

Noise protection circuit for an AM stereo cosine correction factor and method for demodulating the AM stereo signal

Technical field

The present invention relates to the field of receivers for compatible AM stereo reception and, more particularly, to the prevention of increased signal degradation during periods of low S/N ratio.

Background of the invention

In a stereophonic receiver for receiving an AM stereophonic signal of the form $(1+L+R) \cos(\omega_c t + \theta)$ where θ is $\arctan(L-R)/(1+L+R)$, a correction factor proportional to $\cos \theta$ is employed as a divider in order to restore the original and undistorted L and R signals. The cosine factor may be employed once or twice in various stages of the receiver, depending on the design of the receiver. A complete transmitting and receiving system utilizing the above recited compatible signal is fully described in DE—A—2715741. This patent may be referred to for further details as to the transmitted signal, its characteristics and advantages. Another document also assigned to the same assignee, is ES—A—473702 pertaining to another stereo receiver utilizing the same signal. The receiver of the latter application will be referred to hereinbelow. As may be seen, the envelope of the signal contains only L+R or monophonic information, and no distortion due to the stereo information is produced in monophonic receivers.

As is known, in a typical received audio signal very little of the contained energy is representative of the higher sound frequencies; e.g., the highest fundamental frequency played by a piccolo is only slightly higher than 2 KHz and higher harmonics of voice, instruments, etc., have little energy. Thus, when relatively high energy high frequencies are present in a demodulated signal, they are practically always due to noise or, in other words, the S/N ratio is very low. When such a noisy signal is processed normally in the cosine correction circuitry of a stereo receiver, division by the cosine correction factor further degrades the already poor signal. It is therefore advisable to reduce or eliminate division by the correction factor during periods of low S/N reception. Such periods may have a duration of as little as a fraction of a modulation cycle.

Summary of the invention

It is an object therefore of the present invention to improve the performance of an AM stereo receiver during periods of low S/N ratio by controlling the cosine correction factor in response to noise in the received signal.

This object is provided in an AM receiver as defined in claim 1, for receiving a compatible stereo signal of the form $(1+L+R) \cos(\omega_c t + \theta)$ where θ is $\arctan[(L-R)/(1+L+R)]$ by having the stereo correction factor controlled in

response to the spectrum of the received signal. In embodiments of the invention a phase-locked loop provides a reference frequency for use in obtaining the proper correction factor. The received signal is limited to remove amplitude variations and multiplied by the reference frequency. The resultant signal is proportional in magnitude to the cosine of the angle θ but has a spectrum related to the spectrum of the received signal. The resultant signal is filtered through a high pass filter and when the filter output contains large amounts of energy (due to noise in the received signal), a voltage-controlled switch is activated to change the correction factor in order to divide the signal by a factor of one instead of a factor proportional to $\cos \theta$.

Brief description of the drawing

Fig. 1 is a block diagram of an AM stereo receiver incorporating the invention.

Fig. 2 is a partial schematic of a preferred embodiment of the invention.

Detailed description of the preferred embodiment

The present invention is shown in Fig. 1 in a stereo receiver similar to one shown in ES—A—473702 but is not limited thereto. This invention is, in fact, applicable to any receiver for receiving compatible AM stereophonic transmission and utilizing a cosine correction factor. A compatible AM stereo signal as described above is received by an antenna 10 and processed in a customary fashion in an RF stage 11 and an IF stage 12. The output of the IF stage 12 is demodulated in an envelope detector 13 to provide the sum signal (L+R). It will be appreciated that other types of demodulators could provide the sum signal as well. It will also be appreciated that the terms "sum" and "difference" or "L" and "R" as used herein are only exemplary of any pair of signals which might have been transmitted in quadrature. The sum signal and the difference signal (L-R) as derived hereinafter are processed in a matrixing circuit 14 to provide the original L and R signals. An AGC detector 15 is coupled to the IF stage 12 to provide automatic gain control for the receiver.

The IF stage 12 is also coupled to a synchronous detector 16 and a limiter 17. The limiter output contains only the phase information of the received signal including, possibly, external noise, and it is coupled to a phase locked loop 18 including a phase detector 19, a low pass filter 20 and a VCO 21. A $\sin \omega_c t$ output 22 of the VCO 21 is coupled to the synchronous detector 16 where the multiplication process $(1+L+R) \cos(\omega_c t + \theta) (\sin \omega_c t)$ produces an output signal $(L-R) \cos \theta$ (disregarding the double frequency term). A second output signal

23 from the VCO 21 of the PLL 18 which is $\cos \omega_c t$ is coupled to a cosine phase detector 24 as is the output signal from the limiter 17. The instantaneous phase difference ϕ between the two carrier frequencies (unmodulated and as transmitted) thus provides the $\cos \phi$ information needed to correct the output of the synchronous detector 16 which is $(L-R) \cos \phi$. In other words, when the $(L-R) \cos \phi$ signal is divided by $\cos \phi$ in divider 25, the difference signal $(L-R)$ is provided and it is this signal which is normally coupled to the matrix 14.

The receiver as described thus far is a workable one and is completely satisfactory in the presence of a strong received signal; i.e., a signal having a satisfactory S/N ratio. However, when the S/N ratio of the received signal is relatively low, the apparent $\cos \phi$ correction factor may be due primarily to noise and when the $(L-R) \cos \phi$ signal is divided by this invalid correction factor, distortion in the signal is increased rather than decreased or eliminated. In accordance with the invention, therefore, the output of the phase detector 24, instead of being directly coupled to the divider 25, is coupled to the divider 25 through a switching circuit 27. The output of the cosine phase detector 24 is also coupled to a high pass filter 29, an output of the high pass filter 29 being coupled to a first control input of the switching circuit 27. A second control input 30 provides a reference signal. The switching circuit 27 functions to couple the cosine correction factor from the cosine phase detector 23 directly to the divider 25 as long as the received signal is an acceptable one; i.e. has an acceptable S/N ratio. When the S/N ratio of the received signal is low and the output of the limiter 17 thus contains large amounts of high frequency energy, the high pass filter 29 will provide to the switching circuit 27 a control voltage sufficient to disconnect the output of the cosine phase detector 24 from the divider 25 and to substitute therefor the reference voltage from the terminal 30. This reference voltage is such as to cause the divider 25 to effectively divide the $(L-R) \cos \phi$ signal from the synchronous detector 16 by a factor of one.

As described in ES-A-473702 the cosine phase detector 24 output may also be coupled to a low pass filter 31 (2—10 Hz cut-off) where the average DC level of the output can be used to control a mono/stereo mode switch 33. The mode switch 33 is a voltage-controlled switch and is set to remain in the "monophonic" position until the PLL locks in on $\omega_c t$, then it switches to the "stereophonic" position.

Fig. 2 includes a portion of Fig. 1 with one embodiment of the high pass filter 29. A capacitor 37 and a resistor 38 make up a high pass filter, per se; i.e., 3 db down at 3 KHz. The D.C. level of the signal appearing at a point 40 (from a diode 41) is therefore a function of the amount of high frequency energy (noise) present in the received signal. When the signal

at the point 40 exceeds a predetermined threshold level, the switching circuit 27 prevents the correction factor signal from the cosine phase detector 24 ($\cos \phi + \text{noise}$) from reaching the divider 25 and provides instead a signal equal to one, i.e., a signal which will cause the divider 25 to divide the $(L-R) \cos \phi$ signal by a factor of one. While the preferred embodiment has been disclosed hereinabove and in the drawing, it will be recognized by those skilled in the art that a suitable input for the high pass filter 29 could also be derived from the output of any detector circuit in the receiver. It should be noted that where "periods of excessive high frequency energy" are referred to hereinabove, these periods may be as short as a small fraction of a modulation cycle or could extend over many cycles.

Claims

1. An AM receiver for receiving signals of the form $(1+L+R) \cos (\omega_c t + \phi)$ where L and R are information signals, $\omega_c t$ is the carrier frequency, and ϕ is $\arctan [(L-R)/(1+L+R)]$ and including an RF stage (11), an IF stage (12), demodulator means (16), corrector means (17, 18, 24) coupled to the demodulator means (16) for providing an output signal proportional to the cosine of the angle ϕ and divider means (25) coupled to receive an output signal from the demodulator means (16), characterised by the further inclusion of a circuit means (29) providing a signal which is a function of the frequency spectrum of the corrector means output signal, a source of reference signal (30), and a switching means (27) coupled to receive the reference signal and corrector means output signal and to selectively couple one of said signals to the divider means (25) in response to the level of the output signal of the circuit means (29), the divider means (25) dividing the output signal from the demodulator means (16) by the selected signal from the switching means (27).

2. An AM receiver in accordance with claim 1 and wherein the demodulator means comprises a synchronous detector.

3. An AM receiver in accordance with claim 2 and wherein the output signal of the synchronous detector is proportional to $(L-R) \cos \phi$.

4. An AM receiver in accordance with claim 3 and further including second demodulator means (13) for providing a signal proportional to $(L+R)$ and matrixing means (14) for receiving the output signals of the second demodulator means and the divider means and deriving therefrom the L and R signals.

5. An AM receiver in accordance with claim 1 and wherein the corrector means comprises limiter means, phase locked loop means coupled to the limiter means, cosine phase detector means coupled to the outputs of the limiter means and the phase locked loop means.

23 from the VCO 21 of the PLL 18 which is $\cos \omega_c t$ is coupled to a cosine phase detector 24 as is the output signal from the limiter 17. The instantaneous phase difference ϕ between the two carrier frequencies (unmodulated and as transmitted) thus provides the $\cos \phi$ information needed to correct the output of the synchronous detector 16 which is $(L-R) \cos \phi$. In other words, when the $(L-R) \cos \phi$ signal is divided by $\cos \phi$ in divider 25, the difference signal $(L-R)$ is provided and it is this signal which is normally coupled to the matrix 14.

The receiver as described thus far is a workable one and is completely satisfactory in the presence of a strong received signal; i.e., a signal having a satisfactory S/N ratio. However, when the S/N ratio of the received signal is relatively low, the apparent $\cos \phi$ correction factor may be due primarily to noise and when the $(L-R) \cos \phi$ signal is divided by this invalid correction factor, distortion in the signal is increased rather than decreased or eliminated. In accordance with the invention, therefore, the output of the phase detector 24, instead of being directly coupled to the divider 25, is coupled to the divider 25 through a switching circuit 27. The output of the cosine phase detector 24 is also coupled to a high pass filter 29, an output of the high pass filter 29 being coupled to a first control input of the switching circuit 27. A second control input 30 provides a reference signal. The switching circuit 27 functions to couple the cosine correction factor from the cosine phase detector 23 directly to the divider 25 as long as the received signal is an acceptable one; i.e. has an acceptable S/N ratio. When the S/N ratio of the received signal is low and the output of the limiter 17 thus contains large amounts of high frequency energy, the high pass filter 29 will provide to the switching circuit 27 a control voltage sufficient to disconnect the output of the cosine phase detector 24 from the divider 25 and to substitute therefor the reference voltage from the terminal 30. This reference voltage is such as to cause the divider 25 to effectively divide the $(L-R) \cos \phi$ signal from the synchronous detector 16 by a factor of one.

As described in ES-A-473702 the cosine phase detector 24 output may also be coupled to a low pass filter 31 (2-10 Hz cut-off) where the average DC level of the output can be used to control a mono/stereo mode switch 33. The mode switch 33 is a voltage-controlled switch and is set to remain in the "monophonic" position until the PLL locks in on $\omega_c t$, then it switches to the "stereophonic" position.

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at the point 40 exceeds a predetermined threshold level, the switching circuit 27 prevents the correction factor signal from the cosine phase detector 24 ($\cos \phi + \text{noise}$) from reaching the divider 25 and provides instead a signal equal to one, i.e., a signal which will cause the divider 25 to divide the $(L-R) \cos \phi$ signal by a factor of one. While the preferred embodiment has been disclosed hereinabove and in the drawing, it will be recognized by those skilled in the art that a suitable input for the high pass filter 29 could also be derived from the output of any detector circuit in the receiver. It should be noted that where "periods of excessive high frequency energy" are referred to hereinabove, these periods may be as short as a small fraction of a modulation cycle or could extend over many cycles.

Claims

1. An AM receiver for receiving signals of the form $(1+L+R) \cos(\omega_c t + \phi)$ where L and R are information signals, $\omega_c t$ is the carrier frequency, and ϕ is $\arctan [(L-R)/(1+L+R)]$ and including an RF stage (11), an IF stage (12), demodulator means (16), corrector means (17, 18, 24) coupled to the demodulator means (16) for providing an output signal proportional to the cosine of the angle ϕ and divider means (25) coupled to receive an output signal from the demodulator means (16), characterised by the further inclusion of a circuit means (29) providing a signal which is a function of the frequency spectrum of the corrector means output signal, a source of reference signal (30), and a switching means (27) coupled to receive the reference signal and corrector means output signal and to selectively couple one of said signals to the divider means (25) in response to the level of the output signal of the circuit means (29), the divider means (25) dividing the output signal from the demodulator means (16) by the selected signal from the switching means (27).

2. An AM receiver in accordance with claim 1 and wherein the demodulator means comprises a synchronous detector.

3. An AM receiver in accordance with claim 2 and wherein the output signal of the synchronous detector is proportional to $(L-R) \cos \phi$.

4. An AM receiver in accordance with claim 3 and further including second demodulator means (13) for providing a signal proportional to $(L+R)$ and matrixing means (14) for receiving the output signals of the second demodulator means and the divider means and deriving therefrom the L and R signals.

5. An AM receiver in accordance with claim 1 and wherein the corrector means comprises limiter means, phase locked loop means coupled to the limiter means, cosine phase detector means coupled to the outputs of the limiter means and the phase locked loop means.



6. An AM receiver in accordance with claim 1 and wherein the signal-providing circuit means comprises a high pass filter.

7. An AM receiver in accordance with claim 6 and wherein the high pass filter is down substantially 3 db at 3 KHz.

8. An AM receiver in accordance with claim 1 and wherein the switching means couples the correction signal to the divider means when the output signal of the signal providing circuit means is less than a predetermined level.

9. A method of demodulating a signal of the form $(1+L+R) \cos(\omega_c t + \theta)$ for providing output signals proportional to L and R comprising the steps of:

receiving said signal;

demodulating said received signal to provide a signal proportional to $(L+R)$;

demodulating said received signal to provide a signal proportional to $(L-R) \cos \theta$;

detecting the phase modulation on said received signal to provide a signal proportional to cosine θ ;

filtering the signal proportional to cosine θ to provide a signal indicative of the high frequency energy therein;

providing a reference signal;

dividing the signal proportional to $(L-R) \cos \theta$ by the signal proportional to cosine θ when the signal indicative of the high frequency energy is lower than a predetermined threshold level, and dividing the signal proportional to $(L-R) \cos \theta$ by the reference signal when said indicative signal is greater than the predetermined threshold signal; and

matrixing the signal proportional to $(L+R)$ and the $(L-R) \cos \theta$ signal after said division to provide output signals proportional to L and R.

Patentansprüche

1. AM-Empfänger zum Empfangen von Signalen der Form $(1+L+R) \cos(\omega_c t + \theta)$, wobei L und R Informationssignale, ω_c die Trägerfrequenz und θ gleich $\arctan [(L-R)/(1+L+R)]$ sind, und die eine Hochfrequenzstufe (11), eine Zwischenfrequenzstufe (12), eine Demodulatoreinrichtung (16), eine Korrektureinrichtung (17, 18, 24), die mit der Demodulatoreinrichtung (16) gekoppelt ist, um ein Ausgangssignal zu erzeugen, das proportional dem $\cos$ des Winkels θ ist, sowie eine Teilereinrichtung (25) aufweist, die ein Ausgangssignal von der Demodulatoreinrichtung (16) erhält, gekennzeichnet durch das weitere Vorsehen einer Schaltungseinrichtung (29), die ein Signal erzeugt, das eine Funktion des Frequenzspektrums des Ausgangssignals der Korrekturereinrichtung ist, eine Bezugssignalquelle (30) und eine Schaltereinrichtung (27), die das Bezugssignal und das Ausgangssignal der Korrekturereinrichtung erhält und wahlweise eines dieser Signale an die Teilereinrichtung (25) in Abhängigkeit von dem Pegel des Ausgangssignals der Schaltungseinrichtung (29)

ergibt, wobei die Teilereinrichtung (25) das Ausgangssignal von der Demodulatoreinrichtung (16) durch das ausgewählte Signal von der Schaltereinrichtung (27) teilt.

2. AM-Empfänger nach Anspruch 1, dadurch gekennzeichnet, daß die Demodulatoreinrichtung einen synchronen Detektor aufweist.

3. AM-Empfänger nach Anspruch 2, dadurch gekennzeichnet, daß das Ausgangssignal des synchronen Detektors $(L-R) \cos \theta$ proportional ist.

4. AM-Empfänger nach Anspruch 3, weiter gekennzeichnet durch eine zweite Demodulatoreinrichtung (13) zum Erzeugen eines Signals, das $(L+R)$ proportional ist, und durch eine Matrizeneinrichtung (14), die die Ausgangssignale von der zweiten Demodulatoreinrichtung und der Teilereinrichtung erhält und aus diesen die L- und R-Signale ableitet.

5. AM-Empfänger nach Anspruch 1, dadurch gekennzeichnet, daß die Korrekturereinrichtung eine Begrenzereinrichtung, eine mit dieser verbundene phasenverriegelte Schleifeneinrichtung und eine $\cos$ -Phasendetektoreinrichtung, die mit den Ausgängen der Begrenzereinrichtung und der phasenverriegelten Schleifeneinrichtung verbunden ist.

6. AM-Empfänger nach Anspruch 1, dadurch gekennzeichnet, daß die das Signal erzeugende Schaltereinrichtung ein Hochpaßfilter aufweist.

7. AM-Empfänger nach Anspruch 6, dadurch gekennzeichnet, daß das Hochpaßfilter bei 3 KHz einen Abfall von im wesentlichen 3 db hat.

8. AM-Empfänger nach Anspruch 1, dadurch gekennzeichnet, daß die Schaltereinrichtung das Korrektursignal an die Teilereinrichtung gibt, wenn das Ausgangssignal von der das Signal erzeugenden Schaltungseinrichtung geringer als ein bestimmter Pegel ist.

9. Verfahren zum Demodulieren eines Signals der Form $(1+L+R) \cos(\omega_c t + \theta)$ zum Erzeugen von Ausgangssignalen, die proportional zu L und R sind, das die Verfahrensschritte hat:

empfangen des Signals,

demodulieren des empfangenen Signals zum Erzeugen eines Signals, das $(L+R)$ proportional ist,

demodulieren des empfangenen Signals zum Erzeugen eines $(L-R) \cos \theta$ proportionalen Signals,

erfassen der Phasenmodulation in dem empfangenen Signal, um ein $\cos \theta$ proportionales Signal zu erzeugen,

filtern des $\cos \theta$ proportionalen Signals zum Erzeugen eines Signals, das die Hochfrequenzenergie in dem Signal angibt,

erzeugen eines Bezugssignals,

teilen des $(L-R) \cos \theta$ proportionalen Signals durch das Signal, das $\cos \theta$ proportional ist, wenn das die Hochfrequenzenergie angegebende Signal niedriger als ein bestimmter Schwellwertpegel ist, und Teilen des $(L-R) \cos \theta$ proportionalen Signals durch das Bezugssignal,



wenn das die Hochfrequenzenergie angegebene Signal größer als das bestimmte Schwellwert-signal ist, und

matrizenverarbeiten des $(L+R)$ proportionalen Signals und des $(L-R) \cos \emptyset$ Signals nach der Teilung, um Ausgangssignale zu erzeugen, die L und R proportional sind.

Revendications

1. Un récepteur de modulation d'amplitude destiné à recevoir des signaux de la forme $(1+L+R) \cos(\omega_c t + \emptyset)$ où L et R sont des signaux d'information, ω_c est la fréquence de porteuse, et $\emptyset$ vaut $\arctg [(L-R)/(1+L+R)]$ et comportant un étage de haute fréquence (11), un étage de fréquence intermédiaire (12), un moyen démodulateur (16), un moyen correcteur (17, 18, 24) connecté au moyen démodulateur (16) afin de fournir un signal de sortie proportionnel au cosinus de l'angle $\emptyset$, et un moyen diviseur (25) connecté de façon à recevoir un signal de sortie du moyen démodulateur (16), caractérisé en ce qu'il comprend en outre un moyen servant de circuit (29) produisant un signal qui est fonction du spectre de fréquence du signal de sortie du moyen correcteur, une source de signal de référence (30), et un moyen de commutation (27) connecté de façon à recevoir le signal de référence et le signal de sortie du moyen correcteur et à sélectivement appliquer un desdits signaux au moyen diviseur (25) selon le niveau du signal de sortie du moyen servant de circuit (29), le moyen diviseur (25) divisant le signal de sortie du moyen démodulateur (16) par le signal choisi venant du moyen de commutation (27).

2. Un récepteur en modulation d'amplitude selon la revendication 1 et dans lequel le moyen démodulateur consiste en un détecteur synchrone.

3. Un récepteur en modulation d'amplitude selon la revendication 2 et dans lequel le signal de sortie du détecteur synchrone est proportionnel à $(L-R) \cos \emptyset$.

4. Un récepteur en modulation d'amplitude selon la revendication 3 et comportant en outre un deuxième moyen démodulateur (13) destiné à fournir un signal proportionnel à $(L+R)$ et un moyen matriciel (14) destiné à recevoir les signaux de sortie du deuxième moyen démodu-

lateur et du moyen diviseur et à déduire de ceux-ci les signaux L et R.

5. Un récepteur en modulation d'amplitude selon la revendication 1 et dans lequel le moyen correcteur comprend un moyen limiteur, un moyen servant de boucle de verrouillage de phase connecté au moyen limiteur, un moyen détecteur de phase de cosinus connecté aux sorties du moyen limiteur et du moyen servant de boucle de verrouillage de phase.

6. Un récepteur en modulation d'amplitude selon la revendication 1 et dans lequel le moyen servant de circuit qui fournit un signal consiste en un filtre passe-haut.

7. Un récepteur en modulation d'amplitude selon la revendication 6 et dans lequel le filtre passe-haut descend sensiblement de 3 db à 3 KHz.

8. Un récepteur en modulation d'amplitude selon la revendication 1 et dans lequel le moyen de commutation applique le signal de correction au moyen diviseur lorsque le signal de sortie du moyen servant de circuit qui fournit un signal est inférieur à un niveau prédéterminé.

9. Procédé de démodulation d'un signal ayant la forme $(1+L+R) \cos(\omega_c t + \emptyset)$ destiné à produire des signaux de sortie proportionnels à L et R et comprenant les opérations suivantes:

recevoir ledit signal;

démoduler ledit signal reçu afin de produire un signal proportionnel à $(L+R)$;

démoduler ledit signal reçu afin de produire un signal proportionnel à $(L+R) \cos \emptyset$;

détecter la modulation de phase dudit signal reçu afin de produire un signal proportionnel à $\cos \emptyset$;

filtrer le signal proportionnel à $\cos \emptyset$ de façon à produire un signal indicatif de l'énergie de haute fréquence qu'il contient;

produire un signal de référence;

diviser le signal proportionnel à $(L-R) \cos \emptyset$ par le signal proportionnel à $\cos \emptyset$ lorsque le signal indicatif de l'énergie de haute fréquence est inférieur à un niveau de seuil prédéterminé, et diviser le signal proportionnel à $(L-R) \cos \emptyset$ par le signal de référence lorsque ledit signal indicatif est supérieur au signal de seuil prédéterminé; et

appliquer à un moyen matriciel le signal proportionnel à $(L+R)$ et le signal en $(L-R) \cos \emptyset$ après ladite division afin de produire des signaux de sortie proportionnels à L et R.



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