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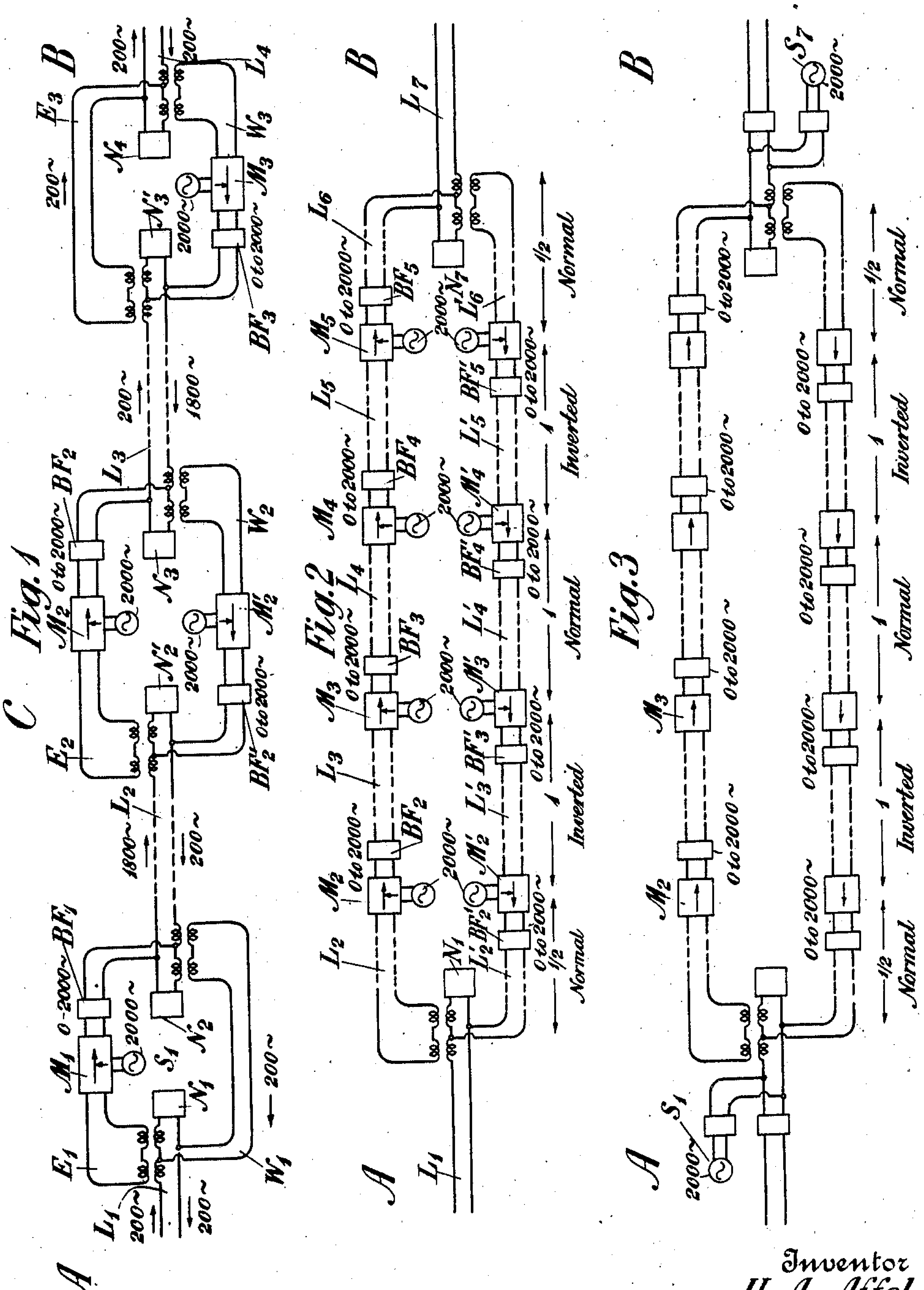

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UNITED STATES PATENT OFFICE.

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MEANS FOR AND METHOD OF EQUALIZING ATTENUATION.

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To all whom it may concern:

Be it known that I, HERMAN A. AFFEL, residing at Brooklyn, in the county of Kings and State of New York, have invented certain Improvements in Means for and Methods of Equalizing Attenuation, of which the following is a specification.

This invention relates to the transmission of alternating currents for signalling or other purposes, and more particularly to the equalization of the attenuation of the currents transmitted over a circuit at different frequencies.

It is a well known fact that when variable currents such as telephone or telegraph currents are transmitted over a long conductor, distortion occurs owing to the difference in the attenuation of the different frequencies involved in the transmission, the higher frequencies being subjected to greater attenuation than the lower frequencies. This is particularly undesirable in the case of telephone transmission, as good quality of speech transmission requires that the wave form of the signal initiated at one end of the line must be maintained at the receiving end, and when the distortion becomes serious, the transmission tends to become unintelligible. In accordance with the present invention it is propesed to overcome this difficulty by transmitting the telephone or other signalling band in its normal condition over one half of the entire length of a transmission system, and transmitting the band inverted over the other half of the system. In other words, over one half of the circuit the voice band is transmitted in such a manner that the frequency relations of the band are normal, while over the other half of the circuit the frequency relations are inverted so that the higher frequencies of the voice band become low frequencies, and the lower frequencies become high frequencies. The half of the total system over which the voice currents are transmitted at their normal frequencies gives the usual rising frequency-attenuation curve; the second half of the system has a similar frequency-attenuation characteristic but the frequency band, being reversed, in effect reverses the attenuation curve itself. For example, if a frequency of 2,000 cycles in the normal portion of the system is translated to 200 cycles in the inverted portion, the total attenuation suffered by the 2,000 cycle component is the same as that suffered by a 200 cycle component, which in the inverted half of the system appears as 2,000 cycles.

In order to invert the band when desired and to restore it to normal for receiving purposes, advantage is taken of the principle of modulation whereby as a result of modulating a carrier frequency by a transmission band, two side bands will result on either side of the carrier, each side band having the same width as the transmission band, and one side band having the same frequency relations as the original bands, but the other side band having the frequency relations reversed. If the carrier be so chosen as to correspond to the upper frequency of the normal voice band, the lower side band resulting from modulation will be reversed with respect to the normal voice band, but will occupy the same frequency range.

The invention may now be more fully understood by referring to the following detailed description when read in connection with the accompanying drawing, Figures 1, 2 and 3 of which represent three schematic embodiments of the invention.

Referring to Figure 1, L_1 and L_4 designate telephone circuits, incoming to stations A and B, to which voice currents or other signalling currents may be applied for transmission between stations A and B, said stations being interconnected by line sections L_2 and L_3, over which it is desired to equalize the attenuation. In order to equalize the attenuation the circuit is so arranged that in transmitting from station A to station B, the frequency relations of the voice band will be inverted in transmitting over the line section L_2, but will be restored to their normal condition for transmission over the line section L_3. In transmitting from station B to station A, the frequency relations will be inverted in transmitting over the line section L_3 and restored to normal condition in transmitting over the line section L_2.

In order to invert the transmission band for transmission from station A over the line section L_2, the line section L_1 is associated with the line section L_2 at the station A through a circuit arrangement having the general form of a 22 repeater circuit, comprising channels E_1 and W_1, the channel E_1 being used for transmission from west to east, and the channel W_1 from east to west. The channel E_1 is provided with a modulating apparatus M_1 which may be of any well known type, such as for example, a vacuum tube modulator. The modulator is supplied with a carrier frequency from a source S_1 having in the assumed case a frequency of 2,000 cycles per second, it being assumed that the voice band extends from the lower limit of zero cycles to an upper limit of 2,000 cycles. The band filter BF_1 is included in the output circuit of the modulator, and this band filter is arranged to select the lower side band resulting from modulation. For this purpose, the band filter is designed to have an upper cut-off frequency of 2,000 cycles. It will be understood, of course, that the line sections L_1 and L_2 will be balanced in the usual manner by means of artificial lines or networks N_1 and N_2.

Similarly at station B a 22 circuit having channels E_3 and W_3 is provided for interconnecting the line sections L_3 and L_4 and inverting the band transmitted from east to west. The line sections L_3 and L_4 are balanced with respect to these channels by means of networks N_3' and N_4 respectively, and the channel W_3 is provided with a modulating arrangement M_3 and a band filter BF_3 similar to the modulating apparatus and band filter in the channel E_1 at station A.

At an intermediate point C a 22 form of circuit organization is arranged to interconnect the line sections L_2 and L_3 for the purpose of reinverting the inverted bands transmitted to this point from the terminal stations so that the bands may be transmitted from this point to the terminal stations in the normal frequency relation. The circuit organization at station C comprises channels E_2 and W_2, connected as indicated, the artificial lines or networks N_2' and N_3 being provided to balance the line sections L_2 and L_3. Modulating apparatus M_2 and M_2' is included in the channels E_2 and W_2 respectively, this apparatus being similar to the modulating apparatus already described. Band filters BF_2 and BF_2' are also included in the output circuits of the modulators, these band filters being similar to the band filter at station A.

Further details of the apparatus will be acquired from the description of the operation, which is as follows: Assuming that a band of voice currents is to be transmitted from the station A to the station B, the band of frequencies will pass from the line section L_1 into the channel E_1 to modulate the carrier frequency of 2,000 cycles, which coincides with the upper limit of the voice band. In order to understand the operation more clearly the processes to which one frequency in the voice range is subjected in passing from station A to station B will be considered. A frequency of 200 cycles, for example, in passing into the modulator M_1 modulates the carrier frequency of 2,000 cycles to produce frequencies of 1,800 cycles and 2,200 cycles. The upper frequency is eliminated by the band filter BF_1 and the lower frequency of 1,800 cycles passes to the line section L_2 and over said line section into the channel E_2 at station C. It will be observed that during transmission over the line section L_2 the frequency relations are inverted and the frequency of 200 cycles which normally lies near the lower side of the voice band is translated to 1,800 cycles, which is correspondingly near the upper limit of the voice band. When the 1,800 cycle frequency passes into the modulator M_2 at station C it modulates the carrier frequency of 2,000 cycles to produce frequencies of 200 cycles, and 3,800 cycles respectively. The upper of these two frequencies is eliminated by the band filter BF_2 and the 200 cycle frequency, which it will be noted is now restored to normal condition, is transmitted over the line section L_3 and passes through the channel E_3 to the line section L_4 at station B. It will be readily apparent that the voice band was inverted during transmission over the line section L_2 and was reinverted and transmitted over the line section L_3 in normal condition, so that on the average all frequencies were subjected to substantially the same attenuation.

The transmission from station B to station A is similar to that already described. A frequency of 200 cycles incoming from the line section L_4 passes through the modulator M_3, is translated to a frequency of 1,800 cycles and after transmission over the line section L_3 is translated by the modulator M_2' to the normal frequency of 200 cycles, which in turn is transmitted over the line section L_2 and through the channel W_1 to the line section L_1.

Figure 4 indicates schematically an arrangement for obtaining the same result by means of a four-wire circuit extending between station A and B. For transmission from west to east, the line sections L_1 and L_7 at stations A and B respectively are interconnected by a transmission line comprising sections L_2, L_3, L_4, L_5 and L_6 and for transmission in the opposite direction the terminal line sections are interconnected by a line circuit comprising sections L_2', L_3', L_4', L_5' and L_6'. Between sections L_2 and L_3 a band inverting apparatus is provided comprising a modulator M_2 and a band filter BF_2, similar to the modulators and band filters already described. Similar band inverting apparatus is provided between each of the other line sections used in transmitting from west to east, and the circuit used in transmitting from east to west is also provided with band inverting apparatus at the junction point of each line section. The circuit as thus arranged will result in normal transmission over the line sections marked "Normal" and inverted transmission over the line sections marked "Inverted." If line sections L_2 and L_2' as well as line sections L_6 and L_6', are made of one-half the length of the other line sections, the other line sections being made of equal length, it will be apparent that the telephone band will be transmitted inverted over one-half of the distance between A and B and will be transmitted normal during the other half. The same result may, of course, be obtained by making the line sections unequal, but in this case it is desirable that the total lengths of the sections transmitting the band inverted be substantially equal to the total lengths of the sections transmitting the band in normal condition.

Assuming a band of telephone frequencies incoming from the line L_1 is to be transmitted to station B, the band will be transmitted over the half line section L_2 where, by modulating with a carrier frequency of 2,000 cycles, and by suppressing the upper side band, the band will be inverted for transmission over the section L_3. The inverted band, by means of the modulator M_3 and band filter BF_3 will in turn be reinverted and transmitted in normal frequency relations over the section L_4. It is again inverted by the apparatus M_4 and BF_4 and transmitted with the frequencies in inverse relation over the section L_5, after which it is restored to normal by the modulator M_5 and the band filter BF_5 and transmitted in normal condition to the line L_7. The transmission in the opposite direction is similar, the band being transmitted in normal condition over the line section L_6', inverted and transmitted over the line section L_5', reinverted and restored to normal for transmission over the line L_4', again inverted for transmission over the line section L_3', and finally restored to normal for transmission over the line section L_2'.

A somewhat similar arrangement is illustrated in Fig. 3, this figure differing from that of Fig. 2, however, in that the carrier frequency, instead of being supplied locally at each modulating point, is transmitted along with the telephone band or inverted band, as the case may be; for example, for transmission from west to east the carrier frequency is supplied at the terminal station A from a source S_1 and is transmitted with the normal band to the modulator M_2, where the telephone band modulates with the carrier frequency to invert the band in the same manner as in the case of Fig. 2. The modulating apparatus must in this instance be of a type which does not suppress the carrier, whereas in the case of Fig. 2, the modulator may be of the carrier suppression type illustrated and described, for example, in Carson Patent 1,343,307, issued June 15, 1920. From modulator M_2 to modulator M_3 the inverted side band is transmitted with the carrier and the modulator M_3 in conjunction with the associated band filter, reinverts the telephone band and restores it to normal. The further transmission of the carrier and the telephone band over the circuit will be readily apparent without further description. In transmitting from east to west, the carrier will be supplied by the source S_7 at station B and transmitted with the normal or inverted side band as the case may be, just as described in connection with transmission from west to east.

It will be evident that the method above described involves a form of carrier system. For the sections in which the band is inverted the carrier or reference frequency is an alternating current whose frequency coincides with the upper limit of the telephone or signalling band, while in sections in which the band is transmitted normal, the carrier or reference frequency is a zero frequency. In inverting the telephone band, it will be advantageous ordinarily to keep it as low in frequency as possible, thereby causing the inverted band to occupy substantially the same position in the broad frequency range as does the normal band. It will be evident, however, that the inverted band may be made to occupy any position in the broad frequency range and that in fact both the inverted and non-inverted bands may be bands of ordinary carrier channels.

In other words, the scheme described is applicable also in ordinary carrier transmission, although attenuation equalization is not in general as essential for carrier channels as it is for channels operated at ordinary signalling frequency. Very long carrier circuits may, however, warrant inverting the band for equalization purposes. A convenient way of inverting the carrier bands obtains in a system employing opposite side bands referred to the carrier frequency for transmission east and west respectively. For example, if the common carrier is 10,000 cycles, and one channel operates on the upper band up to 12,000 cycles, and the oppositely directed channel operates on the lower band down to 8,000 cycles, these bands may be readily interchanged at a repeater point by being modulated in a common modulator, if desired, with 10,000 cycles.

It will be understood that in the previous description the various frequencies referred to, and the apparatus described, is for purposes of illustration only, and the invention is applicable to other frequency ranges and relations, and the method may be performed with other forms of apparatus than those referred to in the description and illustrated in the drawing.

It will also be obvious that the general principles herein disclosed may be embodied in many other organizations widely different from those illustrated without departing from the spirit of the invention as defined in the following claims.

What is claimed is:

1. The method of equalizing the attenuation of a band of frequencies transmitted over a transmission system which consists in subjecting the band to attenuation variable with frequency in a given manner during transmission over a part of the system, and subjecting the band to attenuation varying with frequency in a complementary manner during transmission over the remainder of the system.

2. The method of equalizing the attenuation of a band of frequencies transmitted over a transmission system which consists in transmitting the band in normal frequency relation over a portion of the system, and transmitting the band in an inverted frequency relation and in the same frequency range over the remainder of the system.

3. The method of equalizing the attenuation of a band of frequencies transmitted over a transmission system which consists in transmitting the band over a portion of the system in normal condition, modulating the band with a carrier frequency, thereby producing side bands, selecting the lower side band which corresponds to the original band inverted, and trasmitting the inverted band over another portion of the system.

4. The method of equalizing the attenuation of a band of frequencies transmitted over a transmission system which consists in transmitting the band over a portion of said system in normal condition, modulating the band with a carrier frequency in the neighobrhood of the upper limit of the band, selecting the lower resultant side band which corresponds to the original band with frequencies inverted and transmitting the inverted band over another portion of the system.

5. A system for the equal attenuation of a band of transmitted frequencies comprising a system of conductors over which the band is transmitted in normal frequency relation, means for inverting the frequency relation of the band, and applying it to a similar system of conductors so that it will be transmitted over the second system of conductors in inverted frequency relation.

6. A system for the equal attenuation of a band of transmitted frequencies comprising a system of conductors over which the band may be transmitted in normal frequency relation, means for modulating the band in accordance with a carrier frequency, thereby producing side bands, means to select the lower side band corresponding to the original band in inverted frequency relation, and to impress said inverted band upon a second similar system of conductors, whereby the band may be transmitted over the second system of conductors in inverted frequency relation.

7. A system for the equal attenuation of a band of transmitted frequencies comprising a system of conductors over which a band of frequencies may be transmitted in normal frequency relation, means for modulating said band of frequencies with a carrier whose frequency corresponds substantially to the upper limit of the transmitted band, thereby producing side bands, means for selecting the lower side band corresponding to the original band in inverted frequency order and impressing said inverted band upon a second similar system of conductors, so that the band may be transmitted over said second system of conductors in inverted frequency relation.

8. The method of compensating for the distortion in wave shape produced by transmitting a band of signaling frequencies over a transmission system, which consists in transmitting the signaling frequencies in normal frequency relation over a portion of the circuit to produce distortion of one character and transmitting said frequencies in inverted frequency relation and in the same frequency range over the remainder of the system to produce distortion of a complementary character.

9. A system for compensating the distortion resulting from the transmission of a band of signaling frequencies over a transmission system, said system comprising conductors over which the currents are transmitted in normal frequency relation to produce distortion of one character, and means for inverting the frequency relation of the signaling currents and applying them to a similar system of conductors so that distortion of a complementary character with be produced in transmitting them over the second system of conductors.

In testimony whereof, I have signed my name to this specification this 31st day of May, 1921.

HERMAN A. AFFEL.