog AM signal and the AGC signal;

an analog-digital converter and down-sampling module connected to the AM front-end module and configured to convert and sample the amplified and mixed signal to generate a digital AM signal;

a digital mixer module connected to the ADC and down-sampling module and configured to digitally mix the digital AM signal to generate a first digital AM envelope signal;

an AM compensator module connected to the digital mixer module and to the AGC module and configured to compensate the first digital AM envelope signal by an AM compensating AGC signal from the AM compensator module to generate a second digital AM envelope signal;

a demodulation module connected to the AM compensator module and configured to demodulate the second digital AM envelope signal; and

an output module connected to the demodulation module and configured to output a demodulated AM audio signal;

wherein the analog AM signal is $A\cdot(1+m\cos(\Omega t))\cdot\cos(\omega t+\sigma t)$, wherein the A is amplitude value of an AM carrier wave, m is a degree of modulation, Ω is an angular frequency of an AM audio signal, ω is an angular frequency of the AM carrier wave, and σ is an offset angular frequency of the carrier wave, and wherein the amplitude value of the AM carrier wave is changed from A to B due to a gain change from the AGC module;

wherein the first digital AM envelope signal is $A\cdot(1+m\cos(\Omega t))\cdot\cos(\sigma t)$; and

wherein the AM compensator module further configured to multiply the first digital AM envelope by the AM compensating AGC signal according to the AGC signal, a value of gain change, and a time of duration for gain change.

7. The device of claim **6**, the value of gain change is δ and a starting value of the AM compensating AGC signal is A/B, wherein the A/B is $10^{(-0.05*\delta)}$.

8. The device of claim **7**, the demodulation module further comprises:

a cordic module connected to the AM compensator module and configured to digitally rotate the second digital AM envelope signal;

an AM high-pass filter module connected to the cordic module and configured to filter the rotated signal;

an AM low-pass filter module connected to the cordic module and configured to filter the rotated signal; and

an AM normalization module connected to the AM high-pass filter module and to the AM low-pass filter module and configured to normalize the signal filtered by the AM low-pass filter module and the signal filtered by the AM high-pass filter module to output the demodulated AM audio signal.

9. The device of claim **8**, wherein an angular frequency of the AM low-pass filter module is ω_{LPF} and the time of duration for gain change is

$$\frac{3}{\omega_{LPF}}.$$

10. The device of claim **9**, wherein the value of the AM compensating AGC signal is 1, the value of the rotated signal is $B\cdot(1+m\cos(\Omega t))$, and the value of the demodulated AM audio signal is $m\cos(\Omega t)$ when the time of duration for gain change is

$$\frac{3}{\omega_{LPF}}.$$

* * * * *