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DYNAMIC SPEECH EQUALIZING SYSTEM HAVING A CONTROL CIRCUIT THAT SEPARATES AND COMPARES THE HIGH AND LOW FREQUENCY ENERGY
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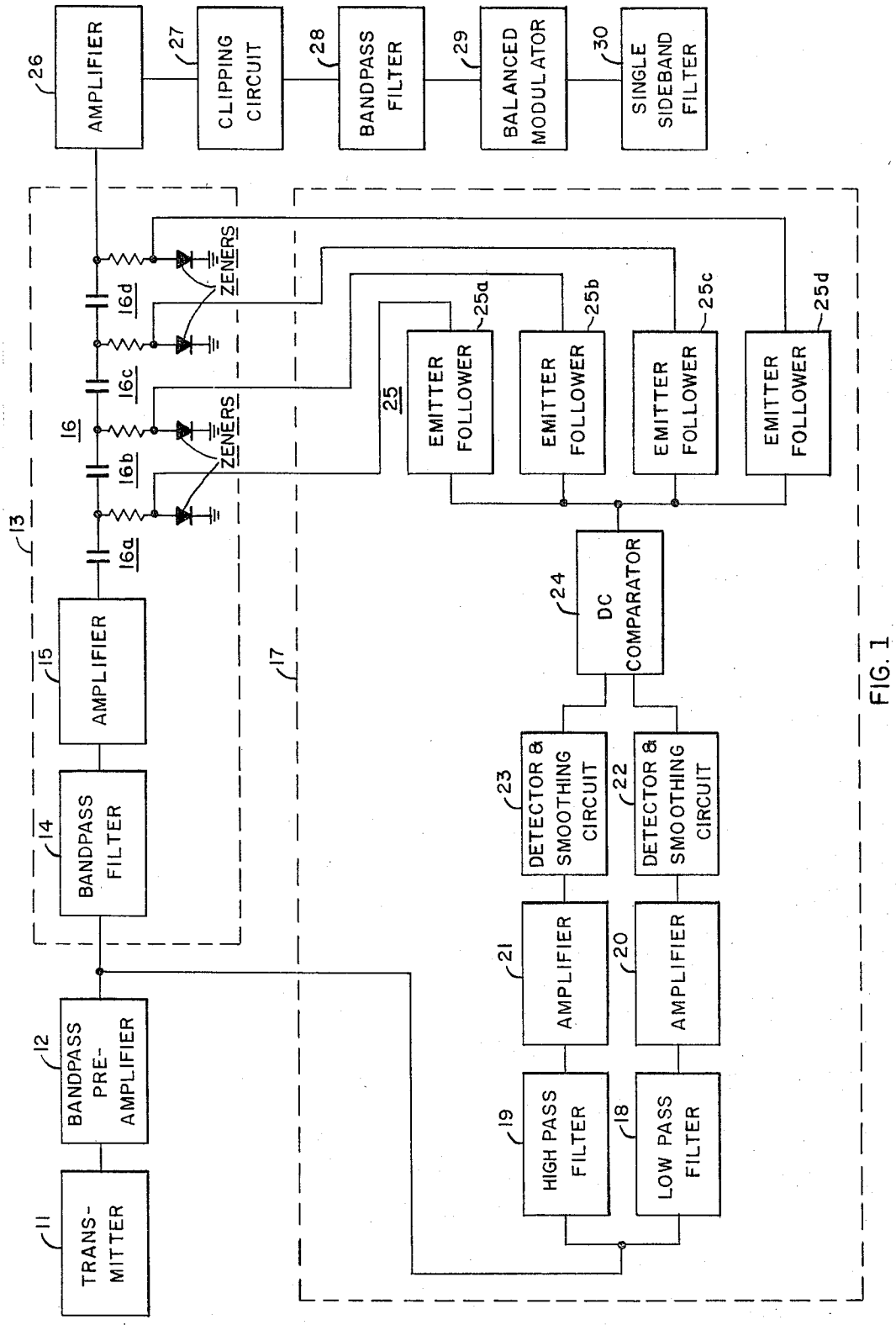


FIG. 1

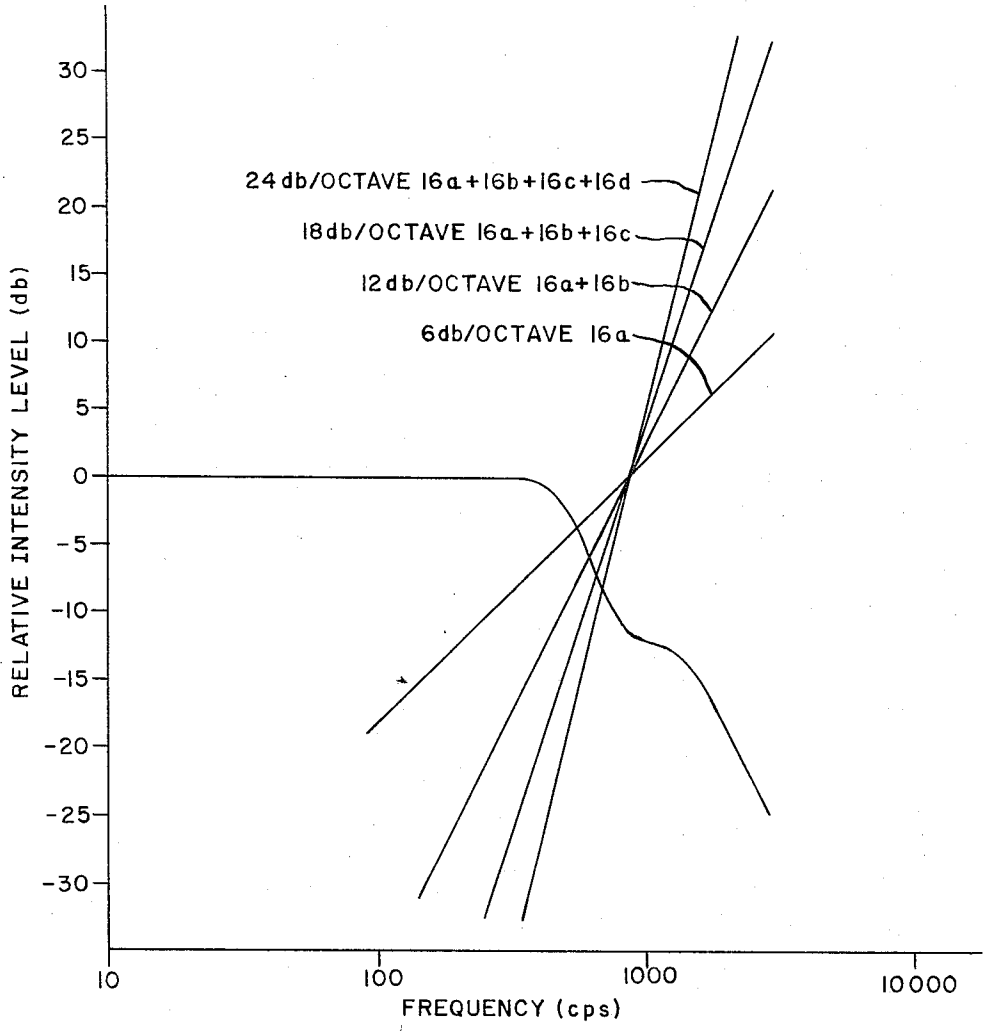

30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
RELATIVE INTENSITY LEVEL (db)
24 db/OCTAVE 16a+16b+16c+16d
18db/OCTAVE 16a+16b+16c
12db/OCTAVE 16a+16b
6db/OCTAVE 16a
10
100
1000
10000
FREQUENCY (cps)

FIG. 2

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3,292,116

DYNAMIC SPEECH EQUALIZING SYSTEM HAVING A CONTROL CIRCUIT THAT SEPARATES AND COMPARES THE HIGH AND LOW FREQUENCY ENERGY

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4 Claims. (Cl. 333—18)

The present invention is directed to voice communications systems and more particularly to systems for improving the intelligibility of a transmitted vocal message.

Statistical analyses of human voice power spectrum densities indicate that most of the vocal energy is concentrated at frequencies below 500 cycles per second and, at higher frequencies in which the greatest amount of intelligence is transmitted, the spectral density decreases at a significant rate. This presents a problem where machinery or other low-frequency noise-producing elements in a broadcasting area have a tendency to destroy the intelligibility by masking high-frequency energy content of the measure. Speech processing techniques, such as pre-emphasis, compression amplifiers and speech clipping, are presently used to increase the modulation index or percentage of energy transmitted at different frequencies in an attempt to form a signal which will best convey an intelligible message. Pre-emphasis circuits presently used are passive networks with a fixed attenuation slope and corner frequency based on the statistical characteristics of many voice spectrums. Since each person has a different power spectrum, manual controls for the adjustment of the speech amplifying circuits are necessary to increase the intelligibility of the vocal message. However, manual adjustment of the speech amplifying circuits is not efficient because the trial and error method of selecting the correct amount of amplification is required since the exact power density spectrum of the speaker is not known at the start of transmission.

It is an object of the present invention to provide a new and improved speech equalizing circuit whereby the intelligibility of the transmitted vocal message is automatically increased to its optimum value.

It is another object of the present invention to provide an efficient and inexpensive method of increasing the high-frequency vocal energy in proportion to the ratio between the high- and low-frequency energy.

In accordance with the present invention there is provided a dynamic speech equalizing system for improving the intelligibility of a transmitted vocal message including first means for providing an adjustable increase in the relative energy content of the high-frequency portion of an input signal in the vocal frequency spectrum, second means responsive to the input signal for providing output signals representative of the relative energy contents of the high- and low-frequency portions of the input signal, and third means responsive to the output signals for controlling the operation of the first means so that the relative energy content of the high-frequency portion is increased in relation to the relative energy contents of the high- and low-frequency portions of the input signal.

For a better understanding of the present invention, together with other and further objects thereof, reference is had to the following description, taken in connection with the accompanying drawings, and its scope will be pointed out in the appended claims.

Referring to the drawings:

FIG. 1 is a schematic of a dynamic speech equalizing system constructed in accordance with the present invention, and

FIG. 2 shows a statistical analysis of a large number of human voice power spectrum densities together with curves of use in the explanation of the operation of the FIG. 1 system.

General description

Referring now to FIG. 1 there is represented one embodiment of a dynamic speech equalizing system for increasing the intelligibility of a transmitted vocal message constructed in accordance wtih the present invention. As illustrated, the system of FIG. 1 includes a source **11** of transmitted signals in the vocal frequency spectrum, which may be a microphone, coupled to equalization control circuit **17** and equalization circuit **13** through bandpass preamplifier **12** which has a frequency response between 100 to 5000 cycles per second. The sharp low-frequency cutoff of 100 cycles per second is chosen in order to eliminate spurious low-frequency noise which serves only to destroy the intelligibility of the signal and the high-frequency cutoff of 5000 cycles per second is selected since signals above this range contain negligible intelligence.

Equalization circuit **13** includes first means, equalizing circuit **16**, for providing an adjustable increase in the relative energy content of the high-frequency portion of the input signal. As illustrated, equilization circuit **13** further comprises bandpass filter **14** having a frequency response between 300 and 3000 cycles per second coupled to the output of bandpass preamplifier **12** and amplifier **15** coupled to the output of bandpass filter **14**. The frequency response of bandpass filter **14** is restricted to 300 to 3000 cycles per second since most of the intelligible energy is located in this frequency range. The output of amplifier **15** is coupled to equalizing circuit **16** which comprises four selectively controlled pre-emphasis networks **16***a*, **16***b*, **16***c* and **16***d*, each network comprising a capacitor serially coupled through a resistor and zener diode to ground. As illustrated, the values of the components in each network are such, that each network has a positive rising frequency slope characteristic of 6 db per octave.

Equilization control circuit **17** includes second means responsive to an input signal in the vocal frequency spectrum for providing output signals representative of the relative energy contents of the high- and low-frequency portions of said input signal. As illustrated, second means comprises low-frequency bandpass filter **18**, having a frequency response between 100–500 cycles per second, coupled through amplifier **20** to detector and smoothing circut **22**. Detector and smoothing circuit **22** is of such construction that it produces a substantially D.-C. signal representative of the relative energy content of the low-frequency portion of the input signal.

Second means further comprises high-frequency bandpass filter **19**, having a frequency response between 500–5000 cycles per second, coupled through amplifier **21** to detector and smoothing circuit **23**. Detector and smoothing circuit **23** is of such construction that it produces a substantially D.-C. signal representative of the relative energy content of the high-frequency portion of the input signal.

Equalization control circuit **17** further includes third means responsive to the output signals from the diode detector and smoothing circuits **22** and **23** for controlling the operation of the first means so that the relative energy content of the high-frequency portion is increased in relation to the relative energy contents of the high- and low-frequency portions of the input signal. As illustrated, third means comprises D.-C. voltage comparator **24** coupled to emitter-follower circuits **25***a*–**25***d*. The D.-C. voltage comparator **24** is of such construction that when the output signals from detector and smoothing circuits **22** and **23** are applied to its input terminals simultaneously, it produces an output signal

representative of the ratio between the relative energy contents of the low- and high-frequency signals. Emitter-followers **25***a*–**25***d*, respectively, are coupled to pre-emphasis networks **16***a*–**16***d*, respectively, in equalization circuit **13** and control the operation of those networks, selecting any or all of the pre-emphasis networks depending upon the ratio between the relative energy contents of the low- and high-frequency signals.

As illustrated, the system of FIG. 1 further comprises amplifier **26** coupled to the output of equalization circuit **13** for additional amplification of the adjusted signal. The output of amplifier **26** is coupled to fourth means, clipping circuit **27**, which is responsive to the adjusted signal output from the first means for increasing the effective speech power of the adjusted signal. Clipping circuit **27** is of such construction that it provides 20 to 30 db of hard clipping on normal speech variations. This clipping increases the effective speech power and minimizes the effects of variations in distance between the speaker and microphone and the variations in sound intensity created by this variation. Bandpass filter **28** is connected to the output of clipping circuit **27** and has a high-frequency cutoff of 3000 cycles per second in order to eliminate the high-frequency components in the adjusted signal generated during clipping.

The system of FIG. 1 further comprises fifth means, single sideband filter **30**, coupled to the fourth means through bandpass filter **28** and balanced modulator **29** for restricting the voice communication channel to a predetermined bandwidth for use in single sideband communications. As illustrated, single sideband filter has a frequency response between 380 and 1750 cycles per second since this is a range which is utilized extensively in single sideband communications.

Operation of the FIG. 1 dynamic speech equalizing system

Considering now the operation of the dynamic speech equalizing system of FIG. 1, a message is spoken into microphone **11** and converted into electrical energy. Bandpass preamplifier **12** amplifies the signal and restricts it to a frequency range between 100–5000 cycles per second. The signal is thereupon applied simultaneously to equalization control circuit **17** and equalization circuit **13**.

In the operation of equalization control circuit **17**, the vocal signal input is divided into its low-frequency portion (100–500 cycles per second) and its high-frequency portion (500–5000 cycles per second) by bandpass filters **18** and **19**, respectively. The low-frequency and high-frequency signals are then amplified by amplifiers **20** and **21** respectively before being detected and averaged by diode detector and smoothing circuits **22** and **23**, respectively. Both D.-C. voltages are then applied to D.-C. voltage comparator **24** which produces an output representative of the ratio between the relative energy contents of the low- and high-frequency signals. The output from D.-C. voltage comparator **24** is then applied simultaneously to emitter-follower circuits **25***a*, **25***b*, **25***c* and **25***d* whose respective output voltages selectively control the operation of pre-emphasis networks **16***a*, **16***b*, **16***c* and **16***d* in equalizing circuit **16**. Thus, depending upon the ratio between the relative energy contents of the low- and high-frequency signals one, two, three or all four emitter-follower circuits will produce output voltage signals that will exceed the breakdown voltages of the zener diodes in pre-emphasis networks **16***a*–**16***d* in equalizing circuit **16** and thereby change the over-all slope of equalizing circuit **16** in 6 db per octave incremental steps.

In the operation of equalization circuit **13**, the vocal signal input bandwidth is restricted to a range between 300 and 3000 cycles per second. Referring now to FIG. 2, there is represented a statistical analysis of a large number of human vocal power spectrum densities which show that the greatest amount of vocal energy is concentrated between 0 and 500 cycles per second and, that over this frequency range, the relative intensity of the signal remains reasonably constant. Although, by selecting the low-frequency cutoff of 300 cycles per second, some of the vocal power will be lost, the increase in the relative high-frequency energy by equalizing circuit **16** will more than compensate for the high vocal power, negligibly intelligent, low-frequency signals. The high-frequency cutoff of 3000 cycles per second is selected in bandpass filter **14** because the vocal energy contained in frequencies above 3000 cycles per second contain negligible intelligence.

Equalization circuit **13** further comprises amplifier **15** and equalizing circuit **16** coupled to the output of bandpass filter **14**. The output signal from bandpass filter **14**, having a frequency bandwidth from 300 to 3000 cycles per second, is then amplified by amplifier **15**. The magnitude and slope of the amplified signal is dependent upon which of the four selectively controlled pre-emphasis networks **16***a*, **16***b*, **16***c* and **16***d*, respectively, each having positive rising frequency slope characteristics of 6 db per octave, are included in the output. Depending upon the proportion between the high-frequency energy content and the low-frequency energy content of the input signal, as determined by equalization control circuit **17**, the output signal from amplifier **15** is varied in positive 6, 12, 18, or 24 db per octave increments. Referring now to FIG. 2, it can be seen that from 100 to 500 cycles per second the relative intensity level remains reasonably constant and from 500 to 3000 cycles per second, wherein the greatest amount of intelligible energy lies, the spectral density decreases at a rate of approximately 12 to 24 db per octave. Therefore, the selection of pre-emphasis networks **16***a*, or **16***a* and **16***b*, or **16***a*, **16***b* and **16***c*, or **16***a*, **16***b*, **16***c* and **16***d* by equalization control circuit **17** equalizes the decrease in the relative intensity level of the intelligible high-frequency energy and has negligible effect on the low-frequency energy whose spectral density remains nearly constant. The addition of one or more pre-emphasis networks **16***a*, **16***b*, **16***c* and **16***d* to the output of amplifier **15** is accomplished by exceeding the breakdown voltages of the Zener diodes in pre-emphasis networks **16***a*, **16***b*, **16***c* and **16***d* and thereby connecting each respective network to ground. In the analysis depicted in FIG. 2, the four positive rising slopes are shown breaking at the same frequency based on the values of the components given infra. It should be understood that by a different selection of values for the components in the pre-emphasis networks each slope can be made to break at a different frequency than the other slopes and also have different characteristics.

The output signal from equalization circuit **13** is then applied to amplifier **26** which adjusts the level of the signal to drive clipping amplifier **27**. Clipping amplifier **27** is adjusted to provide 20 to 30 db of clipping on normal speech in order to increase the effective speech power and to remove amplitude variations peculiar to certain human vocal characteristics. The output of clipping amplifier **27** is coupled to balanced modulator **29** through bandpass filter **28** which has a high-frequency cutoff of 3000 cycles per second in order to eliminate high-frequency components generated during clipping. The output of balanced modulator **29** is coupled to single sideband filter **30** which has a frequency bandwidth of 380 to 1750 cycles per second in order to achieve more effective communication for any given size and weight of equipment.

From the foregoing description, it is seen that the present invention embodies a system wherein the intensity of the high-frequency vocal energy of a transmitted vocal message is increased in proportion to the ratio between the high-frequency energy and the amount of low-frequency vocal energy contained in the message itself as well as the amount of low-frequency energy introduced

by undesirable sources. Equalization circuit 13 contains four selectively controlled pre-emphasis networks 16*a*, 16*b*, 16*c* and 16*d* which will vary the intensity of the high-frequency vocal energy anywhere from 6 to 24 db per octave but have negligible effect on the intensity of the low-frequency vocal and spurious energy. Equalization control circuit 17 compares the relative energy contents of the low-frequency and the high-frequency portions of the input signal and determines to what extent the intensity of the high-frequency energy should be increased to achieve optimum intelligible transmission.

While applicants do not wish to be limited to any particular set of circuit constants, the following have proved useful in the pre-emphasis networks of FIG. 1.

Pre-emphasis network 16*a*:

Resistor	ohms	200
Capacior	microfarad	.266
Zener diode	type	1N746AM

Pre-emphasis network 16*b*:

Resistor	ohms	2,000
Capacitor	microfarad	.0266
Zener diode	type	1N750AM

Pre-emphasis network 16*c*:

Resistor	ohms	20,000
Capacitor	microfarad	.00266
Zener diode	type	1N754AM

Pre-emphasis network 16*d*:

Resistor	ohms	200,000
Capacitor	microfarad	.000266
Zener diode	type	1N757AM

While there has been described what is at present considered to be the preferred embodiment of this invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention and it is, therefore, aimed to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. A dynamic speech equalizing system for improving the intelligibility of a transmitted vocal message comprising:

first equalization means comprising a plurality of selectively controlled pre-emphasis networks, each network having a positive rising frequency slope characteristic, for adjusting the relative energy content of the high-frequency portion of an input signal in the vocal frequency spectrum in incremental steps;

second means responsive to said input signal for separating the high-frequency energy content from the low-frequency content and averaging said separated high- and low-frequency contents for providing output signals, the amplitudes of which are representative of the relative energy contents of the high- and low-frequency portions of said input signal;

and third means responsive to said output signals for comparing their respective amplitudes and controlling the operation of said first equalization means so that the relative energy content of said high-frequency portion is increased in incremental steps in relation to the relative energy contents of said high- and low-frequency portions of said input signal.

2. A dynamic speech equalizing system for improving the intelligibility of a transmitted vocal message according to claim 1, which further comprises:

fourth means comprising clipping circuitry responsive to the adjusted vocal signal output from said first equalization means for increasing the effective speech power of said adjusted signal;

and fifth means coupled to said fourth means for restricting the voice communication channel to a predetermined bandwidth for use in single sideband communications.

3. A dynamic speech equalizing system for improving the intelligibility of a transmitted vocal message comprising:

a source of transmitted signals in the vocal frequency spectrum;

first equalization means comprising a plurality of selectively controlled pre-emphasis networks, each network having a positive rising frequency slope characteristic of 6 db per octave for adjusting the relative energy content of the high-frequency portion of said input signal in 6 db per octave steps;

second means including a plurality of bandpass filters responsive to said input signal for separating the high-frequency energy content from the low-frequency energy content and a plurality of detector and smoothing circuits for averaging said separated high- and low-frequency energy contents for providing output signals, the amplitudes of which are representative of the relative energy contents of the high- and low-frequency portions of said input signal;

and third means comprising a D.-C. voltage comparator circuit responsive to said output signals for comparing the respective amplitudes and controlling the operation of said first equalization means so that the relative energy content of said high-frequency portion is increased by 6 db per octave, 12 db per octave, 18 db per octave, or 24 db per octave steps in accordance with the relative energy contents of said high- and low-frequency portions of said input signal.

4. A dynamic speech equalizing system for improving the intelligibility of a transmitted vocal message according to claim 3, which further comprises:

fourth means responsive to the adjusted vocal signal output from said first equalization means for providing 20 to 30 db of clipping of voltage variations in said adjusted signal;

and fifth means comprising a single sideband filter coupled to said fourth means for restricting the voice communication channel to a predetermined bandwidth for use in single sideband communications.

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