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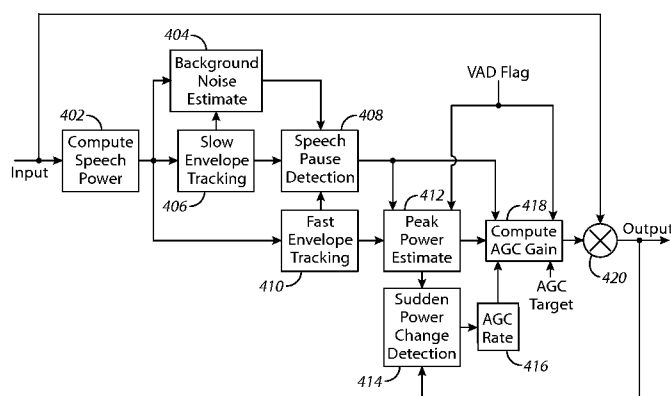
(54) **Title:** APPARATUS AND METHOD FOR AUTOMATIC GAIN CONTROL

FIG. 4

(57) **Abstract:** A speech signal is received at an input. At least one electrical value associated with the received speech signal is tracked. A dynamic adjustment of the speech signal is determined. The dynamic adjustment is selected at least in part so as to minimize a distortion and minimize an over-amplification of the speech signal based at least in part upon an analysis of the at least one electrical value. The dynamic adjustment is further selected to obtain a desired output signal characteristic for the speech signal presented at an output. The dynamic adjustment value is applied to the speech signal and the adjusted speech signal is presented at the output. The gain of the signal can also be limited to prevent over-amplification.

APPARATUS AND METHOD FOR AUTOMATIC GAIN CONTROL

FIELD OF THE INVENTION

[0001] The invention relates generally to providing voice signals to users, and, more specifically to providing automatic gain control for these signals.

BACKGROUND OF THE INVENTION

[0002] Automatic gain control (AGC) systems are generally designed to provide a normalized speech level at the output of the system by applying a gain to voice signals received at an input. It is typically desirable that this gain is made as a function of time and that this gain is varied very slowly from one frame to another. However, if the gain that will be applied to speech signal is high, then it will take very long time for AGC to settle to the normalized desired speech level. Unfortunately, many previous AGC algorithms suffered in effectiveness by providing normalized speech very quickly without considering the level of speech signal at the input.

[0003] Another problem with previous AGC systems involves noisy environments such as automobile applications. In these applications, where background noise is often high, communications sometimes become impossible when AGC algorithms amplify noise signals more than speech signals. This is a considerable problem in vehicle-to-vehicle communications, which results in an increased noise loop back problem from one vehicle to another, often making effective communications difficult or impossible to achieve.

[0004] Still another problem associated with previous AGC approaches is the tendency to over or under amplify the input signal under certain conditions, creating a non-desirable output. More specifically and when normalizing audio signals, unintentional over-amplification can produce a noticeably unpleasant (e.g., noisy) output. When used in vehicle-based hands-free applications where an AGC algorithm is intended to normalize speech, over amplified signals can be unintentionally produced by noise and other sounds common to the environment in the input signal that are misrecognised as speech.

[0005] The problems described above result in the limited use of AGC algorithms in automobile and other noisy applications. And when used, user dissatisfaction with these approaches has been high.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] The present invention is illustrated, by way of example and not limitation, in the accompanying figures, in which like reference numerals indicate similar elements, and in which:

[0007] FIG. 1 comprises a block diagram of an apparatus that provides automatic gain control according to various embodiments of the present invention;

[0008] FIG. 2 comprises a flowchart of an approach for providing automatic gain control according to various embodiments of the present invention;

[0009] FIG. 3 comprises a flowchart of an approach for providing automatic gain control according to various embodiments of the present invention;

[0010] FIG. 4 comprises a flowchart showing an approach for providing automatic gain control according to various embodiments of the present invention;

[0011] FIG. 5 comprises a graph showing the provision of gain control according to various embodiments of the present invention.

[0012] Skilled artisans will appreciate that elements in the figures are illustrated for simplicity and clarity and have not necessarily been drawn to scale. For example, the dimensions and/or relative positioning of some of the elements in the figures may be exaggerated relative to other elements to help to improve understanding of various embodiments of the present invention. Also, common but well-understood elements that are useful or necessary in a commercially feasible embodiment are often not depicted in order to facilitate a less obstructed view of these various embodiments of the present invention. It will further be appreciated that certain actions and/or steps may be described or depicted in a particular order of occurrence while those skilled in the art will understand that such specificity with respect to sequence is not actually required. It will also be understood that the terms and expressions used herein have the ordinary meaning as is accorded to such

terms and expressions with respect to their corresponding respective areas of inquiry and study except where specific meanings have otherwise been set forth herein.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0013] In the approaches described herein, noise-adaptive Automatic Gain Control (AGC) algorithms that are particularly applicable and effective in noisy environments (e.g., vehicular applications) are provided. Some of these approaches normalize the level speech signals instantaneously without adding any or substantially any distortion.

[0014] In noisy environments, AGC approaches tend to increase the noise power level much more than speech signals which is not desired. Consequently, many of the present approaches employ a robust noise adaptive mechanism that controls the amplification of noise and, as a result, the noise power level is not increased more than the speech power level.

[0015] The approaches described herein are also applicable to a wide range of applications such as hands-free communications in vehicles. Many of these approaches are based upon calculations involving the background noise estimate, slow and fast envelope tracking of speech signals, speech pause detection, and speech peak power estimate, among other factors.

[0016] Many of these approaches prevent over-amplification by an Automatic Gain Control (AGC) algorithm by pre-determining the maximum allowed amplitude of the output signal. If an absolute limit can be established for the output signal, over-amplification can be limited or eliminated, thereby reducing its negative impact on the system.

[0017] In many of these embodiments, a speech signal is received at an input. At least one electrical value associated with the received speech signal is tracked. A dynamic adjustment of the speech signal is determined. The dynamic adjustment is selected at least in part so as to minimize a distortion and minimize an over-amplification of the speech signal based at least in part upon an analysis of the at least one electrical value. The dynamic adjustment is further selected to obtain a desired output signal characteristic for the speech signal presented at an output. The dynamic adjustment value is applied to the speech signal

and the adjusted speech signal is presented at the output.

[0018] In some aspects, a power level is measured that is associated with an electrical envelope. In other aspects, a speech pause associated with an electrical envelope is detected.

[0019] The tracking may include tracking at least one difference between a power level associated with the speech signal and a desired power level. In this case and to take one example, the dynamic adjustment is effective to maintain the signal at the output at substantially the desired power level. Other tracking approaches may also be used.

[0020] The analysis may include a variety of different calculations. In one aspect, the analysis includes a computation of a maximum gain based upon a desired output divided the input and applying the dynamic adjustment value includes limiting the gain of the adjusted speech signal at the output to substantially the maximum computed gain.

[0021] In other aspects, the speech signal is transmitted to an audio application in a vehicle. The audio application may be a speaker associated with any application such as hands-free applications in vehicles.

[0022] In others of these embodiments, a speech signal is received. Based upon at least one characteristic of the speech signal and at least one characteristic of the desired output signal, a maximum gain so as to limit over amplification of the received speech signal is determined. The determined maximum gain is applied to the signal so as to limit over-amplification of the input signal.

[0023] In some aspects, the maximum gain is the gain that would be effective to saturate the speech signal. By “saturation”, it is meant _____. In other aspects, the maximum gain is the maximum desired output divided by a maximum magnitude of the received speech signal.

[0024] In still others of these embodiments, an apparatus configured to control automatic gain control for speech signals includes an interface and a controller. The interface includes an input and an output and the input is configured to receive a speech signal.

[0025] The controller is coupled to the interface and configured to track at least one electrical value associated with the received speech signal. The controller is further configured to determine a dynamic adjustment of the speech signal and the dynamic

adjustment is selected at least in part so as to minimize a distortion and minimize an over-amplification of the speech signal based at least in part upon an analysis by the controller of the at least one electrical value. The dynamic adjustment is further selected to obtain a desired output signal characteristic for the speech signal to be presented at the output. The controller is configured to apply the dynamic adjustment value to the speech signal and present the adjusted speech signal at the output of the interface.

[0026] In some aspects, the controller is configured to track a power level measured associated with an electrical envelope. In other aspects, the controller is configured to detect a speech pause associated with an electrical envelope. In yet other aspects, the controller is configured to track at least one difference between a power level associated with the speech signal and a desired power level, and the dynamic adjustment is effective to maintain the signal at the output at substantially the desired power level.

[0027] In some examples, the analysis performs a computation of a maximum gain based upon a desired output divided the input and the gain of the adjusted speech signal is limited at the output to substantially the maximum gain.

[0028] In some aspects, the output is coupled to an audio application in a vehicle. In other aspects, the audio application is selected from the group consisting of a speaker and a microphone. Other examples of audio applications and environments are possible. In this regard, it will be appreciated that although the approaches described herein are often described as being implemented in vehicular environments, they may be applied to any environment and are in no way limited to vehicular environments.

[0029] Referring now to FIG. 1, an apparatus 100 configured to control automatic gain control for speech signals includes an interface 102 and a controller 104. The interface 102 includes an input 106 and an output 108 and the input 106 is configured to receive a speech signal 110.

[0030] The controller 104 is coupled to the interface 102 and is configured to track at least one electrical value associated with the received speech signal 110. The controller 104 is further configured to determine a dynamic adjustment of the speech signal 110 and the dynamic adjustment is selected at least in part so as to minimize a distortion and minimize an over-amplification of the speech signal 110 based at least in part upon an analysis by the

controller 104 of the at least one electrical value. The dynamic adjustment is further selected to obtain a desired output signal characteristic for the modified speech signal 112 to be presented at the output 108. The controller 104 is configured to apply the dynamic adjustment value to the speech signal 110 and present the adjusted speech signal 112 at the output 108 of the interface 102.

[0031] In some aspects, the controller 104 is configured to track a power level measured associated with an electrical envelope. By an electrical envelope, it is meant _____. In other aspects, the controller 104 is configured to detect a speech pause associated with the electrical envelope. By “speech pause,” it is meant t _____. In yet other aspects, the controller 104 is configured to track at least one difference between a power level associated with the speech signal 110 and a desired power level, and the dynamic adjustment is effective to maintain the signal at the output signal 112 at substantially the desired power level.

[0032] In some examples, the controller 104 computes a maximum gain based upon a desired output divided the input. The gain of the adjusted speech signal 112 is limited at the output to substantially the maximum gain.

[0033] In some other aspects, the output 108 is coupled to an audio application 114 in a vehicle. In other aspects, the audio application may be or may utilize a speaker and a microphone as used, for example, in hands-free vehicle applications.

[0034] In the above-described approaches, the speech signal 110 is scaled very effectively without depending on the level of input speech (e.g., approximately 40 dB/sec of gain is applied to the speech signal 110 where is necessary without adding any noticeable distortion to speech). In order to realize this, the relative power ratio between the instantaneous speech power level and desired speech power level may be compared.

[0035] Based on this ratio, then the AGC scaling rate is determined. In some of these approaches, possible AGC scaling rates may be split into multiple regions and then the actual rate selected from these regions and according to various conditions including the above-mentioned ratio. In one example, the AGC scaling rate is split into three regions: (a) a low AGC scaling rate; (b) a medium AGC scaling rate; and (c) a high AGC scaling rate. In this example, a low AGC scaling rate means that the instantaneous speech power and desired

speech power levels are very close (e.g., within _____ of each other); therefore, the AGC gain applied to signal vary very slowly from one frame to another (e.g., applying 0.5 dB per second AGC gain). A medium AGC scaling rate means that the instantaneous speech power and desired speech power levels are not that close (e.g., within _____ of each other); in this case, AGC gain applied to signal is in the middle range (e.g., applying 7 dB per second AGC gain). A high AGC scaling rate means that the difference between the instantaneous speech power level and desired speech power level are very big (e.g., _____); in this case, the AGC gain applied to signal should be in the high range (e.g., applying 40 dB per second AGC gain). In these approaches speech levels are normalized as effectively as possible in a short period of time and, hence, providing the desire speech level at the output of HF system.

[0036] These approaches also improve the robustness of AGC in extremely noisy environments. More specifically, the above-mentioned AGC algorithms are immune or substantially immune to amplifying noise power and, hence, eliminate or substantially eliminate AGC creep for noise signals under heavy noise environments such as in automobile applications. “AGC creep” as used herein means _____.

[0037] For this purpose, speech pauses are detected based on the slow and fast envelope tracking mechanisms. If the speech pauses are detected, then the signal is not scaled and as a result of this the noise power is not amplified. In order to increase the robustness of these approaches, the degree of periodicity measure for speech signals may also be introduced and utilized. Combining both of these methods, the AGC algorithms become very robust in heavy noisy environments and eliminate (or substantially eliminate) the AGC creep problem without amplifying noise while still amplifying speech signals.

[0038] Referring now to FIG. 2, one example of an approach for providing AGC is described. At step 202, a speech signal is received at an input. At step 204, at least one electrical value associated with the received speech signal is tracked. In some aspects, a power level is measured that is associated with an electrical envelope is tracked. In other aspects, a speech pause associated with an electrical envelope is tracked. The tracking may include tracking at least one difference between a power level associated with the speech signal and a desired power level. In this case and to take one example, the dynamic adjustment is effective to maintain the signal at the output at substantially the desired power

level.

[0039] At step 206, a dynamic adjustment of the speech signal is determined. The dynamic adjustment is selected at least in part so as to minimize a distortion and minimize an over-amplification of the speech signal based at least in part upon an analysis of the at least one electrical value. The dynamic adjustment is further selected to obtain a desired output signal characteristic for the speech signal presented at an output. The analysis may utilize a variety of different calculations. In one aspect, the analysis includes a computation of a maximum gain based upon a desired output divided the input and applying the dynamic adjustment value comprises limiting the gain of the adjusted speech signal at the output to substantially the maximum computed gain.

[0040] At step 208, the dynamic adjustment value is applied to the speech signal and the adjusted speech signal is presented at the output. The speech signal may then be transmitted to an audio application in a vehicle. The audio application may be a speaker associated with any application such as hands-free applications in vehicles. Other examples of audio applications are possible.

[0041] Referring now to FIG. 3, another approach for providing AGC is described. At step 302, a speech signal is received. Based upon at least one characteristic of the speech signal and at least one characteristic of the desired output signal, at step 304, a maximum gain so as to limit over amplification of the received speech signal is determined. In some aspects, the maximum gain comprises a gain that would be effective to saturate the speech signal. In other aspects, the maximum gain comprises a maximum desired output divided by a maximum magnitude of the received speech signal.

[0042] For a given input signal I and a desired output signal O , there exists a bounded gain relationship (G), with a predetermined Lower Limit (LL) that will ensure that O does not exceed a given amplitude:

[0043] $LL \geq G \geq \text{Max Amplitude}_{(O)} / \text{Max Amplitude}_{(I)}$

[0044] Where $G_{(max)}$ is $\text{Max Amplitude}_{(O)} / \text{Max Amplitude}_{(I)}$ and the input and output signals share a common maximum dynamic range.

[0045] The choice of LL can be arbitrary or determined by knowledge concerning the limits of I and O . For example, if the amplitude of the output signal cannot exceed that of the

input signal, LL is 0dB (no gain). Thus, the choice of LL reduces under-amplification error.

[0046] Since $MaxAmplitude_{(o)}$ is pre-determined, G will vary with $MaxAmplitude_{(i)}$ and will be bounded by LL below. It will only change (and only ever downwards) when a higher-than-previously-seen $MaxAmplitude_{(i)}$ is encountered for a given input/output set.

[0047] At step 306, the determined maximum gain is applied to the signal so as to limit over-amplification of the input signal. Since G is now bounded by the above formula, the level of over-amplification the AGC process can apply is limited, reducing its effect. The effect is most pronounced when the signal to be normalized (e.g. speech) is substantially greater in magnitude than the signals that may be misrecognised and normalized erroneously (e.g. noise).

[0048] An example application would be the normalization of the signal received from a telephony device where the input is normalized to maximize use of the dynamic range of the output signal. In this case, LL will be 0dB and G will be limited by the maximum amplitude of the input signal, which may range from full-scale (limiting G to 0dB) to a lower (normally at most 6dB, or half) value.

[0049] In each case, since the AGC will be operating near $G_{(max)}$ (to normalize speech to full scale), the AGC will be prevented from substantially over-amplifying smaller signals (such as noise) that are misrecognised as speech.

[0050] Referring now to FIG. 4, an example of an approach at AGC is described. This approach describes various modules that can be used to implement the functions described with respect to FIGs. 1 and 2 above. It will be appreciated that these functions may be implemented by any combination of hardware and/or software (e.g., computer instructions stored on computer media). The approach of FIG. 4 utilizes a speech power computation module 402, a background noise estimator, a slow envelope tracking module 406, a speech pause detection module 408, a fast envelope tracking module 410, a peak power estimator 412, a sudden power change detection module 414, an AGC rate module 416, an AGC gain computational module 418, and a summer 420.

[0051] The speech power computation module 402 computes power of the speech. The average power, P_0 of a speech segment, $s_m(n)$ is computed for the m^{th} speech frame as follows:

$$[0052] \quad P_0 = \frac{1}{N} \sum_{n=0}^{N-1} s_m(n) s_m(n) \quad (1)$$

[0053] The slow envelope tracking module 406 provides for the slow envelope tracking, first order IIR smoothing of the average power for the input speech signal. The slow envelope tracking, $P_s(m)$ for the m^{th} frame is computed as given in the following equation:

$$[0054] \quad P_s(m) = \beta_s(m) P_s(m-1) + (1 - \beta_s(m)) \sqrt{P_0} \quad (2)$$

[0055] The time variant constant, $\beta_s(m)$ for the IIR filter is chosen differentially for rising and falling signal edges as given in the following equation:

$$[0056] \quad \beta_s(m) = \begin{cases} \beta_{s,r} & ; \sqrt{P_0} > P_s(m-1) \\ \beta_{s,f} & ; \text{Otherwise} \end{cases} \quad (3)$$

[0057] A rising signal edge is followed faster than a falling one as:

$$[0058] \quad 0 << \beta_{s,r} < \beta_{s,f} < 1 \quad (4)$$

[0059] The fast envelope tracking module 410 performs the fast envelope tracking, $P_F(m)$ for the m^{th} frame and is computed in the same manner as the slow envelope tracking as given in the following equation:

$$[0060] \quad P_F(m) = \beta_F(m) P_F(m-1) + (1 - \beta_F(m)) \sqrt{P_0} \quad (5)$$

[0061] Where

$$[0062] \quad \beta_F(m) = \begin{cases} \beta_{F,r} & ; \sqrt{P_0} > P_F(m-1) \\ \beta_{F,f} & ; \text{Otherwise} \end{cases} \quad (6)$$

[0063] One difference between slow and fast envelope tracking filters, is that the different time varying constants are used which provide the following conditions:

$$[0064] \quad \begin{aligned} \beta_{s,r} &> \beta_{F,r} \\ \beta_{s,f} &> \beta_{F,f} \end{aligned} \quad (7)$$

[0065] The background noise estimator module 404 provides for estimation of the background noise level, minimum statistics and power smoothing only during speech pauses is used for the AGC algorithm. For estimation of the long term average power of the signal, $P_N(m)$ for the m^{th} frame, first order IIR can be utilized to smooth the instantaneous power

of speech signals as given in the following:

$$[0066] \quad P_N(m) = \beta_N(m)P_N(m-1) + (1 - \beta_N(m))P_0 \quad (8)$$

[0067] To detect rising speech signal powers very rapidly, different smoothing constants for rising and falling signal edges are used as given:

$$[0068] \quad \beta_N(m) = \begin{cases} \beta_{N,r}; & P_0 > P_N(m-1) \\ \beta_{N,f}; & \text{Otherwise} \end{cases} \quad (9)$$

[0069] Where $0 < \beta_{N,r} < \beta_{N,f} < 1$. For estimating the background noise

level, $P_{BNE}(m)$ for the m^{th} frame, the minimum of the current average short term power and the output of the background noise level for the previous frame are compared. To avoid freezing at a global minimum, the result of the minimum operator is multiplied by a constant slightly larger than one as:

$$[0070] \quad P_{BNE}(m) = \min\{P_N(m), P_{BNE}(m-1)\}(1 + \varepsilon) \quad (10)$$

[0071] Where the constant, ε , is a small positive value that controls the maximum speed for increasing the estimated noise level. The quantity:

$$[0072] \quad \Delta(\varepsilon) = f_s 10 \log_{10}(1 + \varepsilon) \quad (11)$$

[0073] describes the maximum background noise power increase in decibels (dB) per second where f_s is the sampling frequency. Depending on the type of background noise, ε should be chosen such that $\Delta(\varepsilon)$ is within the interval 0.5 dB/second and 3 dB/second.

[0074] The speech pause detection module 408 compares the outputs of the fast and slow envelope tracking estimators and is the first stage of a simple speech pause detector. At the beginning of speech interval, the output of the fast envelope tracking estimator rises faster than that of the slow one. Due to short term power variations during speech activity on one hand and the choices of the time constants on the other hand, the output signal of the fast envelope tracking estimator is always larger than its slow counterpart. At the end of the voice activity period, the output of the slow envelope tracking estimator does not decrease as rapidly as does that of the fast envelope tracking estimator, and now the output of the slow envelope tracking estimator exceeds that of the fast one.

[0075] In order to avoid wrong decisions during speech pauses or voice activity, the

simple comparison is enhanced by bounding the output of the slow envelope tracking estimator to a constant, $B_N(m)$. This constant should be chosen a few decibels above $(10 \log_{10}(\alpha))$ the background noise level estimate as described above and given as follows:

$$[0076] \quad B_N(m) = \alpha P_{BNE}(m) \quad (12)$$

[0077] The threshold for speech pause or speech activity detector, $T(m)$, is then computed as:

$$[0078] \quad T(m) = \max\{P_S(m), \sqrt{B_N(m)}\} \quad (13)$$

[0079] The speech pauses ($S_{VAD}(m) = 0$) or speech activity ($S_{VAD}(m) = 1$) is detected as follows:

$$[0080] \quad S_{VAD}(m) = \begin{cases} 1; & P_F(m) > T(m) \\ 0; & \text{Otherwise} \end{cases} \quad (14)$$

[0081] The peak power estimator module 412 estimates the peak power of speech signals. During voice intervals, the peak amplitude level is tracked. This is performed again by first order IIR filtering as:

$$[0082] \quad P_P(m) = \begin{cases} \beta_P(m)P_P(m-1) + (1 - \beta_P(m))P_F(m); & S_{VAD}(m) = 1 \\ P_P(m-1); & \text{Otherwise} \end{cases} \quad (15)$$

[0083] The filter is updated only if there is speech activity; otherwise the filter keeps its old output values. The fast envelope tracking estimator is used as an input. In order to avoid an excessive rapid decreases $P_P(m)$ during wrong decision of speech pause detection, a very long time constant for falling signal edges was chosen as:

$$[0084] \quad \beta_P(m) = \begin{cases} \beta_{P,r}; & P_F(m) > P_P(m-1) \\ \beta_{P,f}; & \text{Otherwise} \end{cases} \quad (16)$$

[0085] Where

$$[0086] \quad 0 \ll \beta_{N,r} < \beta_{N,f} < 1 \quad (17)$$

[0087] The sudden power change detection module 414 and AGC rate determination module 416 are used to determine the AGC rate that will be applied during AGC gain computation. Additionally, the sudden power change detection pre-determined variety of AGC variables (i.e., peak power estimate, slow envelope tracking, fast envelope tracking,

and background noise estimate) and AGC gain are used in order to more effectively eliminate the sudden power change affects in a short period of time.

[0088] The AGC gain computation module 418 performs signal scaling. During speech intervals the short term power of the input speech signal is estimated and compared to a desired value. If the speech level exceeds an upper bound, the gain factor, $G(m)$ for the m^{th} frame is decreased – in the other case the gain is increased. In order to avoid fast gain variations during short speech pauses, $G(m)$ is incremented or decremented in very small steps. The gain factors, $G(m)$ is updated only during the periods of speech activity as:

$$[0089] \quad G(m) = \begin{cases} \rho G(m-1); & S_{VAD}(m) = 1 \\ G(m-1); & \text{Otherwise} \end{cases} \quad (18)$$

[0090] The scaling factor, ρ is computed by comparing the amplified or attenuated (depending on $G(m-1)$) speech level estimator, $P_p(m)$ with the desired level, D_L . If the speech level after scaling with $G(m-1)$ is still small, the gain factor is increased as:

$$[0091] \quad \rho = \begin{cases} G_{inc}; & D_L > P_p(m)G(m-1) \\ G_{dec}; & \text{Otherwise} \end{cases} \quad (19)$$

[0092] Where

$$[0093] \quad \begin{aligned} G_{inc} &= (1 + \mu) \\ G_{dec} &= \frac{1}{G_{inc}} \end{aligned} \quad (20)$$

[0094] Where the constant, μ , is a small positive value that controls the maximum speed for increasing or decreasing the AGC gain in a second. The quantity:

$$[0095] \quad \Delta(\mu) = f_s 20 \log_{10}(1 + \mu) \quad (21)$$

[0096] describes the maximum AGC Gain increase/decrease in decibels (dB) per second where f_s is the sampling frequency. μ should be chosen such that $\Delta(\mu)$ is to provide the desired AGC gain increase/decrease in decibels (dB) per second. For example, if $\mu = 0.0001$, then the $\Delta(\mu) = 7$ dB per second.

[0097] The summer 420 sums the gain from the module 418 and the input signal and this is made available at the output. More specifically, the output speech signal of AGC

algorithm for the m^{th} frame, $s_0(m, n)$ is computed by multiplying the input speech signal for the m^{th} frame, $s_m(n)$ with the AGC gain factor, $G(m)$ as:

$$[0098] \quad s_0(m, n) = G(m)s_m(n) \quad (22)$$

[0099] Referring now to FIG. 5, an example graph showing the change in $G_{(max)}$ in response to increasingly larger input signals is described. For each successively higher input sample, $G_{(max)}$ is reduced accordingly. With the upper bound on G shrinking in this fashion, it can be seen that the maximum possible over amplification error (which is often applied to smaller input signals) has been limited by the larger input signals. Thus, over-amplification is prevented and signal quality is improved.

[00100] It will be understood that the functions described herein may be implemented by computer instructions stored on a computer media (e.g., in a memory) and executed by a processing device (e.g., a microprocessor, controller, or the like).

[00101] It is understood that the implementation of other variations and modifications of the present invention and its various aspects will be apparent to those of ordinary skill in the art and that the present invention is not limited by the specific embodiments described. It is therefore contemplated to cover by the present invention any modifications, variations or equivalents that fall within the spirit and scope of the basic underlying principles disclosed and claimed herein.

CLAIMS

What is claimed is:

1. A method of controlling automatic gain control for speech signals, the method comprising:

receiving a speech signal at an input;
tracking at least one electrical value associated with the received speech signal;
determining a dynamic adjustment of the speech signal, the dynamic adjustment selected at least in part so as to minimize a distortion and minimize an over-amplification of the speech signal based at least in part upon an analysis of the at least one electrical value, the dynamic adjustment further selected to obtain a desired output signal characteristic for the speech signal presented at an output;
applying the dynamic adjustment value to the speech signal;
presenting the adjusted speech signal at the output.

2. The method of claim 1 wherein the tracking comprises tracking a power level measured associated with an electrical envelope.

3. The method of claim 1 wherein the tracking comprises detecting a speech pause associated with an electrical envelope.

4. The method of claim 1 wherein the tracking comprises tracking at least one difference between a power level associated with the speech signal and a desired power level, and wherein the dynamic adjustment is effective to maintain the signal at the output at substantially the desired power level.

5. The method of claim 1 wherein the analysis comprises a computation of a maximum gain based upon a desired output divided the input and wherein applying the dynamic adjustment value comprises limiting the gain of the adjusted speech signal at the output to substantially the maximum computed gain.

6. The method of claim 1 further comprising transmitting the speech signal to an audio application in a vehicle.

7. A method of providing automatic speech gain control to prevent over-amplification of speech signals, the method comprising:
receiving a speech signal;
based upon at least one characteristic of the speech signal and at least one characteristic of the desired output signal, determining a maximum gain so as to limit over amplification of the received speech signal;
applying the determined maximum gain to the signal so as to limit over-amplification of the input signal.

8. The method of claim 7 wherein the maximum gain comprises a gain that would be effective to saturate the speech signal.

9. The method of claim 7 wherein the maximum gain comprises a maximum desired output divided by a maximum magnitude of the received speech signal.

10. An apparatus configured to control automatic gain control for speech signals, the apparatus comprising:

an interface with an input and an output, the input being configured to receive a speech signal;

a controller, the controller configured to track at least one electrical value associated with the received speech signal, the controller further configured to determine a dynamic adjustment of the speech signal, the dynamic adjustment selected at least in part so as to minimize a distortion and minimize an over-amplification of the speech signal based at least in part upon an analysis by the controller of the at least one electrical value, the dynamic adjustment further selected to obtain a desired output signal characteristic for the speech signal to be presented at the output, the controller configured to apply the dynamic

adjustment value to the speech signal and present the adjusted speech signal at the output of the interface.

11. The apparatus of claim 10 wherein the controller is configured to track a power level measured associated with an electrical envelope.

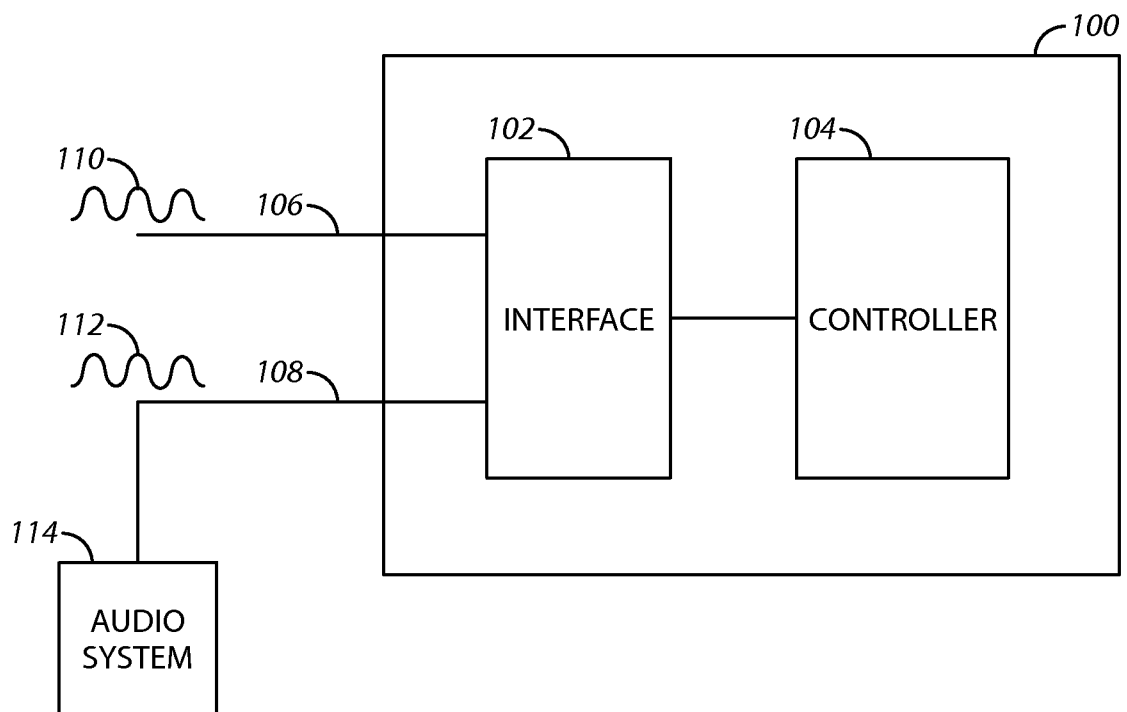
12. The apparatus of claim 10 wherein the controller is configured to detect a speech pause associated with an electrical envelope.

13. The apparatus of claim 10 wherein the controller is configured to track at least one difference between a power level associated with the speech signal and a desired power level, and wherein the dynamic adjustment is effective to maintain the signal at the output at substantially the desired power level.

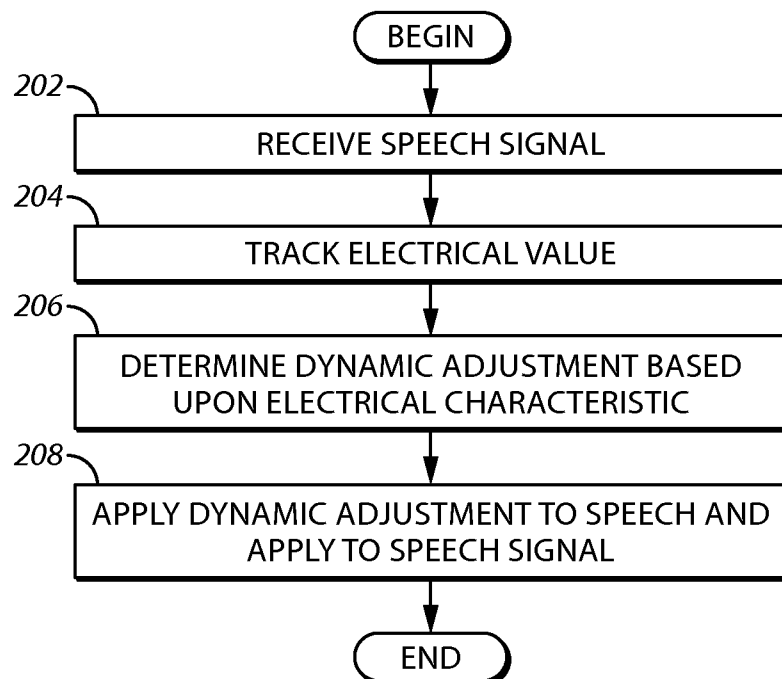
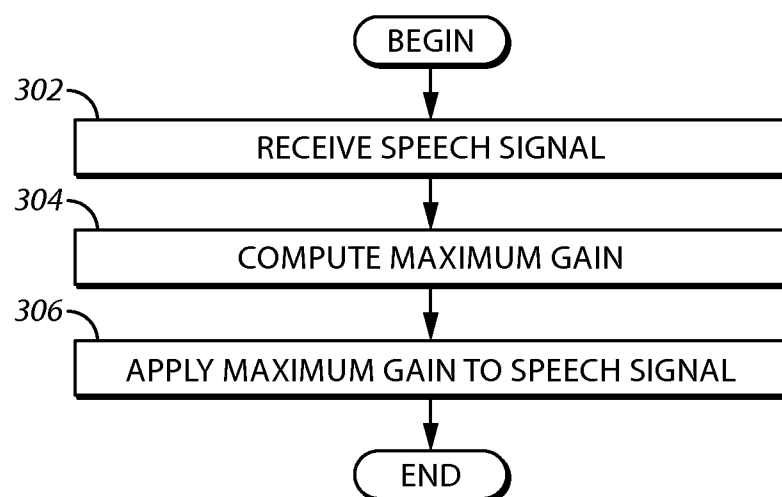
14. The apparatus of claim 10 wherein the analysis comprises a computation of a maximum gain based upon a desired output divided the input and wherein applying the dynamic adjustment value comprises limiting the gain of the adjusted speech signal at the output to substantially the maximum gain.

15. The apparatus of claim 10 wherein the output is coupled to an audio application in a vehicle.

16. The apparatus of claim 15 wherein the audio application is selected from the group consisting of a speaker and a microphone.

1/4***FIG. 1***

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**FIG. 2****FIG. 3**

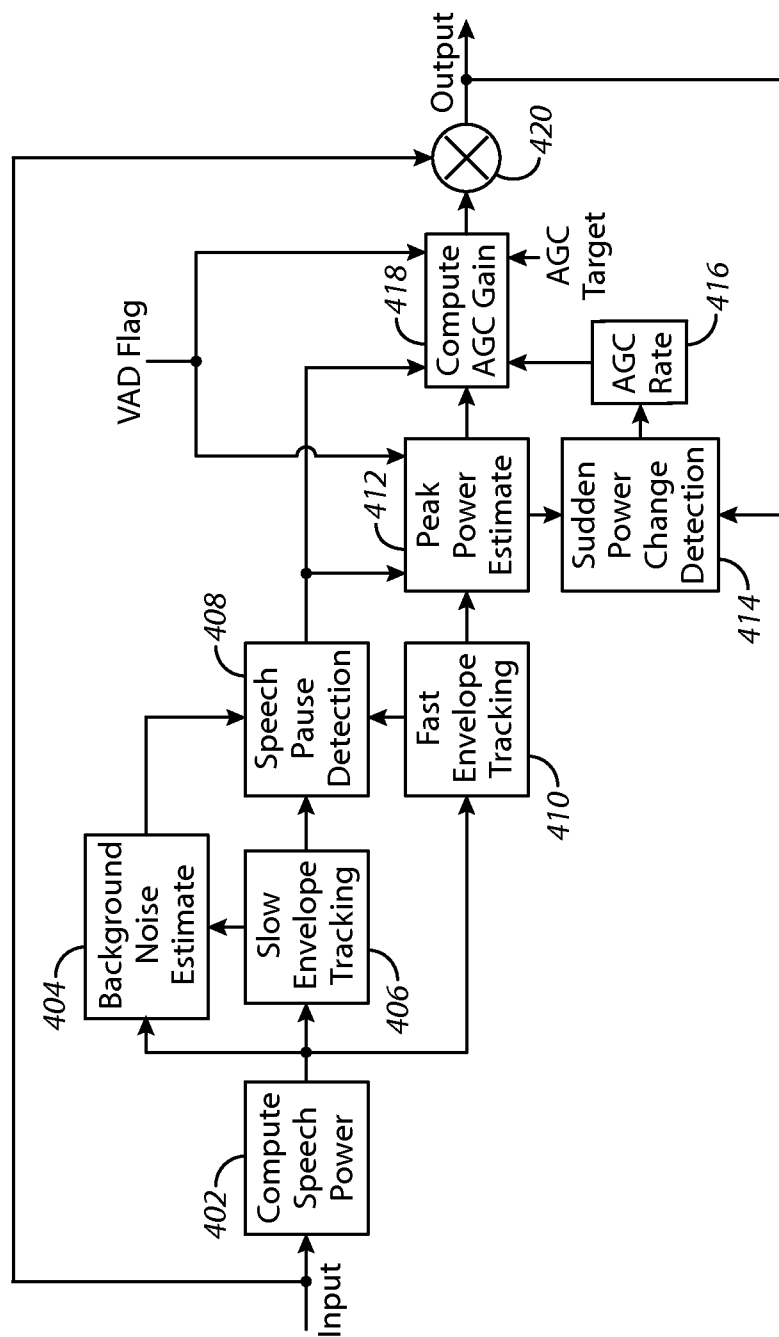


FIG. 4

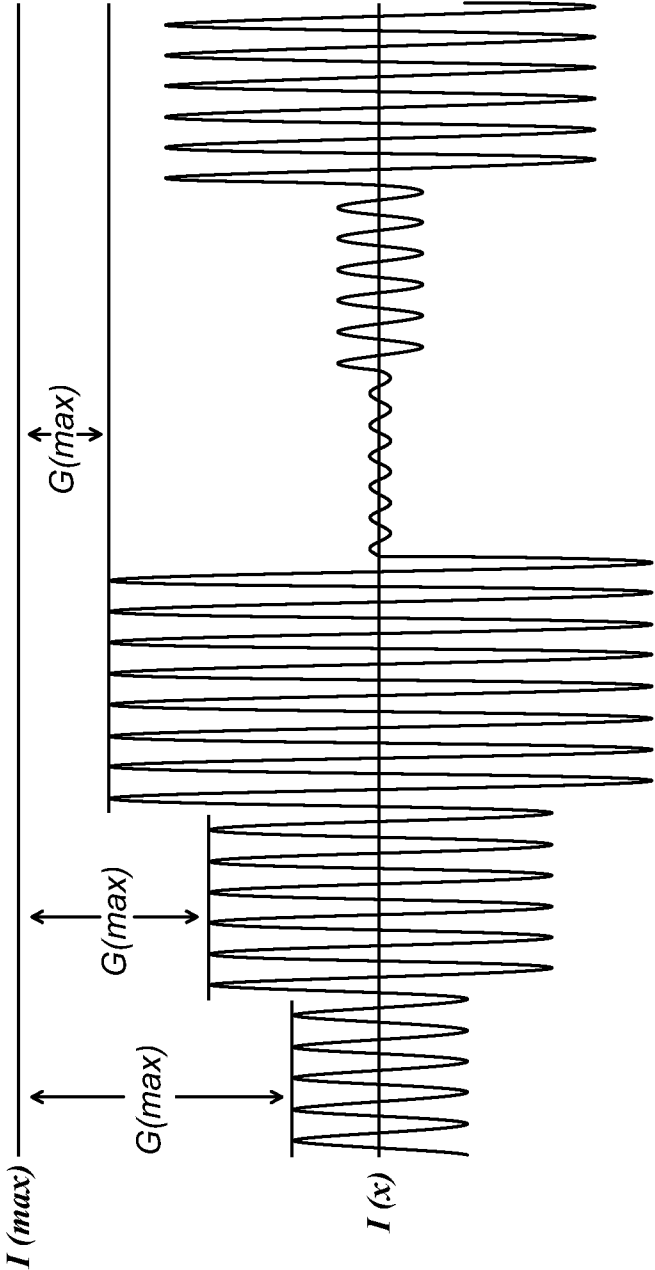


FIG. 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2012/041024

A. CLASSIFICATION OF SUBJECT MATTER
INV. H03G3/30 H04M1/60
ADD.

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)
H04M H03G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6 212 273 B1 (HEMKUMAR NARIANKADU D [US] ET AL) 3 April 2001 (2001-04-03) abstract column 9, lines 52-61; figures 1-5 column 10, lines 35-44 column 1, lines 41-55 column 11, line 52 - column 12, line 4 column 3, lines 5-20 -----	1-16
X	WO 02/097977 A2 (INTEL CORP [US]) 5 December 2002 (2002-12-05) page 7, line 1 - page 8, line 6; figures 1-3 page 5, line 11 - page 6, line 24 -----	1-16
X	EP 2 048 659 A1 (HARMAN BECKER AUTOMOTIVE SYS [DE]) 15 April 2009 (2009-04-15) the whole document -----	1-16



Further documents are listed in the continuation of Box C.



See patent family annex.

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

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Date of the actual completion of the international search

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2012/041024

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 6212273	B1	03-04-2001	NONE

WO 02097977	A2	05-12-2002	AU 2002316129 A1 09-12-2002
			TW 586303 B 01-05-2004
			US 2003002659 A1 02-01-2003
			US 2006271358 A1 30-11-2006
			US 2010121635 A1 13-05-2010
			US 2012101816 A1 26-04-2012
			WO 02097977 A2 05-12-2002

EP 2048659	A1	15-04-2009	AT 521064 T 15-09-2011
			EP 2048659 A1 15-04-2009
			US 2009225980 A1 10-09-2009
