

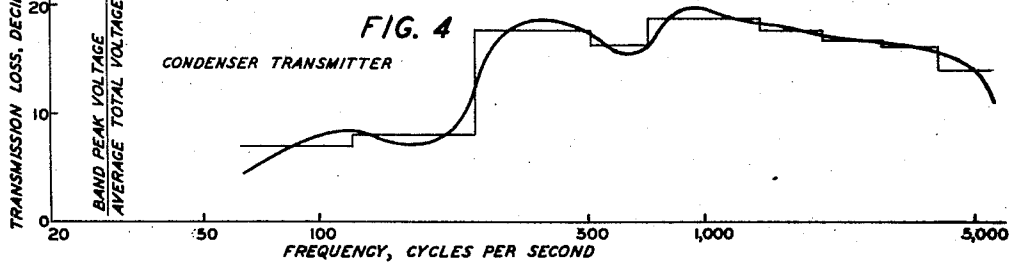
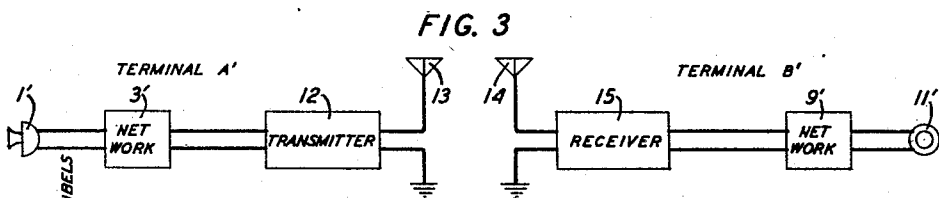
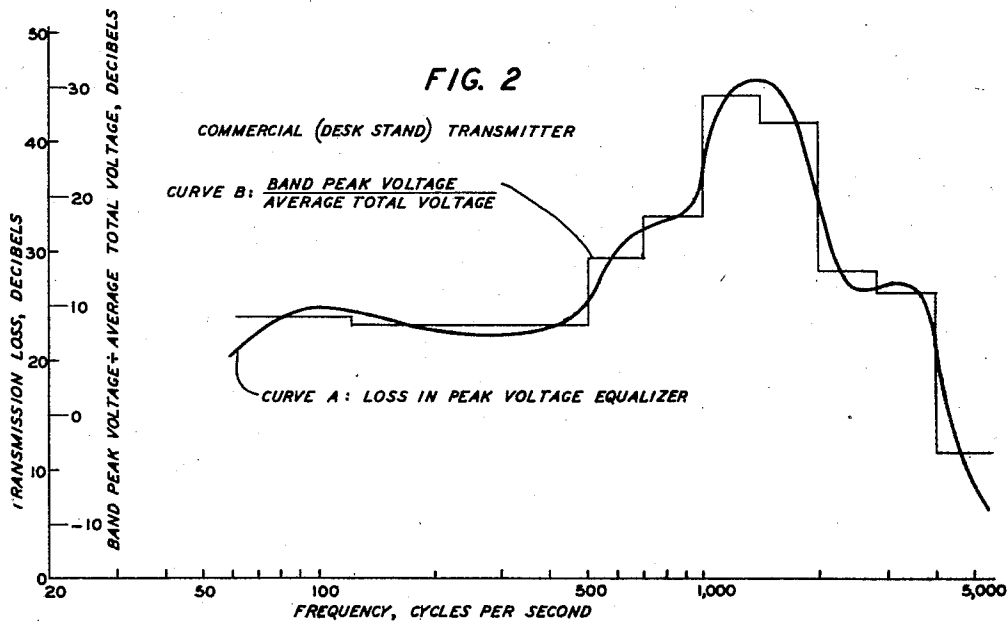
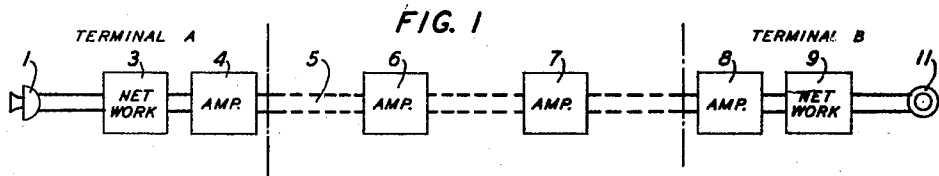
Nov. 17, 1931.

L. J. SIVIAN

1,832,431

ELECTRIC WAVE TRANSMISSION SYSTEM

Filed Aug. 29, 1930



INVENTOR
L. J. SIVIAN
BY
H. O. Burgess
ATTORNEY

UNITED STATES PATENT OFFICE

LEON J. SIVIAN, OF EAST ORANGE, NEW JERSEY, ASSIGNOR TO BELL TELEPHONE LABORATORIES, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK

ELECTRIC WAVE TRANSMISSION SYSTEM

Application filed August 29, 1930. Serial No. 478,654.

This invention relates to wave transmission systems, as for example, telephone systems.

An object of the invention is to decrease deleterious effects of disturbing energy.

Signals must often be transmitted through a noise or interference zone, that is, through a region or through apparatus in which noise or disturbing currents enter or are set up in the transmission system. Methods have heretofore been proposed to increase the signal-to-noise energy ratio obtaining at the receiver. One of these prior methods was to amplify the signal wave before transmitting it into the interference region. (Latour Patent 1,630,346, May 31, 1927; Hitchcock 1,507,178, September 2, 1924). The noise and signal after emerging from the interference region were attenuated sufficiently to reduce the signal energy level at the receiver to the desired value and to correspondingly reduce the noise energy level at the receiver. By this method, if the signal amplification (and therefore the margin of energy in favor of the signal) be sufficiently great, the noise energy can be reduced to a negligibly small value without effacing the signal. That is, the effect of the disturbance can be made negligible if sufficient energy is used at the sending end of the system and sufficient uniform or distortionless attenuation at the receiving end.

However, a limitation on the practice of such method is that restrictions are imposed on the sending energy. In many systems a sending end amplifier or other transmitting apparatus is operated at its maximum permissible load (for the shapes of the waves it is transmitting) regardless of disturbing energy that may enter or be set up in the system between the sending end and the receiving end. In such cases, if greater amplification of each frequency component be attempted, it is at the expense of distortion, and the system is then said to have become overloaded. That is, upon the increase of the power of each frequency component at the sending end, the amplifying apparatus at that end (and in many cases other overloaded apparatus in the system) itself introduces distortion or noise. This distortion limits

the advantage to be gained from increasing the sending end power of every frequency component with the given apparatus. In other words it is of no avail to reduce the disturbing effects of a given interfering energy if in doing so the system becomes so overloaded that, for example, because of harmonic generation (and other distortion frequency or distortion component generation), the signal suffers a degradation that more than offsets the advantage of the reduction of the effects of the given interfering energy.

However, it has also been pointed out heretofore (Hartley Patent 1,737,843, December 3, 1929) that, even when the load limit of the sending apparatus has been reached (for the shapes of the waves it is transmitting), the deleterious effects of noise upon the received signal can in many or most cases still be reduced, by changing the wave shapes. The frequency distribution of signal energy or of time-averaged signal power sent from a transmitting station generally is not uniform. For instance, as indicated by the curve showing the energy frequency distribution of average speech, page 79 of H. Fletcher's "Speech and Hearing", D. Van Nostrand Company, New York, 1929, the frequency spectrum of the energy of normal speech is not uniform; nor is it uniform after modification by the microphone or other sending apparatus. To the contrary, the time averaged value of the power in speech is greater for some frequencies than for others. That is, the frequency spectrum of the signal contains frequencies of comparatively low energy level and frequencies of comparatively high energy level. (A high energy level occurring at any particular frequency region does not necessarily imply high sound intensities in the region, but may result from either a large number of speech sounds having low intensities in the region or a few sounds having components of high intensities in the region.) Moreover, it is usually the case that the frequency distribution of energy of the noise is different from that of the signal, and that when the frequency distribution of the noise energy is not uniform over the utilized frequency range, the maxi-

num value of single frequency time averaged power or of single frequency energy occurs at one frequency for the signal and at a different frequency for the noise. A method heretofore proposed for so changing the wave shape of signals as to increase the amount that noise effects can be reduced, is to change the frequency distribution of the signal energy (as for example, speech energy) before the signal is sent through the sending end amplifier or other apparatus that otherwise might be too greatly overloaded.

According to this method heretofore proposed, this change in the energy-frequency relations in the speech before transmission may be effected by the use of a network having a transmission-frequency characteristic such that the network discriminates against the transmission of components in the frequency regions of certain signal energy levels and in favor of the components in the frequency regions of certain other signal energy levels. For example, it has been proposed that under certain conditions the frequency zones discriminated against be those in which the interference or noise energy to which the line is subjected is small and those frequency zones which the network favors be those in which the interference energy is relatively high. A network at the receiver having a characteristic complementary to that of the transmitter network then restores the speech to its original energy distribution and at the same time attenuates the noise. It is found in practice, that an increase in intelligibility by the use of such complementary networks can be effected if the networks are given the proper characteristics. Instead of making the networks at the transmitter and receiver exactly complementary, they may be so designed as to compensate for distortion in the system such as that due to unequal attenuation of the different signal frequencies. For example if desired the overall system attenuation obtained by adding the individual attenuations of the transmitting and receiving terminal apparatus to that of the line, and considering amplification as a negative attenuation, may be made the same for all frequencies in the entire frequency range which it is desired to transmit. The response-frequency characteristic or loss-frequency characteristic of the transmitter or of some other element or elements of the system without the receiving equalizer may correct or neutralize to a considerable extent the distortion introduced by the sending equalizer, and in some cases no receiving equalizer is needed. A particular proposal heretofore has been that, when the signal, before entering the interference zone, passes through vacuum tube amplifiers or other apparatus having a limited load carrying capacity, the predistortion of the sig-

nal (that is, its distortion before it is transmitted to the interference zone, or to the amplifiers or the other apparatus just mentioned) be made such as to obtain approximately the same energy level for all of its frequencies, in order to bring the energy level of each of its frequencies up to the maximum uniform energy level for the apparatus included in the system. (It has also been proposed, that to override a noise having a narrow frequency range, the predistortion of the signal be made such as to provide a particularly high signal energy gain for the interfering frequency range.)

As indicated above, then, it has already been proposed to override interference by increasing the sending energy of the signal, and moreover, make the increase selective with respect to frequency so that overloading will be less than were the sending energy merely amplified uniformly over the utilized frequency range; and as also indicated above, it has heretofore been particularly proposed to give the sending energy for speech transmission a distribution uniform with respect to frequency (or in other words to equalize the sending energy to a flat energy-frequency characteristic), when the limiting factor determining the sending energy is overloading of amplifiers or other apparatus.

In accordance with the present invention instantaneous maximum amplitudes (i. e. peak amplitudes) at different frequencies in the output voltage of a (sustained) speech or other signal wave as delivered (by a subscriber's circuit, for example,) to a predistorting network or equalizer, are equalized to a substantially uniform value (or other desired relative values) before the speech or signal is sent through amplifiers, or other apparatus susceptible to overloading, into an interference or noise zone; or where from the standpoint of providing apparatus overload capacity it is uneconomical to provide for all peaks, such equalization of the peak amplitudes is approached to some prescribed degree, as for example by so equalizing a chosen percentage, for instance 75% of all of the peak powers occurring in a succession of short time periods. In the case of speech, for example, the transmission capacity required to take care of all of the peak powers is much larger than that required to take care of the lower 75% of the peak powers occurring in a succession of short time periods (for instance periods of $\frac{1}{8}$ second duration).

The equalization of the peak amplitudes or powers, rather than equalization of long time average values of power or energy, is highly advantageous in many cases. Most types of telephone apparatus as now used are relatively indifferent to this long average. In general, it is maximum or high instantaneous values of voltage or power that cause

overloading of such apparatus and consequent limiting values of signal distortion. This is the case, for example, for vacuum tube amplifiers. Moreover, it has been found that in the case of normal speech applied to a high quality telephone transmitter or to a commercial subset transmitter for instance, the characteristic of peak amplitudes vs. frequency in the output is markedly different in form from the characteristic of long time average values of energy vs. frequency.

In receiving signals transmitted over the exposed region (i. e. interference region) in general there is employed a receiving equalizer network having a characteristic of transmission loss or efficiency vs. frequency such as to compensate for the response-frequency or loss-frequency characteristic of any or all of the other elements of the system, as desired. For example, to give the system the same air-to-air characteristic as a corresponding system with no exposed portion, the receiving equalizer has a loss-frequency characteristic which is the inverse of that of the sending equalizer and the exposed portion combined; or to compensate for the loss-frequency characteristic of the sending equalizer, the exposed portion and the telephone receiver, the receiving equalizer has a loss varying with frequency in the inverse manner of the sum of the losses in those elements; or to give the system a flat air-to-air characteristic, the receiving equalizer has a transmission-frequency characteristic which is the inverse of that of the remainder of the system, i. e. a transmission-frequency characteristic such that the sending and acoustic correction is removed and the rest of the system from the sending end to the listener is corrected. In some cases no receiving equalizer is needed, particularly when the transmitter or any portion of the system gives considerable signal distortion which tends to neutralize the signal distortion introduced by the sending end equalizer.

In one specific aspect the invention is a radio telephone system in which an equalizing network is connected between a telephone circuit and a radio transmitter, and the equalizing network is designed to have a given loss versus frequency characteristic such as to change the amplitude frequency distribution of normal speech waves received by it to an amplitude frequency distribution in which the peak amplitudes, (or any chosen fraction of the peak amplitudes occurring in a succession of small time periods, which are lower than the remaining peak amplitudes), have equal values throughout the utilized frequency spectrum. The signal level impressed on the radio transmitter is such as to operate the radio transmitter at its load limit.

The signals transmitted from the transmitting antenna are received by an antenna

which feeds a radio receiver including demodulating or detecting means that yields the speech signal. The detected signal is transmitted to a receiver, through a receiving equalizer network if desired. The receiving equalizer, if used, can have any suitable characteristic as indicated above.

The principle of the invention is not limited to application to radio transmission systems nor to transmission of speech signals, but is of general application to transmission systems and signals of various types as for example loaded submarine cable systems.

Other objects and aspects of the invention will be apparent from the following description and claims.

Fig. 1 shows schematically a voice frequency telephone system embodying a form of the invention:

Fig. 2 shows curves for facilitating explanation of the form of the invention shown in Fig. 1;

Fig. 3 shows a radio telephone system embodying a second form of the invention; and

Fig. 4 shows curves for facilitating explanation of the latter form of the invention.

In Fig. 1 at terminal A, a telephone transmitter 1, which is the usual transmitter of a commercial deskstand subset, represents a transmitting source of speech frequency signals. The output of the transmitter 1 is fed through the subscriber's loop to a predistorting equalizing network 3. The output of network 3 is fed to amplifier 4 which in turn is connected with line circuit 5, having therein a plurality of amplifiers such as 6 and 7, the purpose of which is to maintain the level of the transmitted signal well above the noise level of the line, thereby rendering the signal free from interference produced by the noise. The line circuit 5 is connected at the receiving terminal B with amplifier 8, which in turn is connected with a corrective network or receiving equalizer 9. The output of the network 9 is fed to receiver 11. The system has been shown as arranged for one-way signaling, to simplify description of the invention; but corresponding two-way signaling can be effected by well-known adaptations.

Curve A of Fig. 2 shows approximately the relative losses required in network 3 at the different frequencies in order to predistort or change the peak voltage-frequency characteristic of the speech signals received by it from the transmitter 1, when normal speech is impressed on the transmitter, to a flat or uniform peak voltage-frequency characteristic of speech signals for delivery to the amplifier 4. This curve A is derived from the staircase curve B of Fig. 2, which is plotted from measurements of peak voltage amplitudes of speech signals delivered by a subset transmitter such as 1 in a typical commercial subscriber's circuit when normal

speech is impressed on the transmitter. In making these measurements, the output of the subscriber's circuit was divided into frequency bands by filters and the peak voltage amplitudes for short periods of time were measured for each frequency band. For the curve B, each of the time periods was of one second duration, and thus the peak value in each selected frequency band corresponds to the maximum voltage occurring in the selected band during one second of sustained speech. Simultaneously with these peak measurements, the value of the integrated totals of voltages in one half (positive half or negative half) of the entire speech wave (for the whole frequency range, all of the bands) for fifteen seconds of sustained speech, also were observed. The curve B is plotted between frequency, in cycles per second on a logarithmic scale, and band peak voltage divided by average total voltage, in decibels. By average total voltage is meant the time integrated voltage of the total frequency range divided by the total time of the integration.

The curve B is a composite curve for four male voices, and is for the Western Electric #337 deskstand transmitter. For each caller approximately sixty peak values were observed in each band. All this was then repeated for the next band, and so on until the entire range had been covered. The curve A is drawn somewhat arbitrarily as a smooth curve corresponding to the staircase curve B, the smooth curve including approximately the same area below as above the staircase curve.

The transmission characteristic or loss-frequency characteristic of network 9 is not shown, as it may be of any suitable character, as indicated above. For example, it may be complementary to that of network 3 (i. e. the inverse of that of network 3) in case it is not desired to have the network 9 compensate for distortion in portions of the system other than network 3, or it may be designed to take care also of the distortion introduced in any or all of the other portions of the system, notably the receiver. In some cases the network 9 is not needed, and may be omitted, particularly when the transmitter 1 or another portion of the system gives considerable signal distortion which tends to neutralize the signal distortion introduced by equalizer 3.

It will be obvious that the line circuit 5 may, if desired, be one of the channels of a carrier telephone system, including the necessary apparatus for modulation, demodulation, etc.

In Fig. 3 transmitter 1' at terminal A' represents a source of speech frequency signals connected with a predistorting network 3', which in turn is connected with a radio frequency transmitter 12. In this case, the telephone transmitter is assumed to be of the

"high-quality" type, as for example a condenser transmitter, producing substantially no distortion in transforming the air waves comprising its input into electrical variations. The output of the radio transmitter is connected with the antenna 13, which radiates the high frequency signal to a receiving antenna 14 associated with terminal B'. The noise level through which the radio transmission course occurs is ordinarily fairly uniform over the utilized radio frequency range. At station B' the antenna 14 is connected with a radio receiver 15, which detects the signal and transmits it through a corrective or equalizing network 9' to receiver 11.

Network 3' may have the loss-frequency characteristic A' shown in Fig. 4 which is of such form that when normal speech signals are impressed on transmitter 1' the peak amplitudes of the network output voltage will be substantially equal for all the transmitted frequencies. This curve A' is derived from the staircase curve B' of Fig. 4 as curve A is derived from curve B. Curves A' and B' are curves for a distortionless transmitter which correspond to the curves A and B respectively for the transmitter of Fig. 1. The curve B' is plotted from measurements of peak voltage amplitudes of speech signals delivered by a transmitter such as 1' when normal speech is impressed on the transmitter. These measurements were made as described above in connection with curve B, except that curve B' is a composite curve for five male voices instead of four, and is for the Western Electric 394 type condenser transmitter alone, rather than in a subscriber's circuit of a commercial type.

Corresponding to case of network 9, the transmission-frequency characteristic or loss-frequency characteristic of network 9' may be of any suitable type, as for example, complementary to that of the predistorting network 3', or such as to take care also of the distortion in any or all of the other portions of the system. In some cases the network 9' is not needed, and may be omitted.

If desired the characteristics of the predistorting networks such as 3 and 3', instead of being such as to render the maximum peak amplitudes of the signals uniform or of any other predetermined relative values over the utilized frequency range, can be such as to give such uniform or other predetermined relative values to any chosen percentage of the peak amplitudes occurring in a succession of short time periods, which are lower than the remaining peak amplitudes. For example, the loss-frequency characteristic of equalizer 3' instead of being derived from curve B' can be correspondingly derived from the solid line curve of the lower half of Fig. 14 of my paper on "Speech power and its measurement", published in the Bell System Technical Journal, October 1929.

The latter curve is a composite curve for three male voices. It shows the relative values of the lower 75% of the peak amplitudes, for periods of one eighth second duration, of signal pressure (or voltage) in selected frequency bands of the utilized frequency range, for normal speech. Comparison of that curve with the solid line curve in the upper half of the same figure, which is the corresponding curve of relative values of the maximum peaks in the various bands, shows how much larger the transmission capacity of the system must be to take care of the highest 25% of the peaks. For the peak amplitudes equalized, the amplifiers 4, 6, 7 and 8 in Fig. 1 and some portion of the radio transmitter in Fig. 3, for example a power amplifier employed as usual to raise the power of the radio frequency signal waves before applying them to the antenna 13, operate at their maximum input amplitude capacity, i. e. at the maximum input amplitudes that they can handle without producing substantial signal distortion as a result of overloading. The networks 3 and 3' may include amplifiers for raising the power level of the predistorted signal, if desired.

If desired the characteristic of the predistorting networks such as 3 and 3' may be such as to give a flat or other desired shape of peak amplitude versus frequency characteristic for a chosen type of signals other than speech. For example, in the case of transmission or reproduction of piano music, the network 3' may have as its loss-frequency characteristic a smooth curve corresponding in form to the staircase curve A or B of Fig. 15 of my paper, mentioned above, in the same manner in which curve A' corresponds in form to curve B'. The curves A and B of that paper give peak amplitude-frequency characteristics for sounds representing a piano selection instead of for speech, but otherwise correspond respectively to the curves of the upper and lower halves of Fig. 14 of that paper.

In practicing the invention, in general the predistorting network (such as 3 or 3') changes the peak amplitude-frequency characteristic of the power delivered to the network in such manner as to cause the peak powers of the network output to have any predetermined frequency distribution or frequency characteristic, as for example, to cause the peak powers of the network output to have their maximum permissible values at the various utilized frequencies. For instance, overloading limits are in general a function of frequency and the network may change the frequency distribution of the peak powers of the given signal delivered to it in such manner as to cause apparatus subject to overloading to be operated at its maximum permissible values of peak powers (for the given output of the predistorting network)

at the various utilized frequencies; or, in other words, the predistorting network may change the given signal delivered to it in such manner that the peak power-frequency characteristic of the output of the predistorting network conforms to (i. e., is substantially the same as) the peak power-frequency overload characteristic (for the given output of the predistorting network) of the apparatus subject to overloading. Although the peak power-frequency overload characteristic of the apparatus subject to overloading depends to some extent upon the form of the peak power-frequency characteristic of the output to that apparatus, for practical purposes ordinarily this dependence can be neglected.

It is desired to emphasize the fact that, as indicated above, the predetermined frequency distribution or frequency characteristic which it is desired to give the peak powers of the output of the predistorting network is not in all cases flat. The desired characteristic may be determined by limiting factors other than overloading in the most restricted sense of that term. For example, when the limiting factor is cross-talk into other circuits, the desired characteristic ordinarily is not flat, but slopes in many cases in a way to indicate that higher values of peak power can be transmitted at the low frequencies in the utilized frequency range than at the higher frequencies. In the case of eddy current shielding, however, the slope usually is the reverse. Moreover, even when the maximum permissible values of peak power at the various utilized frequencies in the output of the predistorting network are determined by overloading in a more restricted sense, the desired peak power versus frequency characteristic of the network output may be non-uniform with respect to frequency (i. e. may be not flat) because the peak power versus frequency overload characteristic of the apparatus subject to overloading is not in all cases flat. For example, in the case of a radio transmitter such as that of Fig. 3, the impedance into which the power amplifier subject to overloading works may vary with frequency, and then the maximum output power that the amplifier can deliver without introducing objectionable distortion is less for some frequencies than for others. Consequently, the output of the network such as 3' should in that case have a peak power versus frequency characteristic conforming to the non-uniform peak power versus frequency overload characteristic of the power amplifier. By way of further example, if desired the peak power versus frequency overload characteristic of the apparatus subject to overloading can be considered to be such as to take into account the variation with frequency in disturbing effect of a given peak value of single frequency disturbing power (such as modulation power). In other

words, the peak powers of interference (such as modulation products) relative to the peak speech powers may be made to vary considerably over the frequency range. Moreover, in determining the desired peak power versus frequency characteristic of the network output, such factors as the attenuation characteristic of the portion of the system in the exposed region, and the frequency distribution of the noise picked up by that portion of the system may be taken into account if desired.

The predistorting network transmission characteristic required to give the network output any predetermined characteristic of peak power versus frequency will be apparent from the network transmission characteristic (for example A or A') required to give the network output a flat characteristic of peak power versus frequency; for the network transmission characteristic required to produce any given output characteristic of form other than flat is obtained by algebraically subtracting at each frequency from the network transmission characteristic required for the flat output characteristic the difference between the given output characteristic and the flat output characteristic.

It is true that, as indicated above, in general, the predistorting network such as 3 or 3' is given a transmission characteristic such that its output has a predetermined peak power versus frequency characteristic for a given peak power versus frequency characteristic of its input. That is, it is true that, in general, the transmission characteristic of the network is chosen to take into account both (1) the original peak power versus frequency characteristic of a given type of undistorted signal (speech, for example) and (2) the transmission characteristic of the portion of the system ahead of the network (for example, the response-frequency characteristic of the transmitter and circuit which feeds the network). However, in the case of a system such as that of Fig. 3, employing the condenser transmitter 1', the latter characteristic is substantially flat, so that it has little effect upon the transmission characteristic required for the predistorting network relative to the corresponding effect in the case of a system such as that of Fig. 1. On the other hand, the latter effect may be of major importance and, therefore, if desired the frequency distribution of peak power in the original undistorted signal can be neglected (regarding as uniform with respect to frequency) in determining the transmission characteristics of the predistorting network. To do this the difference between the characteristics A and A' may be taken to give the (transmitting) effective peak response-frequency characteristic of the commercial subscriber's circuit (i. e. the relative responses of the subscriber's circuit to equal input ampli-

tudes at the different frequencies in the utilized frequency range). Then, in the system using the commercial transmitter, as for example the system of Fig. 1, the sending end equalizer can be given a transmission-frequency characteristic complementary to the (transmitting) response-frequency characteristic of the subscriber's circuit, to equalize or compensate for merely the (transmitter) distortion of the subscriber's circuit instead of for both that distortion and the peak amplitude versus frequency characteristic of the speech or other signal. Such choice of the transmission-frequency characteristic of the sending end equalizer might be warranted especially in case the same transmitter is to be used for transmitting types of signals differing considerably in the frequency distribution of their peak powers. The compensation for the subscriber's circuit may be made only partly, if desired, since the part compensation may be more effective than complete compensation in case, for example, the line noise in the exposed portion of the system is highest at the frequencies at which the transmitter characteristic is highest. When the sending equalizer is made to compensate for the characteristic of only the subscriber's circuit, and not for the peak amplitude versus frequency characteristic of the signal, then no receiving end equalization for the sending end equalizer is needed, since the sending end equalizer has then merely compensated for signal distortion.

While the invention has been disclosed as embodied in particular forms, it is capable of embodiment in other forms without departing from the spirit and scope of the appended claims.

What is claimed is:

1. The method which comprises changing the differences between the maximum instantaneous powers at the different frequencies, in a signal of substantial time duration, by amounts such as to give the maximum instantaneous powers of the signal at the different frequencies magnitudes having predetermined relative values.
2. The method which comprises changing the differences between the maximum instantaneous powers at the different frequencies in a signal of substantial time duration by amounts such as to give the signal a predetermined characteristic of peak power versus frequency more nearly flat than the corresponding characteristic of the signal before said change.
3. The method of operating on a signal in a signaling system including signal transmitting apparatus that has overloading limits in general a function of frequency, which comprises changing the peak amplitudes of the signal at its different frequencies to the maximum values that can be supplied to the ap-

paratus without exceeding its overloading limits.

4. The method which comprises reducing the differences between the maximum instantaneous powers at the different frequencies, in a signal of substantial time duration, by such amount as to render the relative values of said powers of the different frequencies substantially equal.

5. The method of reducing deleterious effects of noise on a signal of substantial time duration in a signaling system including signal transmitting apparatus subject to overload primarily by instantaneous amplitude values of the signal, which comprises reducing the differences between the maximum instantaneous values of signal power that occur respectively in a number of mutually exclusive frequency bands of the signal which together constitute the signal, by amounts such as to render the relative values of the band peak signal powers substantially equal, and transmitting the resulting form of the signal through said apparatus to a noise zone, whereby said apparatus is loaded substantially equally by said different frequency bands of the signal passing into the noise zone.

6. In combination, a signal source, signal transmitting means subject to overloading by the signal from said source, and signal distorting means connected between said source and said signal transmitting means, said signal distorting means having transmission efficiency independent of the amplitude of waves impressed thereon but varying with frequency in such manner as to change the differences between the peak amplitudes of the signal at its different frequencies by predetermined relative amounts.

7. A speech signal transmitting system comprising a portion subject to overloading and a corrective network preceding said portion in the system, said network having its characteristic of transmission efficiency versus frequency such as to change the original amplitude-frequency distribution of the signal into one in which the peak speech powers have predetermined relative values at the different frequencies.

8. A speech signal transmitting system comprising a portion subject to overloading and a corrective network preceding said portion in the system, said network having its characteristic of transmission efficiency versus frequency such as to change the original amplitude-frequency distribution of the signal into one in which the peak speech powers at the various frequencies have predetermined relative values and to impress the changed speech signal on said portion of the system at the maximum power level consistent with distortionless transmission of the signal.

9. A signal-transmitting system comprising a radio transmitter subject to overload-

ing and a corrective network preceding said radio transmitter in the system, said network having its characteristic of transmission efficiency versus frequency such as to change the original amplitude-frequency distribution of the signal into one in which the signal peak powers at the different frequencies have values that differ from each other by prescribed relative amounts.

10. A signal transmitting system comprising a radio transmitter subject to overloading and a corrective network preceding said radio transmitter in the system, said network having its characteristic of transmission efficiency versus frequency such as to change the original amplitude-frequency distribution of the signal into one in which the peak signal powers at the different frequencies have equal values throughout the utilized frequency range and to impress the changed form of the signal on said radio transmitter at the maximum power level consistent with distortionless transmission of the signal by said radio transmitter.

11. The method which comprises changing to predetermined relative values the differences between a chosen fraction of the peak powers of a signal at its various frequencies which occur in a succession of short time periods and which are lower than the remaining peak powers occurring in those periods.

12. The method of operating on a signal in a signalling system including signal transmitting apparatus that has overloading limits in general a function of frequency, which comprises changing to the maximum magnitudes that can be supplied to the apparatus without exceeding its overloading limits a chosen fraction of the peak powers of a number of mutually exclusive frequency bands of the signal which together constitute the signal, which peak powers occur in a succession of short time periods and are lower than the remaining peak powers occurring in those periods.

In witness whereof, I hereunto subscribe my name this 28 day of August, 1930.

LEON J. SIVIAN.