Aug. 21, 1951 E. R. SHENK 2,564,769

TRANSLATING CIRCUIT

Original Filed April 29, 1944 2 Sheets-Sheet 1

Fig. 1

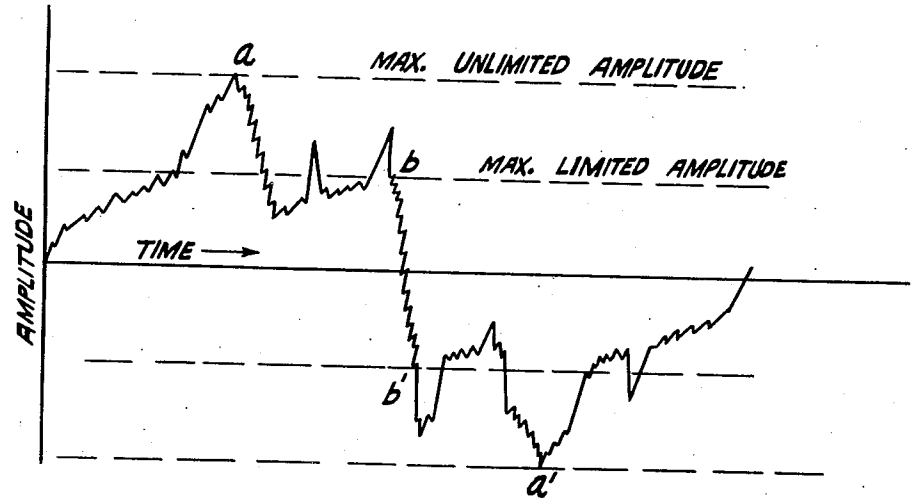
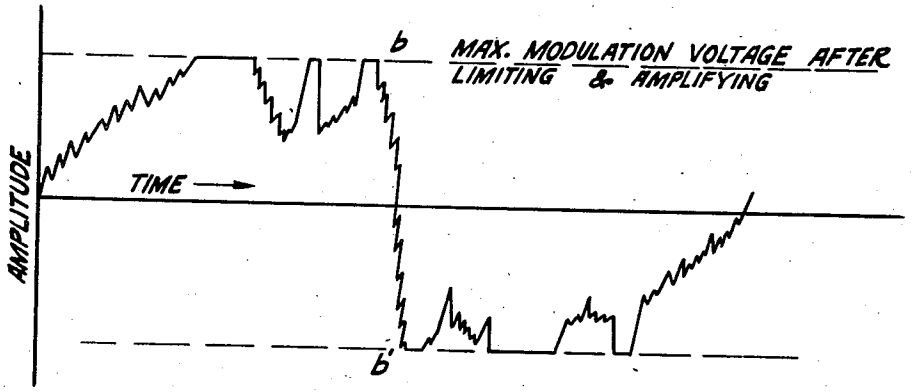


Fig. 2



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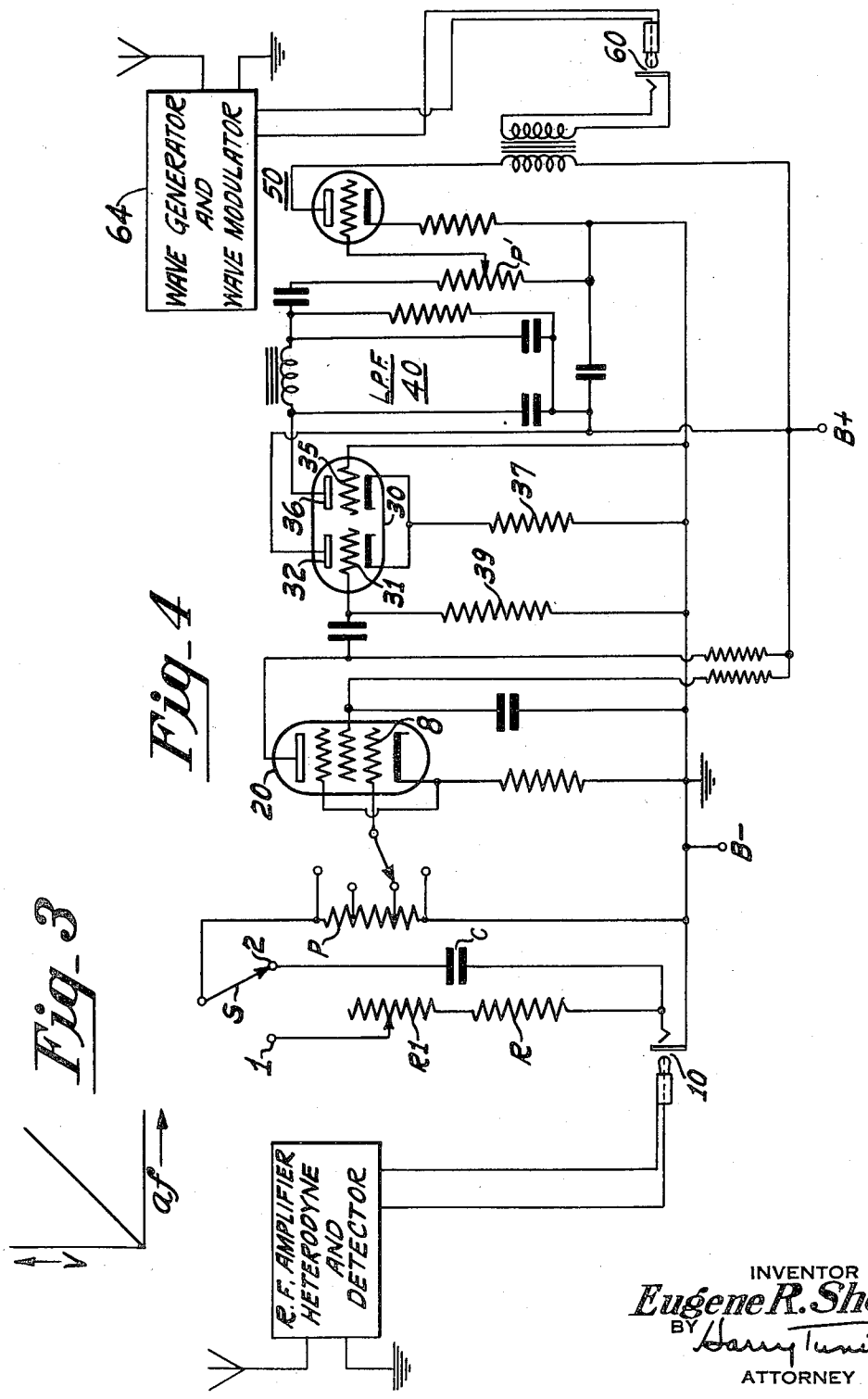


Fig. 4

Fig. 3

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TRANSLATING CIRCUIT

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Continuation of application Serial No. 533,440, April 29, 1944. This application October 25, 1949, Serial No. 123,348

10 Claims. (Cl. 332—37)

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This application is a continuation of my copending application, Serial No. 533,440, filed April 29, 1944, now forfeited.

This application concerns a means for treating signals such as currents representing speech and use of the same as treated in signalling. In the description which follows reference is made to voice signals; however, it will be understood that the invention is applicable to signals such as currents or voltages representing music.

It has been common practice heretofore to adjust the signal output of the modulator of a transmitter to such a level that 90% to 100% modulation occurred on the peaks of the signal. Due to the fact that the average amplitude of the speech signals is much less than the peak value, the average power in the side bands of the transmitted signal is also far below the peak power. The difference between peak and average voltage levels is of the order of 17 db for men and 13 db for women.

By reference herein to modulation of a carrier by the treated signals, I do not intend thereby to limit the treated signals to such use. The improvement claimed is realized by use of the signals in any manner. Where they are used as modulation the carrier may be modulated as to amplitude or timing.

A general object of this invention then is to increase the average amplitude of currents or voltages representing voice signals or music.

It is obvious that the peaks of speech signals contribute little to the average energy of the wave. I have also found that these extreme peaks of amplitude have little to do with the intelligibility of the speech, so that their elimination does not impair the intelligibility of the signal very much. Consequently, an amplitude limiter may be employed to clip the peaks and relatively boost the amplitude of the lower level portions of the voice wave, thereby improving the readability of the signal in the presence of interference. If speech signals are passed through an amplitude limiter having such a characteristic that

1. The portions of the signal having amplitudes less than a predetermined value are faithfully amplified, and
2. All portions of the signal having amplitudes greater than this predetermined value are eliminated, i. e., "clipped off"

then the ratio of peak to average value of the speech signal will be decreased by an amount dependent upon the previously mentioned predetermined level. The most pronounced aural result of such a process is an increase in the sound level or "volume," as it is commonly known. When this signal is used to modulate a transmitter, a considerably greater average side band power will be transmitted. A greater average signal to noise (S/N) ratio results at the receiver.

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A more specific object of my invention then is to improve the readability of signals by making greater use of signal potentials of the lower amplitudes wherein the intelligibility of speech mainly resides, and eliminating peaks of the signals wherein a small portion of the wave energy resides.

The clipping or limiting of the speech signal introduces some extraneous frequency components and if the limiting is carried too far, it eliminates some of the original speech frequencies. The high frequency, high amplitude components, occurring mostly above 3,000 cycles, are the first to be rejected. The reason for this is that these components tend to ride on the lower frequency components with the result that, when the two are additive, their sum overswings the linear portion of the limiter tube. This explains the experimentally observed fact that too great a degree of limiting results in a noticeable partial loss of intelligibility. It also accounts for the fact that as found by experimental observation, attenuating the lower frequencies prior to amplitude limiting greatly restores the intelligibility by reducing the amount of distortion produced by a given degree of limiting. Pre-attenuation of the lower frequencies is the same as preemphasis of the high frequencies. The lower frequencies are attenuated so as to make the amplitude of the audio frequency passed proportional to its frequency. For example, the attenuation might be such as to effect a 6 db rise in output voltage per octave of frequency as frequency increases. However, it usually is not desirable to use a degree of limiting greater than approximately 3 to 1 (somewhat less for women's voices), where the degree of limiting is defined as the ratio of peak to peak voltage applied to the limiter to that required to just cover the relatively linear portion of the limiter characteristic, that is, the range over which the limiter operates as a class A amplifier. For the average voice, the loss of intelligibility resulting from 3 to 1 limiting is negligible while the apparent aural increase in the level is of the order of 2 to 1.

It may at times be desirable at the transmitter to preattenuate the low frequencies and employ a degree of limiting greater than 3 to 1.

If no amplitude limiting has been applied to the signal at the transmitter, some advantage can be gained by limiting in the receiver. Due to the fact that limiting at the receiver greatly amplifies noise in the absence of signal, it is preferable to do the limiting at the transmitter. In any case, it is desirable to employ an amplitude characteristic in the audio amplifier of the receiver such that a maximum output level only slightly greater than the maximum signal level that will be used is possible. Such an arrangement prevents the signal to noise ratio in the audio circuits from dropping below a certain level, even though it might be lower at the input to the demodulator.

If it is desired not to transmit the extraneous frequencies introduced by the amplitude limiter, a suitable low pass filter can be inserted between the limiter and the modulator without loss of intelligibility.

While it is believed that my improved method and means as described hereinbefore will be apparent to those skilled in the art from the description given, the same has been illustrated in the drawings and will now be described with reference thereto.

In the drawings,

Fig. 1 illustrates by a curve the characteristic of voice signals before treatment thereof in accordance with my invention.

Fig. 2 illustrates the same voice signals after treatment in accordance with my invention.

Fig. 3 illustrates the characteristics of the attenuator network used when it is desired to attenuate the lower frequency signals to reduce distortion and loss of intelligibility when considerable limiting of the peaks is accomplished, while

Fig. 4 illustrates an embodiment of a circuit arrangement by means of which the signals are limited and used for modulation purposes. The figure also includes means for pre-attenuating the signal where a higher degree of limiting while still retaining readability is desired. This figure also includes a low pass filter between the limiter and the output. If desired, the limiting amplifier input may be coupled to the detector output of a receiver as illustrated in Fig. 4. Moreover, if desired, the limiting amplifier output may be used as a modulation source for a transmitter, as indicated in Fig. 4.

In Fig. 1, a voice wave is represented by plotting its amplitude as ordinates against time as abscissa. The voice wave may have a maximum unlimited amplitude *a*—*a'* which, if used for modulation, normally would produce maximum modulation of the transmitter, and lower level portions *b*—*b'*, wherein more of the intelligibility resides than in the extreme high peaks. As described hereinbefore, the peaks may be clipped off at a point above *b* and *b'* without important loss of intelligibility to increase the signal to noise ratio, and where the same is used for modulation to increase the average percentage modulation, the side band power and the readability of the signal in the presence of noise at the receiver.

Where the signals are clipped along the dotted lines at points *b* and *b'*, the result is as indicated in Figs. 1 and 2, a larger average signal amplitude with the advantages described above. Moreover, when the voice signals of lower frequencies are relatively attenuated, by a pre-attenuation in accordance with the graph of Fig. 3, then clipped and amplified, results as indicated in Fig. 2 are obtained. Thus, more of the higher frequency components of the signal are preserved so that the intelligibility is even less affected by the peak clipping process. In Fig. 2, note that the peaks have been clipped off (full wave clipper) and the remaining signals boosted in amplitude. The curves of Figs. 1 and 2 do not represent actual readings taken on apparatus in operation, but are used merely by way of illustration.

In Fig. 4, it is assumed that voltages or currents representing voice signals are impressed on the jack at **10**, amplified in the tube **20**, limited in the tube **30**, passed through the low pass filter **40**, further amplified in the amplifier **50** and used. When they are to be used as modulation energy they are fed by plug and jack **60** to a wave generator and wave modulator in **64**.

The signal input at **10** is coupled to the input grid **8** of tube **20** by resistances R and R1 and the potentiometer arrangement P when the switch S is on the #1 contact, or by way of condenser C and said potentiometer when the switch S is in the #2 position. The condenser C and the potentiometer P are an attenuating or differentiating network, by means of which the voice currents are attenuated in accordance with their frequency so that the network has a characteristic as illustrated in Fig. 3 of the drawings.

If a level or flat voltage or frequency-amplitude characteristic is desired, the switch S is placed on the #1 contact to include resistors R and R1 in series with potentiometer P. The variable resistor R1 permits adjustment to equalize the outputs of the "level with frequency network" R, R1, P and the differentiating network C, P.

The voltages, pre-attenuated or level, are fed to the input electrode **8** of the amplifier tube **20**, amplified therein and supplied to a limiter tube **30**. Any type of full wave limiter tube may be used here, but I prefer to use a limiter as disclosed in Crosby's U. S. Patent #2,276,565, dated March 17, 1942. The limiter **30** operates as a class A amplifier and does not require grid current drain for operation. It consists of an input triode including control grid **31** and anode **32** which drives an output triode including control grid **35** and anode **36** through the common cathode resistor **37**. The negative half cycles of the wave are limited by negative cutoff on the input triode. This is because the arrangement is such that the bias on the grid **31** developed in resistor **37** and resistor **39** is such that on the negative half cycles the input triode is cutoff at a selected point so that an increase of applied negative potential beyond said selected point has no further effect on the tube output. The second grid **35**, due to phase reversal of its grid to cathode voltage with respect to the grid to cathode voltage of the first triode, is effective for negative grid limiting on the positive half cycles of the input wave. This is because on positive half cycles of input the potential drop in resistance **37** grows to a point at which the grid **35** is biased negative to cutoff so that further increases in applied positive potential have no effect on the output. The over-all result is an amplifier in which positive saturation and negative cutoff both occur in a negative grid region.

The amplification is linear for inputs below a certain selected point. Above that value symmetrical limiting takes place. The degree of limiting is set by adjustment of potentiometer P. The input level was first set so that linear operation was obtained, but the maximum peaks just reached the limiting point. Then attenuation was removed by means of potentiometer P. The amount of attenuation removed was called the degree of limiting. For instance, if 20 db

were removed, 20 db of limiting was said to be used. This corresponds to an input to the limiter such that the maximum peaks were ten times the input at which limiting started.

A low pass filter **40** couples the output of the limiting amplifier **30** to the input of an additional amplifier **50**. This additional amplifier input includes a potentiometer P' by means of which the amplitude of the wave supplied through the jack at **60** for use may be adjusted.

When the output is used for modulation the plug at **60** is inserted in the jack. The transmitter **64** includes wave generating means, wave modulating means, modulated wave amplifying means and transmitting means.

When the limiting amplifier is used in a receiver it may replace the signal amplifier which usually follows the receiver detector. Then the plug at **10** may couple the receiver detector output to the input of the amplifier including tubes **20** and **30**.

While the present disclosure is written from the standpoint of improving speech on communication channels and should prove useful in war operations communication, it is believed that it will be desirable to apply its principles to other channels, including music. It is my opinion that standard broadcast stations could profitably employ approximately 2 to 1 limiting on speech signals, with or without preemphasis of the higher frequency speech currents.

What I claim to be my invention is:

1. In a signalling system comprising a source of wave energy of carrier wave frequency, a modulator therefor and a source of signals coupled to the modulator to modulate the carrier wave energy, a translating circuit coupling said source of signals to said modulator which translating circuit includes a network which modifies the signal currents in accordance with their frequencies and a current amplitude limiter which limits and removes current peaks which exceed a selected value, said limiter including a pair of space discharge devices each having a cathode, a control element and an anode, said pair of devices each having a cathode-to-anode circuit with a resistance in common, the said control element of one of said devices being connected to receive said signal currents, said common resistance coupling said devices to equally limit signal currents at a predetermined amplitude, and a low pass filter, said source of signals, said translating circuit, and said low pass filter being connected in cascade.

2. In a signalling system comprising a source of wave energy of carrier wave frequency, a modulator therefor and a source of signals coupled to the modulator to modulate the carrier wave energy, a translating circuit coupling said source of signals to said modulator which translating circuit includes a network which modifies the signal currents in accordance with their frequencies and a current amplitude limiter which limits and removes current peaks which exceed a selected value, said limiter including a pair of space discharge devices each having a cathode, a control element and an anode, said pair of devices each having a cathode-to-anode circuit with a resistance in common, the said control element of one of said devices being connected to receive said signal currents, said common resistance coupling said devices to equally limit signal currents at a predetermined amplitude, and a low pass filter, said source of signals, said translating circuit, and said low pass filter being connected in cascade in the order last named.

3. In combination, a modulation frequency input circuit, a differentiating network coupled thereto, said network acting to emphasize waves of higher frequencies fed to said network with respect to waves of lower frequencies fed thereto, a limiter coupled to said network for limiting the amplitude of the wave output of such network, a low pass filter coupled to the output of said limiter for substantially eliminating extraneous frequencies introduced by the limiter, a source of high frequency carrier energy, and a modulating circuit connecting the output of said filter to said source to effect modulation of said carrier energy with the output of said filter.

4. The combination defined in claim 3, in which the differentiating network comprises a resistor and a capacitor connected in series across the input circuit, the voltage across the resistor being the wave output of the network to which the limiter is coupled.

5. The combination defined in claim 3, in which the limiter includes a pair of space discharge devices each having a cathode, a control element and an anode, each of said pair of devices having a cathode-to-anode circuit with a resistance common to such circuits of said devices, the control element of one of said devices being coupled to receive the wave output of the differentiating network, said common resistance coupling said devices to symmetrically clip said wave output at a predetermined amplitude.

6. Apparatus for effectively increasing the average amplitude level of a band of signal waves, comprising a circuit carrying a band of signal waves, a differentiating network coupled thereto for attenuating the lower frequencies of the band with respect to the higher frequencies thereof, a clipper amplifier coupled to said network for symmetrically clipping the positive and negative half cycles of the wave output of the network, a low pass filter coupled to the output of said clipper amplifier for substantially eliminating extraneous frequencies introduced by such amplifier, and a utilization circuit connected to the output of said filter.

7. Apparatus as defined in claim 6, in which the differentiating network includes a resistor and a capacitor connected in series across the said circuit, the voltage across the resistor being the wave output of the network to which the clipper amplifier is coupled.

8. Apparatus as defined in claim 6, in which the clipper amplifier includes a pair of space discharge devices each having a cathode, a control element and an anode, each of said pair of devices having a cathode-to-anode circuit with a resistance common to such circuits of said devices, the control element of one of said devices being coupled to receive the wave output of the differentiating network, said common resistance coupling said devices to effect said symmetrical clipping.

9. Apparatus for effectively increasing the average amplitude level of a band of signal waves, comprising a circuit carrying a band of signal waves, a resistance-capacitance differentiating network coupled to said circuit for attenuating the lower frequencies of the band with respect to the higher frequencies thereof, a pair of space discharge devices each having a cathode, a control element and an anode, means coupling the control element of one of said devices to said network to receive the wave output thereof, a common resistor coupling the cathodes of both of said devices to a point of reference po-

tential, said common resistor coupling said devices to symmetrically clip the positive and negative half cycles of the wave output of the network, a low pass filter coupled to said devices to receive the clipped output thereof, said filter acting to substantially eliminate extraneous frequencies introduced by the action of said devices, and a utilization circuit connected to the output of said filter.

10. Apparatus as defined in claim 9, in which the resistance and capacitance of the differentiating network are connected in series across said circuit, the control element of said one of said devices being coupled to receive the voltage across the resistance of the network.

EUGENE R. SHENK.

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