Aug. 18, 1931. H. A. AFFEL 1,819,054

CARRIER SIGNALING SYSTEM

Filed May 24, 1927

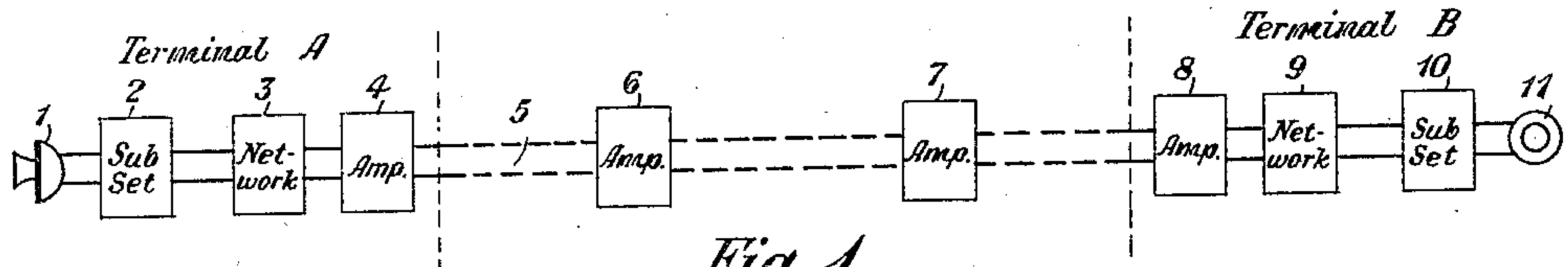

Fig. 1

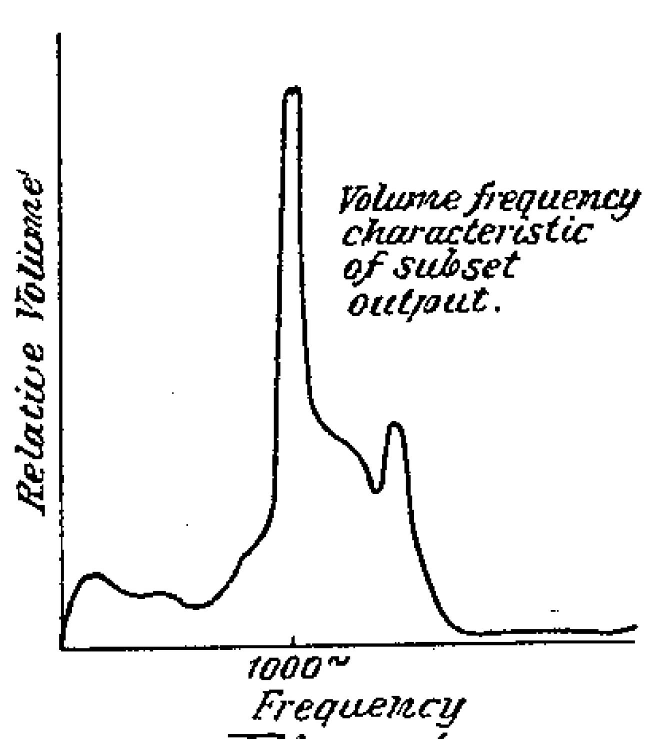

Fig. 1a

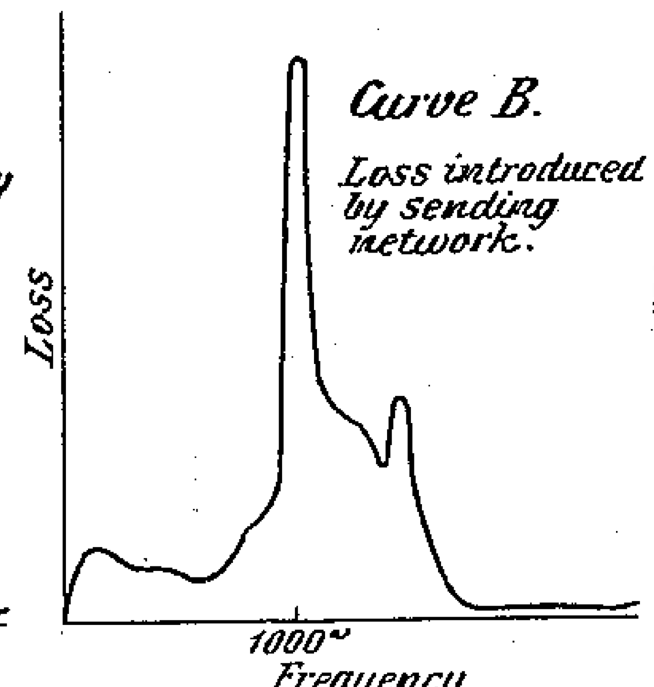

Fig. 1b

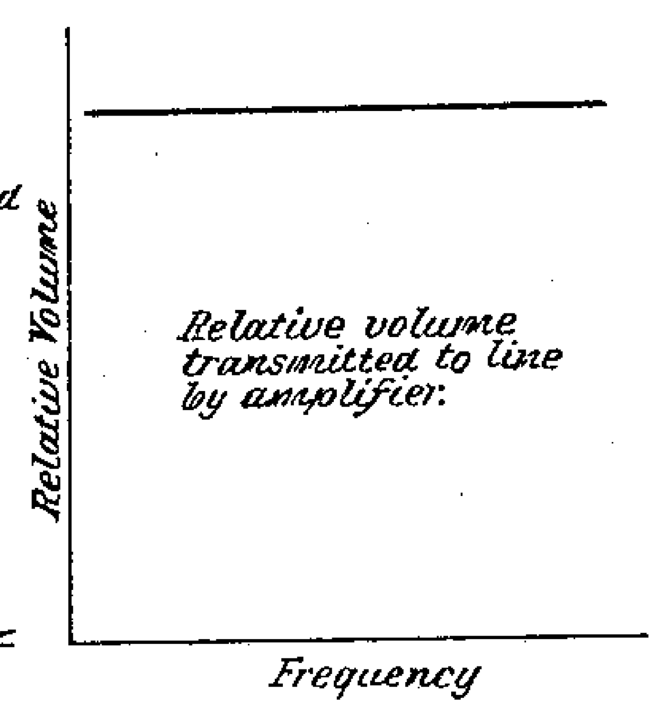

Fig. 1c

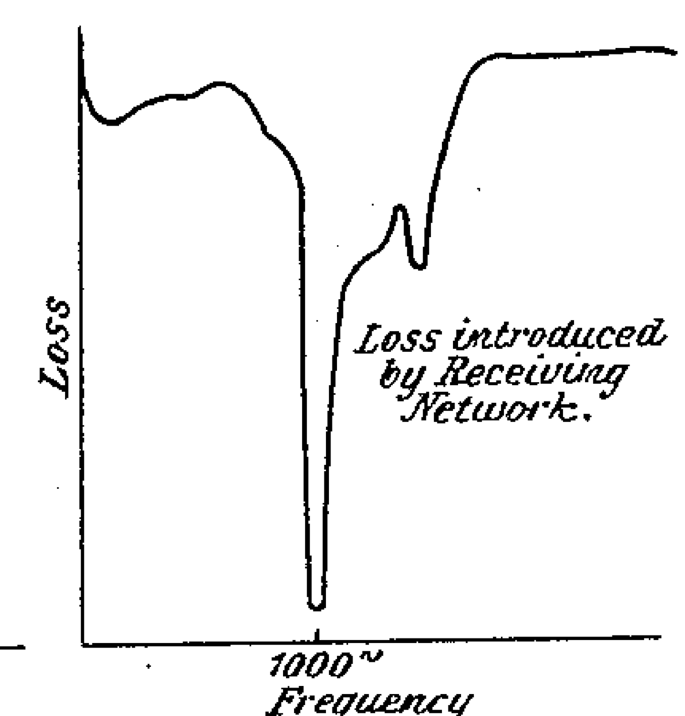

Fig. 1d

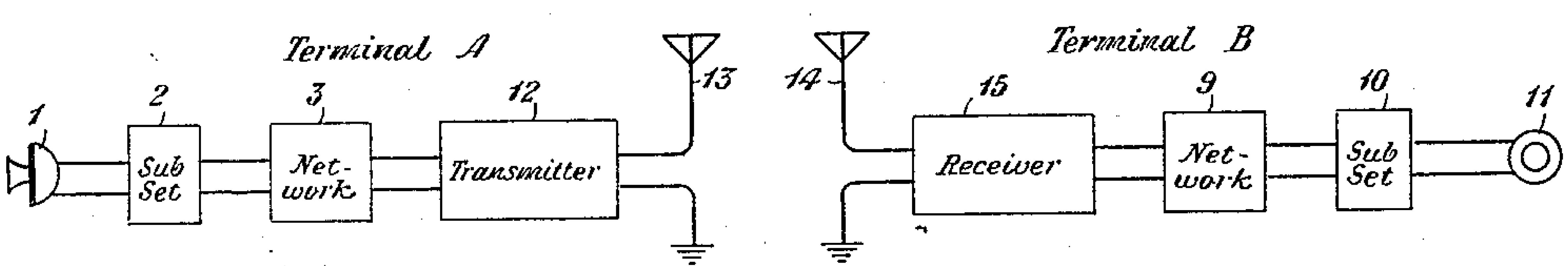

Fig. 2

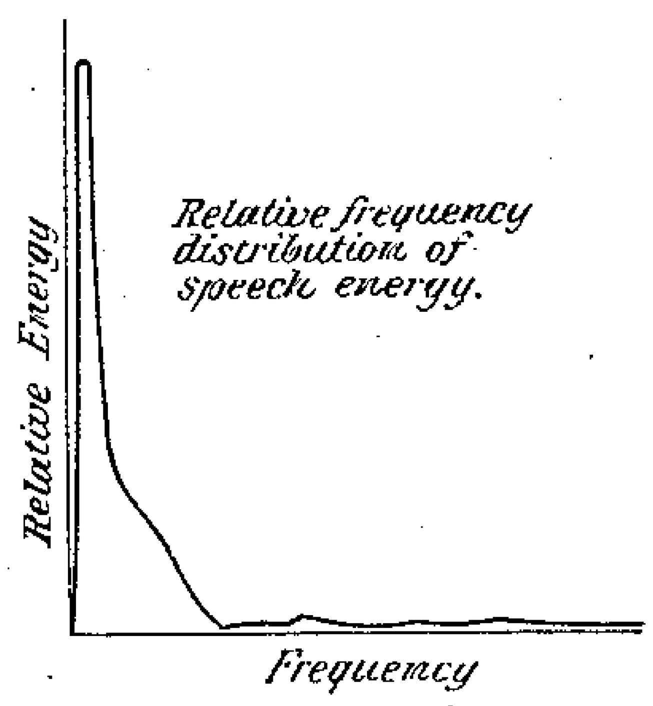

Fig. 2a

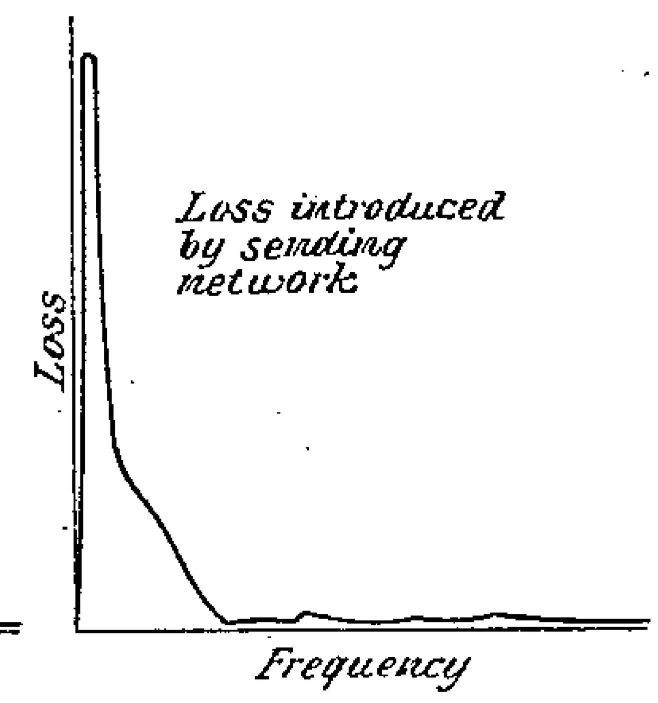

Fig. 2b

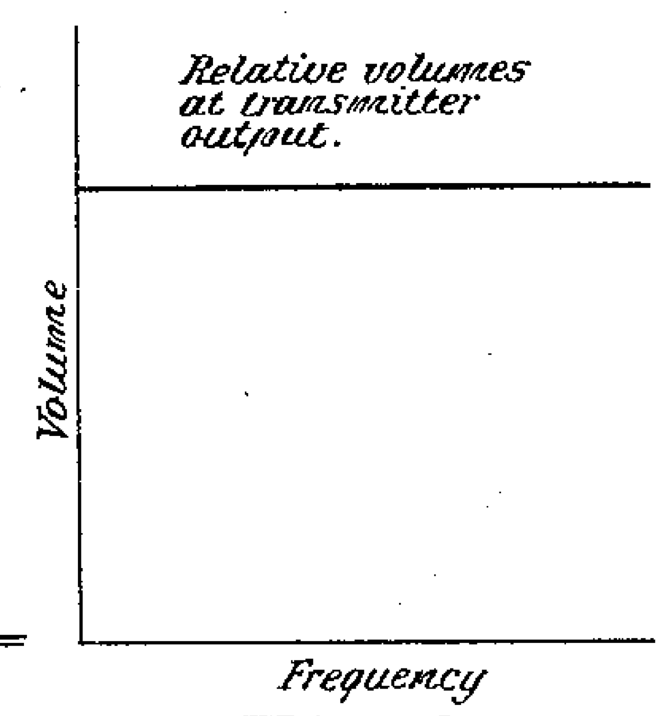

Fig. 2c

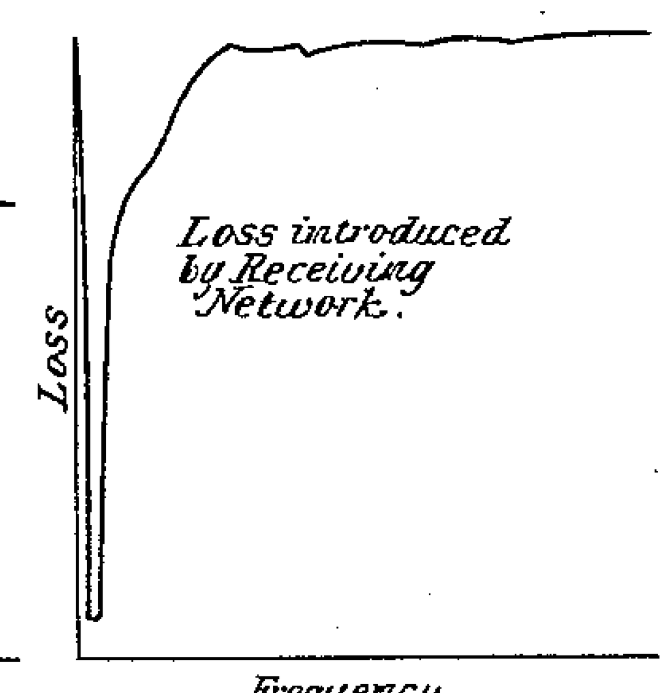

Fig. 2d

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1,819,054

UNITED STATES PATENT OFFICE

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CARRIER SIGNALING SYSTEM

Application filed May 24, 1927. Serial No. 193,902.

This invention relates to signal transmission systems, and particularly to a method of operating such systems to minimize the effect of noise upon the signal wave being transmitted, the said method being characterized by an intentional predistortion of the signal wave, and the restoration to its normal form after its transmission over or through a medium. The invention may be applied to voice frequency transmission systems and to carrier or radio systems.

In the transmission of signals over a signal transmission system, such as a carrier or radio system, it is desirable, in order to avoid distortion, that the system shall have the same over-all equivalent at all frequencies within the range to be transmitted. In the systems heretofore employed, an effort has been made to provide in each part of the system, including the parts subject to external sources of noise, substantially distortionless transmission of the frequencies in the signaling wave. It is well known that under normal conditions some of the frequencies in the original signal wave contain larger amounts of energy than others, and that the energy-frequency distribution may be further distorted during the conversion in the transmitter from air waves into electrical waves. In the ordinary transmission system the non-uniform distribution thus obtained in the transmitter is preserved to a greater or less extent throughout the system.

This invention resides in a method of operating a signal transmission system, which consists in predistorting the signal wave at the transmitting end in such a manner as to ensure a practically constant amplitude for all frequencies in the signaling wave and in restoring the transmitted wave to its original form at the receiving station by a distortion that is the complement of the distortion at the transmitting station.

In a transmission circuit involving a sending terminal, a line or transmission circuit, and a receiving terminal, there are often one or more points at which gain is introduced in the circuit, usually by means of vacuum tube amplifiers, which, of course, have a definite load-carrying capacity. Also, those circuits are invariably affected by noise from external sources. Such a circuit is usually arranged so that the amplification introduced in the circuit will maintain the transmission level sufficiently high to override such noise. I have found that in such a circuit the energy levels may be better distributed and the effective carrying capacity of the amplifier more efficiently employed, with less over-all interference, if there is provided at the sending end of the circuit a certain transmission-frequency distortion, and similarly at the receiving terminal a complementary frequency distortion, both properly related to the volume-frequency characteristic of the transmitting source and the noise-frequency characteristic of the disturbance.

The invention will be clearly understood from the following description when read in connection with the attached drawings, of which Figure 1 shows schematically a voice-frequency circuit embodying the invention; Figs. 1*a*, 1*b*, 1*c* and 1*d* are graphs illustrating the method in which the invention is embodied; Fig. 2 represents schematically a radio circuit embodying the invention, and Figs. 2*a*, 2*b*, 2*c* and 2*d* are graphs illustrating the application of the invention in Fig. 2.

In Fig. 1 at terminal A, the transmitter 1 together with a substation set 2, (consisting of the ordinary substation apparatus, repeating coils, etc.), represents a transmitting source of speech frequency signals. The output of the set 2 after being transmitted through the subscriber's loop is connected with the distortion network 3 having the characteristic shown in Fig. 1*b*, the nature of which will be fully explained hereinafter. The output side of the network is connected with the amplifier 4, which in turn is connected with the 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 transmi ted signal well above the noise level of the line, thereby rendering the signal free from interference due to the noise. The line circuit 5 is connected at the receiving terminal B with the amplifier 8, which in turn is connected with a distortion network 9, the characteristic of which, as shown in Fig. 1*d*, is complementary to that of network 3. The output of the network 9 is connected with a substation set 10 for the detection of the signal which is impressed upon the receiver 11. The arrangement, representing a one-way circuit, has been used for the purpose of simplifying the description of the invention, but it is, of course, to be understood that two-way signaling may be effected by well-known means.

The manner in which the system operates in order to insure the same over-all equivalent at all frequencies is as follows: As stated hereinbefore, the volume-frequency characteristic of the subset 2 is as shown in Fig. 1*a*. This characteristic shows that the maximum volume of energy is in the neighborhood of 1,000 cycles. Furthermore, let it be assumed that the noise-producing interference has a substantially uniform distribution of energy with respect to frequency. I have found that by introducing a loss varying with frequency such as is shown in Fig. 1*b*, the output of the amplifier 4 to the line will be substantially constant for all frequencies within the desired range, such, for example, as that of speech. This loss may be produced by a network 3 having the characteristic shown in Fig. 1*b*. As the curve shows, the network produces the maximum loss at 1,000 cycles, and for frequencies higher or lower than that frequency, the loss will vary with frequency in proportion to the changes in volume, as shown in Fig. 1. The relative volume transmitted to the line, as shown in Fig. 1*c*, will be substantially constant, and the line amplifiers will be loaded to the maximum extent at all times. The frequencies remote from the point of maximum subset output will be maintained at a higher level than is practicable if the circuit is operated in the usual manner with the maximum levels limited by the carrying capacity of the repeaters for a relatively narrow frequency range, such as that in the neighborhood of 1,000 cycles. At the receiving end of such a circuit, a complementary distortion must be introduced in order to restore the transmitted signal to its original form. This is effected by a network 9 having a loss-frequency characteristic, such as is represented by Fig. 1*d*. An inspection of this figure shows a minimum loss in the neighborhood of 1,000 cycles, and greater loss for frequencies above and below that frequency. It will therefore be apparent that the energy impressed by the amplifier 8 on the network 9 will be transmitted through the latter with the various frequencies having losses represented by the characteristic 1*d*, so that the resultant wave impressed upon the subset 10 and detected thereby will have the characteristic shown in Fig. 1*a*, which is the characteristic of the transmitted signal.

The arrangement shown would also be applicable where it is desired to override a noise having a particular characteristic, as, for example, a constant single-frequency tone. In such case, the transmission distortion would be arranged to provide a particularly high gain for the interfering frequency range, and, in a complementary manner, a low receiving gain.

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 aparatus for modulation, demodulation, etc.

The arrangement shown in Fig. 2 illustrates the application of the invention to a radio transmission system. In this figure, the transmitter 1 at terminal A forms part of a substation set 2, the output of which is connected with a distortion network 3, which in turn is connected with a radio frequency transmitter 12. In this case, the transmitter is assumed to be of the "high-quality" type, producing substantially no distortion in the air waves comprising its input. The output of this transmitter is connected with the antenna 13, which radiates the high frequency signal to a receiving antenna 14 assocated with the terminal B. At this station, the antenna 14 is connected with a radio receiver 15, the output of which is connected with the subset 10, the connection including a distortion network 9. The output of the subset is connected with the receiver 11. In the system illustrated, the relative energy distribution at various frequencies of speech may be as represented in Fig. 2*a*, wherein it will be seen that the maximum energy is in the lower frequencies. By the use of a network 3 having the loss-frequency characteristic shown in Fig. 2*b*, the relative volume of the transmitter output will be substantially constant for all the transmitted frequencies, as shown in Fig. 2*c*. At the receiving terminal, the received energy is detected and impressed upon the network 9 which has a loss frequency characteristic as shown in Fig. 2*d*. As this figure shows, the greatest loss is throughout the higher frequency range. The result, therefore, is that the energy impressed upon the network will be modified thereby, and the resultant wave impressed by the subset 10 upon the receiver 11 will have the form of the transmitted wave, as shown in Fig. 2*a*.

It is obvious from the foregoing description of the use of distortion networks in circuits that the networks employed may be designed to take care also of the distortion introduced in other portions of the circuit, such as lines, antennæ, filters, etc., in order that the net over-all transmission characteristic from transmitter to receiver will be substantially flat.

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

What is claimed is:

1. The method of transmission which consists in distorting the signal wave in order to obtain approximately the same level for all frequencies within said wave and introducing a compensating distortion at the receiving end.

2. In a transmission system, the combination with a translating device having a definite load limit, of means for distorting the signal wave to be impressed upon said device in order to bring the level of each frequency of said wave up to the maximum level for the apparatus included in the system.

3. In a signal transmission system the combination with a transmitting station of a receiving station, a medium connecting the said stations, the said transmitting station comprising means to create a signal, and means to distort the said signal to ensure a practically uniform amplitude for all frequencies present in the said signal, and the said receiving station comprising means to introduce a complementary distortion in the received signal impulse to restore the impulse to the same form possessed by it prior to transmission.

4. In a signal transmission system the combination with a source of energy the volume of which varies with frequency, of a transmission medium over which the energy is to be transmitted, an amplifier connected between the said source and the said medium, a distorting network connected between the said source and the said amplifier to introduce a loss in the transmitted energy, which loss varies with frequency directly with the variations in volume as created by the said source, another distorting network also connected with the said medium to introduce a loss in the energy as received, which loss varies with frequency inversely with the variations of the loss produced by the said first mentioned distorting network, thereby restoring to the said energy the wave form possessed by it at the said source.

5. The method for maintaining the overall transmission equivalent of a signal circuit substantially the same for all frequencies within the range transmitted, which consists in distorting the signal prior to transmission so that the volume of energy for each frequency will be the same, transmitting the signal as thus distorted, and distorting at the receiving end of the system by introducing such losses as are necessary to restore the signal energy to the form possessed by it prior to its distortion before transmission.

6. The method for maintaining the overall transmission equivalent of a signal circuit substantially the same for all frequencies within the range transmitted, which consists in distorting the signal prior to transmission so that the volume of energy for each frequency will be the same, introducing a loss into the circuit at its transmitting end, which loss varies with frequency directly with the variation of the volume of energy with frequency, amplifying and transmitting the signal as thus modified, receiving the signal and introducing a loss into the said circuit at the receiving end, which loss varies with frequency inversely with the corresponding loss variations at the transmitting end of the said circuit.

7. The method for maintaining the over-all transmission equivalent of a signal circuit substantially the same for all frequencies within the range transmitted, which consists in creating a signal comprising a band of frequencies, the volume of energy of which varies with frequency, distorting the said signal by introducing a loss which varies with frequency directly with the variation of the relative volume of energy of the signal at its source with frequency, amplifying and transmitting the said energy, receiving the said energy and distorting it by introducing a loss which varies with frequency inversely with the loss variations in the first mentioned distortion step, whereby the signal energy is restored to the form possessed by it at its creation, and detecting the signal as thus restored.

8. In an electrical transmission system, the combination with a translating device having a fixed load limit, of a source of oscillations connected with said device, capable of simultaneously producing a plurality of frequencies, and means interposed between said device and said source to substantially equalize the energy level of all frequencies impressed by the source upon said device.

9. In an electrical transmission system, the combination with a transmission circuit for transmitting electrical waves having therein a translating device through which electrical energy may be passed at a fixed level without distortion of the electrical waves, of a source of oscillations of a plurality of frequencies and means connecting said source to the said transmission circuit to substantially equalize the energy level of the oscillations applied by the source to the transmission circuit.

10. The method of operating an electrical transmission system having therein a device having a fixed load limit, which consists in generating oscillations of a plurality of frequencies, equalizing the energy level of said oscillations and simultaneously impressing upon a transmission circuit the oscillations of all frequencies as thus equalized for transmission thereover.

11. The method of operating an electrical transmission system having therein a translating device having a fixed limit for the

transfer of energy without distortion, which consists in creating a signaling wave containing a plurality of frequencies, equalizing the energy level of all frequencies of said wave, and impressing the frequencies as thus equalized upon the translating device for transmission over said system.

In testimony whereof, I have signed my name to this specification this 23rd day of May, 1927.

HERMAN A. AFFEL.