

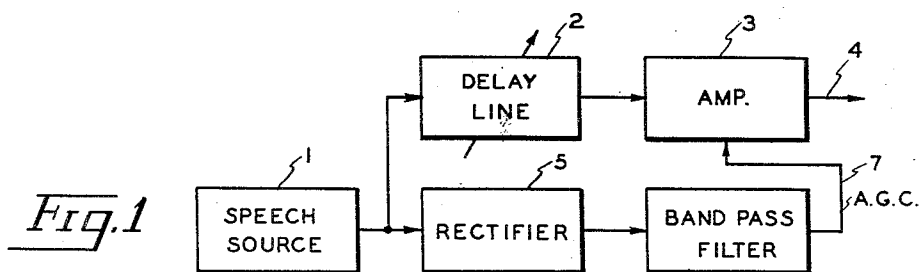
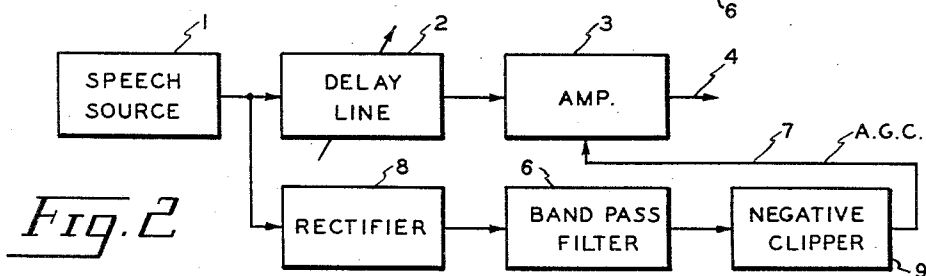
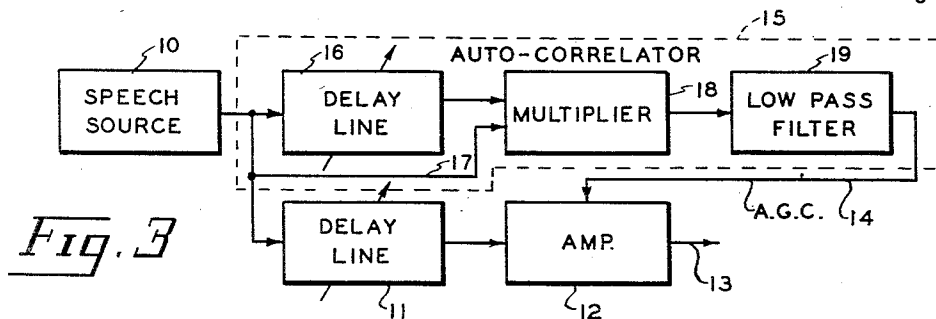
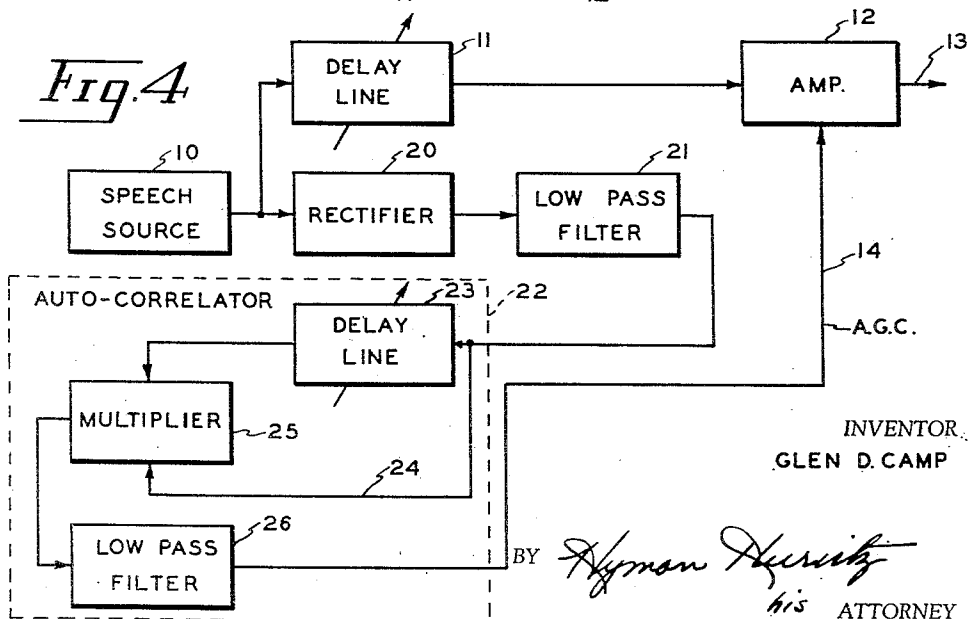
July 16, 1957

G. D. CAMP

2,799,734

SPEECH BRIGHTENERS

Filed April 4, 1952



1

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SPEECH BRIGHTENERS

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18 Claims. (Cl. 179—171)

My invention relates generally to speech brightening systems, and finds particular application to systems in which speech is treated, before transmission or encoding, by brightening those components of speech which tend to lose intelligibility in the presence of noise, because they are themselves of noise-like character. The invention may therefore be applied to advantage in long distance telephony, whether by wire or radio, and to systems in which is attempted transmission of voice information within limited and narrow bands, as by coding the speech signals. Application of the present system to a speech signal provides the signal with intrinsic characteristics such that jamming of the communication channel carrying the speech is rendered difficult, and such that difficulties in the electronic coding of speech, to the end that the speech may be transmitted as a narrow band of frequencies, are decreased.

Speech may, on rough analysis, be considered to be made up of relatively constant power tonal components, and of noise-like components of rapidly varying power. The two types of components may include similar frequencies. The total power in a noise-like component may be less than the total power in a tonal component, when taken over an identical time interval. It is therefore not readily possible to distinguish or separate the noise-like components of speech from the tonal components of speech by means of simple filters. Nor can discrimination be accomplished in terms of relative power, available in the unlike components of speech. The noise-like components, however, are more readily lost in white noise than are the tonal components, so that as the signal to noise ratio in a given communications channel decreases the noise-like components of speech tend to lose intelligibility before the tonal components. If then, the noise-like components could be sufficiently preferentially amplified with respect to the tonal components of a given speech sample, the resulting brightened speech would be more readily distinguishable from noise than would the original speech. The problem of producing brightened speech, in the sense above indicated, reduces itself to one of increasing the gain of a channel carrying the speech, in the presence of rapid changes of power in the channel, or in the presence of noise-like components in the channel, and for maintaining constant the gain of the channel in the presence of tonal or relatively steady components of speech.

In the present invention the noise-like components and the tonal components of speech occur in sequence, substantially, or non-concurrently. Therefore, any system which increases its gain in the presence of noise-like components only, decreases its gain in the presence of tonal components only, or both, may serve to brighten speech representative signals, or other signals having substantially the same make-up in respect to tonal and noise-like components, since the respective gain variations occur sequentially or non-concurrently.

I have, accordingly, devised several general systems of

2

speech brightening. In one such system I pass an electrical signal corresponding with speech through a rectifier, which provides at its output a signal representative of the power of the speech, or some analogous quantity, as a time function. The time function contains a D.-C. term, a steady or slowly varying component representative of the power variations in the speech, and also contains a rapidly varying portion due to frequency doubling and to the interaction of the various frequencies in passing through the rectifier. It is essential that the rapidly varying components be eliminated, and not be utilized as a gain-control voltage for the amplifier carrying the speech, and it is equally required that the slowly varying frequency component representative of power variations in the speech be so utilized. It is found that the sudden sharp variations of power due to noise-like components of speech produced, for example, when the speaker enunciates the sounds s, z, t, p, k, ch, and the like, produce representative components in the region 5 to about 150 cycles per second in the output of the rectifier, due to their rise and decay times, and their durations. These latter frequencies are selected, to the approximate exclusion of all other components of output of the rectifier, and applied as a gain-control voltage to the speech-carrying amplifier or channel. The same result may be accomplished by passing the speech, after rectification, through a low pass filter having a cut-off point at about 150 cycles, and then differentiating the filtered result, to remove what are essentially D. C. components of the speech power.

In accordance with modifications of the invention the speech is passed through an auto-correlator, which provides a relatively large output in the presence of correlated or tonal components of speech, and little output in the presence of uncorrelated or noise-like components of speech, corresponding with those portions of speech signals generated in response to the sounding of letters such as p, t, d, and the like. The output of the auto-correlator is then utilized to control the gain of an amplifier channel carrying the speech signals in such manner as to increase the amplifier gain during the noise-like components of speech. The auto-correlator may analyze speech signals directly, or in the alternative, signals corresponding with power in the speech, or the like.

It is, accordingly, a broad object of the present invention to provide a device for brightening speech signals, television signals, or the like.

It is a further object of the present invention to provide a device for increasing the gain of an amplifier carrying a wide band signal, or the like, in the presence of noise-like components of the signal, maintaining the gain of the amplifier at a relatively reduced level while the amplifier is amplifying relatively steady components of the signal, where the specified gain variations occur substantially in sequence.

It is another object of the invention to measure a factor analogous to or equal to the instantaneous power of a wide band signal having non-concurrent noise-like and relatively steady components, and to provide a control signal when this instantaneous power varies rapidly in level due to the noise-like component, the control signal being applied as a gain control voltage to an amplifier carrying the wide band signal.

Another object of the invention resides in the provision of a system for determining by means of an auto-correlator when the noise-like components of a wide band signal, such as speech, video or the like, occur, for generating a gain control signal at such times, and for applying the gain control signal to increase the gain of an amplifier which is carrying the wide band signal.

The above and still further objects, features and advan-

(ages of the present invention will become apparent upon consideration of the following detailed description of various embodiments thereof, especially when taken in conjunction with the accompanying drawings, wherein:

Figure 1 is a function block diagram of a first embodiment of the invention;

Figure 2 is a functional block diagram of a modification of the system of Figure 1;

Figure 3 is a further functional block diagram of a speech brightener system using an auto-correlator to determine the times when noise-like components of a speech occur; and

Figure 4 is a functional block diagram of a modification of the system of Figure 3, in which speech power is correlated.

Proceeding now more specifically by reference to the accompanying drawings the reference numeral 1 identifies a wide band source, which may be, for example, a microphone, or an audio amplifier, a speech reproduction device, a video signal source, or the like, but which will hereinafter be referred to a speech source, as a preferred exemplification. The signal provided by the speech in source 1 is transmitted via a variable delay line 2 to an amplifier 3, of the controllable gain type. The output of the amplifier 3 is then available on a line 4, and may be utilized as desired. Suggested modes of utilization of the signal appearing on the lead 4 may be, to utilize the signal to modulate a radio or wire transmitter, or as an input for a Vocoder or other speech coding or speech compression device. The delay line 2 is so designed and arranged as not to distort the speech signals passing therethrough to any appreciable extent, and such delay lines being per se well-known in the art, no detailed description thereof is provided herewith.

The output of the speech source 1 is further applied to a rectifier, which may be specifically a square law detector of conventional character, or a half wave or full wave rectifier, and identified by the reference numeral 5. The output of the rectifier 5 is then representative of or analogous to power of the signal provided by the speech source 1, and is in character always of the same polarity. Upon analysis it is found that the output of the rectifier 5 includes frequencies equal to twice each of the frequencies present in the input device, and further intermodulation components. Since the input to the rectifier 5 may be assumed to commence roughly at 75 cycles per second, the output of the device includes frequencies 150 cycles per second and above. In addition the output of the rectifier 5 includes a D. C. component representative of average power, and, lastly, very low frequencies, falling generally below 5 cycles per second. In addition there are frequencies corresponding with variations in speech power due to the formation of the speech, to include tonal and noise-like components, the latter representing sudden or transient increases of power. Connected to the output of the rectifier 5 is a band-pass filter 6, which passes frequencies which may be taken to fall within the range about 5 to 150 cycles per second, although I do not desire to be limited to these precise values in view of the differences in speech make-up found in different languages, and in speech originating in women, men, children, and the like. Accordingly, the precise frequency band for the filter 6 which will provide optimum operation of the present system may best be established when the character of the speech provided by the speech source 1 is known. For some cases a frequency band of about 10 to 200 cycles may prove superior to the first specified band of 5 to 150 cycles per second, and in other cases it may be desirable to narrow the first mentioned band of about 5 to 150 cycles per second, to say from about 5 to 100 cycles per second. In any event the band pass filter removes the D. C. component of output of the rectifier 5, and removes the frequency components caused by squaring of the Fourier spectrum components of speech, allowing only those components of output of the

rectifier 5 to pass which represent variations in power due selectively to noise-like as against total components of the speech. In view of the relatively long durations of tonal components of speech the only output from the band pass filter generated by these components may occur at the beginnings and ends of syllables, while the noise-like components, being relatively brief and sharp, will cause definite components of output from the filter 6, having durations substantially equal to the durations of these noise-like components or pulses.

The output of the band pass filter 6 is applied as voltage to a lead 7, the latter voltage being applied to the amplifier 3 for increasing the gain of the amplifier. Since gain control amplifiers are well known, per se, and have found very extensive development in the electronic art, no specific amplifier or gain control circuit is illustrated and described herein.

The rectifier 5 and the band pass filter 6 introduce a time delay into the channel including these elements. To compensate for this time delay the delay line 2 has been included between the speech source 1 and the input to the amplifier 3. This delay line is illustrated as variable, since it is found in practice that considerable modification of tone may be accomplished at the output of the amplifier 3 by adjustment of the delay introduced by the delay line 2. Ideally the delay line 2 is so adjusted that any given noise-like component of speech passes to the amplifier 3 at the same time as does the pulse of gain control voltage from the line 7, for increasing the gain of the amplifier 3. In this way the gain of the amplifier is increased only during noise-like components, and otherwise remains at some fixed value predetermined by the design of the amplifier.

Referring now more specifically to Figure 2 of the accompanying drawings, there is illustrated a speech source 1, which supplies amplifier 3 via variable delay line 2, the output of the amplifier 3 being found on lead 4. Accordingly, the system of Figure 2 duplicates the system of Figure 1 in respect to the speech source 1, delay line 2 and the amplifier 3. There is further provided in the embodiment of my invention illustrated in Figure 2 of the drawings, a rectifier 8, which may correspond with the rectifier 5 of Figure 1, and the output of which is filtered by means of a band pass filter 6 corresponding in all respects with the band pass filter 6 of Figure 1 of the drawings. The output of the band pass filter 6 is applied via a negative clipper to the gain control lead 7, the latter controlling the gain of the amplifier 3 as in the system of Figure 1. The use of the negative clipper in the system of Figure 2 is the sole distinguishing feature as between the systems of Figures 1 and 2. In the system of Figure 1 the output of the band pass filter will be alternately positive and negative, as the power delivered by the rectifier 5 increases and decreases. Accordingly, the gain of the amplifier 3 in Figure 1 of the accompanying drawings will be increased and then decreased. This decrease may be made to occur while the power of the noise-like component of speech is decreasing, and serves to prevent any relatively slow variation of output from the amplifier 3 in response to such speech components. It is often found desirable, however, to avoid such rapid decreases in gain, and to retain solely the rapid increases in gain caused by rapid increases in speech power. The negative clipper 9 permits this by preventing any output from the band pass filter 6 to be applied as a gain control voltage to the amplifier 3 except those components which are positive going, and therefore which represent sudden increases in speech power. The band pass filter 6 tends to have a relatively slow decay characteristic, so that the gain control voltage which is generated in response to a sudden increase in power, on occurrence of noise-like component of speech, tends to subsist for a sufficiently long time to maintain the increased gain of the amplifier 3 during the entire duration of the noise-like component.

Referring now more specifically to Figure 3 of the accompanying drawings, there is illustrated a speech source 10, which may represent the output of a microphone, a reproducer, an amplifier, or the like. The output of the speech source 10 is applied by a variable delay line 11 to the input of an amplifier 12 of the gain control type. The output of the amplifier 12 is available on a lead 13 and thence may be applied to any desired use, as for example for application to the input of a radio or wire transmitter, to the input of a Vocoder, or the like. The gain of the amplifier 12 is controlled in response to voltage applied over a lead 14, deriving from the output of an auto-correlator 15. The amplifier 12 is so designed, in accordance with principles well known in the pertinent art, as to increase its gain in the absence of signal on lead 14, or in response to a reduction of voltage of the lead 14. The auto-correlator 15 is generally of conventional character per se. It includes a variable delay line 16, connected in parallel with the lead 17, providing no delay. The output of the delay line 16 and the signal on the lead 17 are applied to the input of a multiplier 18, for multiplication of the two signals. It will be realized that the same result may be accomplished by applying the output of the speech source 10 to the multiplier 18 via two delay lines having different delays, although this is not the usual construction adopted, since it involves the use of two delay lines where one will do. The differential delay required is of the order of 1-10 milliseconds. The output of the multiplier 18 is passed through a low pass filter 19, the output of which is the voltage applied to the gain control lead 14. The low pass filter 19 is designed in accordance with principles well understood in the art, to pass all frequencies up to a value which may be predetermined, but which may preferably vary in accordance with the character of the speech provided by the speech source 10, as in accordance with the language utilized, or the physical characteristics of the speech. In general, it may be stated that the upper limit of the low pass filter 19 should fall in the range 50 to 200 cycles per second.

It is a well known property of an auto-correlator, such as the auto-correlator 15 in Figure 3 of the drawings, to provide a definite relatively high output when the input signal to the auto-correlator is of some regular structure, and to provide a low output when this regularity of structure is absent. Accordingly, auto-correlators have been applied widely to the elimination of noise-signals, since noise-signals are of random character, and accordingly have no intercorrelation. In the present case then, the output of the auto-correlator in the presence of tonal components of speech is substantial, in view of the definite regularity of structure of such speech components. On the other hand, in the presence of noise-like components of speech, or of sudden spikes or increases of power representative of the noise-like character of speech, the output of the auto-correlator is substantially zero.

It follows that a control voltage of definite amplitude appears on the lead 14 so long as tonal components of speech are impressed on the auto-correlator 15, and that no output is available in the presence of noise-like components. As already stated the amplifier 12 has a definite relatively low gain in the presence of gain control voltage, and increases its gain as the gain control voltage applied over the lead 14 decreases. It follows that the output of the amplifier 12 will be a brightened or stressed speech representative signal. The delay line 11 is arranged to be variable, as in the systems illustrated in Sheets 1 and 2 of the drawings, to compensate for the delays introduced by the auto-correlator 15, so that the application of the gain control voltage available on the lead 14, to the amplifier 12, shall be synchronized with the passage of noise-like component of speech through the amplifier 12.

Referring now more specifically to Figure 4 of the accompanying drawings, there is illustrated a variation of

the system of Figure 3, in which the input to an auto-correlator is arranged to consist of speech power, as distinguished from the speech itself. In the system of Figure 4, the speech source 10 applies speech representative signal to a variable delay line 11 and to an amplifier 12, the output of the amplifier 12 being available on lead 13. The output of the speech source 10 is further applied to a rectifier 20, the output of the rectifier 20 being detected by a low pass filter 21, having a pass band in approximately the range 0 to 150 cycles per second. The rectifier 20 provides, in its output, intermodulation components of the frequency spectrum provided by the speech source 10, and frequencies equal to twice those present in its input. The low pass filter 21 removes the double frequency components, and all higher intermodulation components, passing only average power signals to the input of the auto-correlator 22. It is the function of the latter to provide an output signal for the gain control lead 14 when the input to the auto-correlator possesses a definite regularity of structure, and to supply no voltage when the auto-correlator possesses no regularity of structure, or is of noise-like character. To this end the auto-correlator consists of a delay line 23, which may be made variable, and have a delay of approximately 1 to 10 milliseconds. The auto-correlator 22 further includes a lead paralleling the delay line 23, identified by the reference numeral 24, in which substantially no delay occurs. The signal available on the lead 24, and the output of the delay line 23, are applied for multiplication to a multiplier 25, and the output of the latter is passed through a low pass filter or integrating circuit 26, which may have a pass band of the order 0 to 50 or to 0 to 100 cycles per second, or some intermediate value. The output of the low pass filter 26 is the voltage which is applied to the gain control lead 14, for controlling the gain of the amplifier 12, while noise-like components of speech pass therethrough. To this end the amplifier 12 of Figure 4 of the accompanying drawings is arranged identically with the amplifier 12 of Figure 3 of the accompanying drawings, i. e. increases its gain in response to a negatively going gain control voltage. The delay line 11, as in the case of Figure 3, compensates for the delays inherent in the circuits utilized to generate the gain control signal.

While I have described and illustrated various specific embodiments of the present invention, it will be clear to those skilled in the art that variations of specific structure arrangement may be resorted to without departing from the true spirit and scope of the invention, as defined by the appended claims.

What I claim is:

1. In combination, a source of wide band electric signal occurring non-concurrently, a gain controllable amplifier for said signal, and means for controlling the gain of said amplifier comprising a source of transient gain control voltage, said last means comprising a square low detector responsive to said signal to generate a voltage wave at least approximately indicative of the instantaneous power of said signal at each instant of time, and means for relatively reducing, in said voltage wave, components of said voltage wave not representative of noise-like components of said wide band electric signal to generate said transient gain control voltage, said means for relatively reducing components of said voltage wave including means for reducing D. C. components to zero.

2. The combination in accordance with claim 1 wherein said means for reducing in said voltage wave components of said voltage wave not representative of noise-like components of said signal comprises a band pass filter having a pass band of substantially 5 to 150 cycles per second.

3. In combination, a source of speech representative signal having substantially sequential tonal and noise-like components, a gain controllable amplifier for said substantially sequential signals, and means for controlling

the gain of said amplifier comprising means for generating a transient gain control voltage wave, said last means responsive to said noise-like and said tonal components of said speech representative signal for generating, respectively and substantially sequentially, relatively gain increasing and gain decreasing portions of said gain control voltage.

4. The combination in accordance with claim 3 wherein said means for generating a transient gain increase control signal includes a square law rectifier responsive to said speech representative electric signal for generating a voltage wave indicative of the power of said speech representative signal at each instant of time, and means for selectively abstracting from said voltage wave portions representative of said noise-like components.

5. In combination, a source of speech representative signal having tonal and noise-like components, a gain controllable amplifier for said signals, and means for controlling the gain of said amplifier comprising means for generating a transient gain control voltage, said last means responsive to said noise-like and said tonal components of said speech representative signal for generating, respectively, relatively gain increasing and gain decreasing portions of said gain control voltage, said means for generating a transient gain increase control voltage in response to said noise-like components including an auto-correlator responsive to said speech representative signal, said auto-correlator including means for separating said speech representative signal in a relatively delayed and an undelayed channel, a voltage multiplier for multiplying together the outputs of said channels, and means for integrating the output of said voltage multiplier.

6. The combination in accordance with claim 3 wherein said means for generating a transient gain increase control signal in response to said noise-like components includes a square law rectifier for said speech representative electric signal, means for separating from the output of said rectifier signals indicative of the variations of power of said speech representative electric signal, and an auto-correlator for distinguishably separating from said signals representative of the variations of power of said speech representative electric signal those components having noise-like characteristics and those components having tonal characteristics.

7. In combination, a source of speech representative electric signal having non-concurrent tonal and noise-like components of similar frequency content, a gain controllable amplifier for said signal, said gain controllable amplifier responsive to both said components, means for generating a gain control voltage for said gain controllable amplifier in response to said signal, said means for generating a gain control signal comprising a circuit responsive to said tonal component and said noise-like component of said signal to generate a voltage wave having one level in the presence of and only substantially during said noise-like component and another level in the absence of said noise-like component, and means in said gain controllable amplifier responsive to said levels of voltage wave for non-concurrently relatively increasing gain in response to said one level and decreasing gain in response to said another level.

8. The combination in accordance with claim 7 wherein said circuit responsive differentially to said tonal component and said noise-like component includes a square law detector for said signal, and means for filtering from the output of said square law detector all frequency components below substantially 5 cycles per second and above 150 cycles per second.

9. The combination in accordance with claim 7 wherein said circuit responsive differentially to said tonal component and said noise-like component includes a square law device responsive to said signal for generating a voltage wave representative of power in said components, and means for filtering from said last mentioned voltage wave

substantially only those components of frequency due to said tonal component.

10. The combination in accordance with claim 7 wherein said circuit responsive differentially to said tonal component and said noise-like component includes an auto-correlator.

11. The combination in accordance with claim 7 wherein said circuit responsive differentially to said tonal component and said noise-like component includes an auto-correlator responsive to said speech representative electric signal, said auto-correlator including means for separating said speech representative electric signal in a relatively delayed channel and a relatively undelayed channel, a voltage multiplier for multiplying together the outputs of said channels, and means for integrating the output of said voltage multiplier.

12. The combination in accordance with claim 7 wherein said circuit responsive differentially to said tonal component and said noise-like component includes a square law rectifier for said signal, means for separating from the output of said square law detector voltages representative of variations of power of said signal, and an auto-correlator for separating from said last named voltages those components representative of said noise-like components and those components representative of said tonal components.

13. In combination, a source of relatively wide band signal having noise-like components and tonal components occupying overlapping portions of said band, a gain controllable amplifier for said wide band and occurring substantially non-concurrently signal, said gain controllable amplifier responsive to both said noise-like components and said tonal components, means for generating a gain control voltage wave for said gain controllable amplifier in response to said wide band signal, said means for generating a gain control signal comprising a circuit responsive differentially and non-concurrently to said tonal components and said noise-like components to generate a voltage wave having one level in the presence of said noise-like components and another level in the absence of said noise-like components, and means in said gain controllable amplifier responsive to said levels of voltage wave for relatively increasing gain in response to said one level and relatively decreasing gain in response to said another level.

14. The combination in accordance with claim 13 wherein said circuit responsive differentially to said tonal component and said noise-like component includes a square law detector for said signal, and means for selectively separating from the output of said square law detector those frequency components primarily representative of tonal components and those frequency components primarily representative of noise-like components.

15. The combination in accordance with claim 14 wherein said means for selectively separating includes a band pass filter.

16. The combination in accordance with claim 14 wherein said means for selectively separating includes an auto-correlator.

17. The combination in accordance with claim 13 wherein said circuit responsive differentially to said noise-like components and said tonal components includes an auto-correlator.

18. In combination, a source of speech representative electric signals, having substantially sequential tonal and noise-like components, a gain controllable amplifier for said signals, and means for controlling the gain of said amplifier comprising means for developing transient gain control voltage waves, said last mentioned means being responsive to variations in power content of said noise-like components for generating a transient gain control voltage wave for relatively increasing gain of said gain controllable amplifier and elements responsive to the substantially constant power content of said tonal components for generating another and non-concurrent

transient gain control voltage wave for relatively decreasing gain of said gain controllable amplifier, said first and second transient gain control voltage waves occurring substantially sequentially.

References Cited in the file of this patent

UNITED STATES PATENTS

1,931,866	Heising	Oct. 24, 1933
2,250,559	Weber	July 29, 1941

5

2,250,596
2,257,782
2,262,846
2,283,241
2,394,544
2,420,204
2,421,136
2,602,885

Mountjoy	July 29, 1941
Boucke	Oct. 7, 1941
Herold	Nov. 18, 1941
Van Cott	May 19, 1942
Gottier	Feb. 12, 1946
Sinnett	May 6, 1947
Wheeler	May 27, 1947
Armstrong	July 8, 1952

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 2,799,734

July 16, 1957

Glen D. Camp

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 6, line 56, for "low" read -- law --; column 8, lines 30 and 31, strike out "and occurring substantially non-concurrently" and insert the same after "band" and before the comma, in line 29, same column; line 73, for "can" read -- gain --.

Signed and sealed this 24th day of September 1957.

(SEAL)

Attest:

KARL H. AXLINE

Attesting Officer

ROBERT C. WATSON
Commissioner of Patents