Dec. 17, 1929. C. W. GREEN 1,739,668

TRANSMISSION SYSTEM

Filed Aug. 31, 1926

Fig. 1.

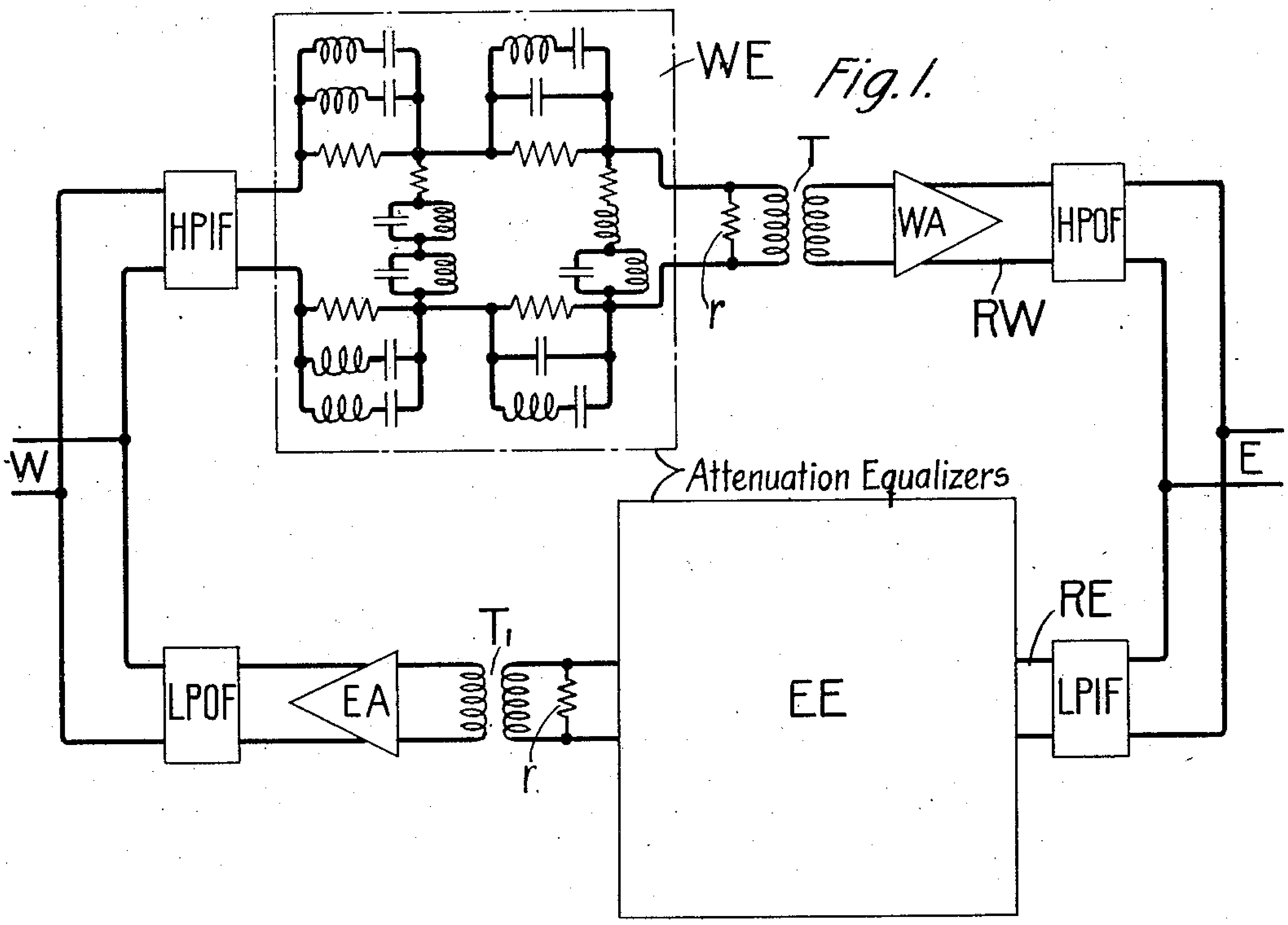


Fig. 2.

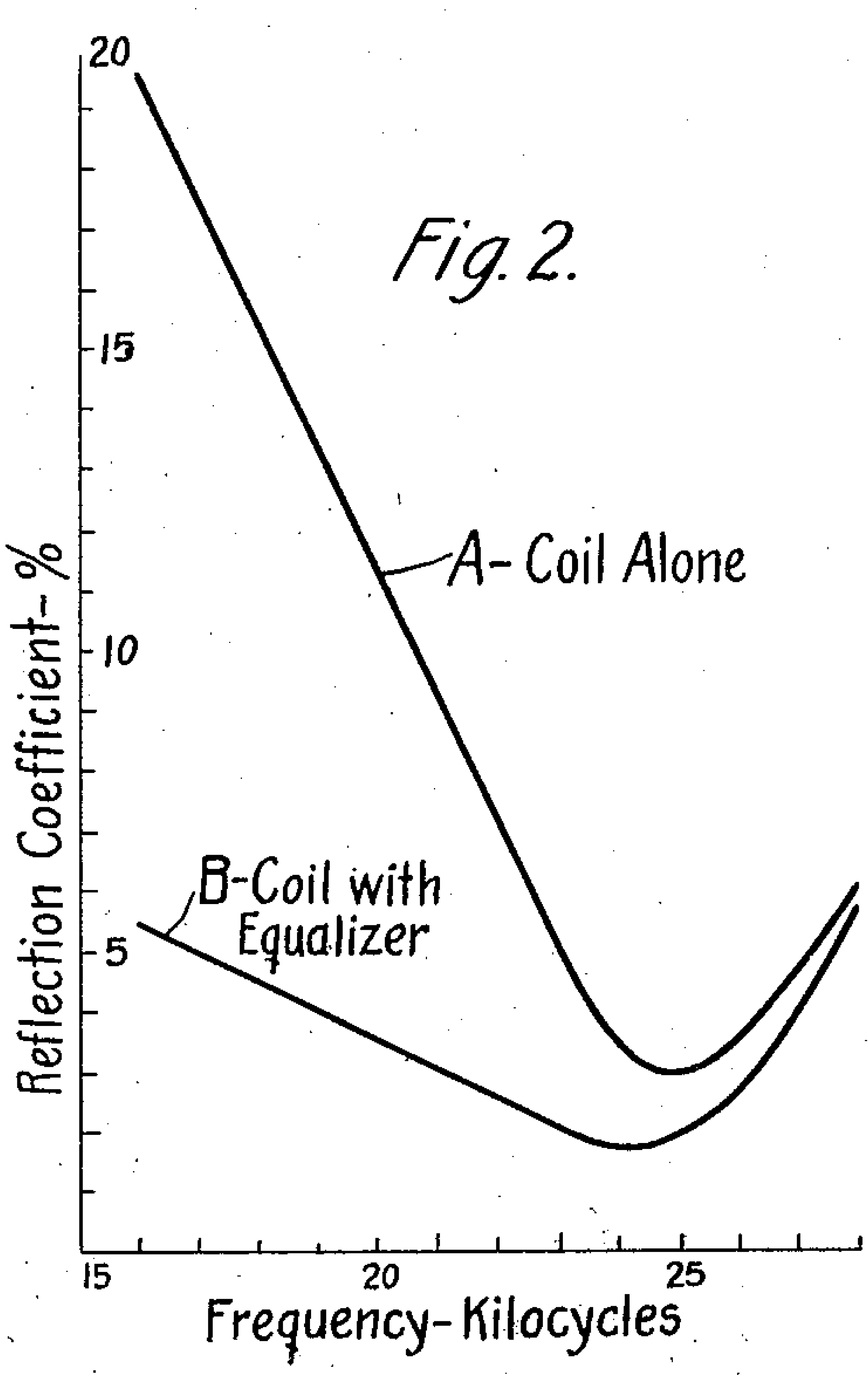


Fig. 3ª

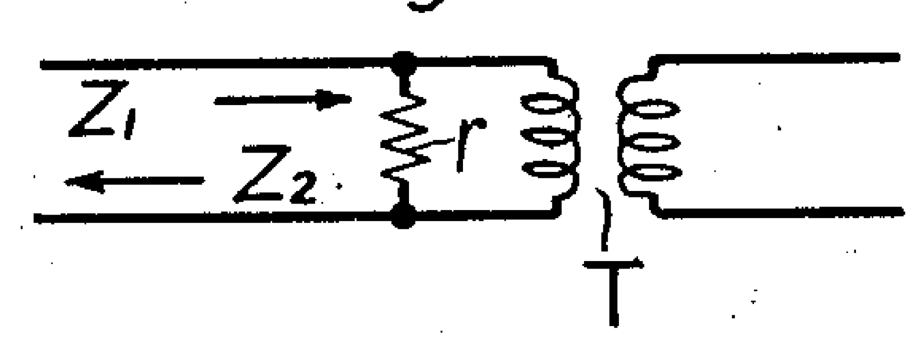
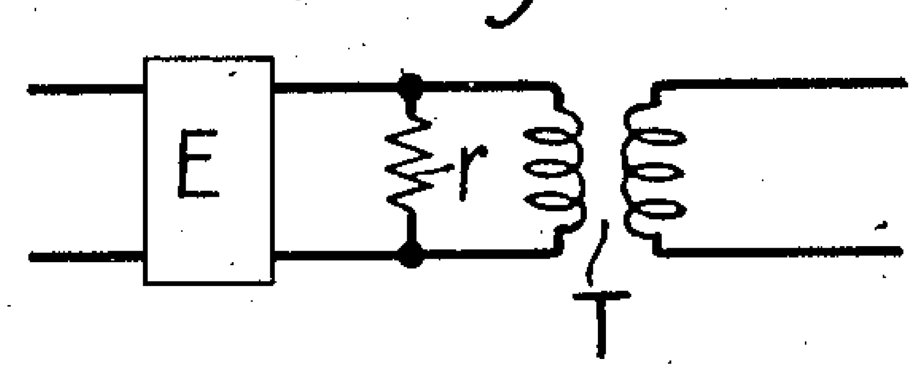


Fig. 3ᵇ



Inventor:
Charles W. Green.
by W. Griggs Attorney.

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UNITED STATES PATENT OFFICE

CHARLES W. GREEN, OF MILLBURN, NEW JERSEY, ASSIGNOR TO BELL TELEPHONE LABORATORIES, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK

TRANSMISSION SYSTEM

Application filed August 31, 1926. Serial No. 132,670.

This invention relates to transmission systems, and particularly to carrier current signaling systems.

An object of the invention is to reduce reflection effects such as are commonly due to impedance irregularities in electric signaling systems.

A related object of the invention is to repeat a plurality of waves of different frequencies efficiently and without substantial reflection.

The invention is particularly adapted for use in multiplex carrier current telephone and telegraph systems, where several conversations or messages in the form of modulated carrier waves are transmitted in both directions over a common transmission line.

When the waves in traversing the line meet an impedance irregularity, portions of the waves are reflected back over the line. Such reflection usually occurs at translating devices which are connected to the line but do not accurately match the impedance of the line. The reflected waves set up cross-talk in adjacent paralleling lines, thus interfering with the normal transmission of signals thereover.

According to this invention reflection is materially reduced by means of an attenuation network which is so situated and proportioned with respect to the device causing reflection that the reflected waves are greatly attenuated.

It is well known that in systems of this type, particularly those employing long transmission lines, the waves of higher frequencies are more greatly attenuated in traversing the line than the waves of lower frequencies. It is therefore customary to employ attenuation equalizers to compensate for the unequal attenuation of the carrier waves. At carrier current repeaters, for example, it is customary to connect the repeater amplifier to the incoming line by means of an attenuation equalizer and a repeating coil which is designed to have substantially the same high voltage transformation ratio at all frequencies within the transmitted band. However, in designing the repeating coil to have the desired high voltage transformation ratio over a wide band of frequencies, it has been found that the characteristic impedance of the repeating coil does not match the impedance of the incoming line at all the transmitted frequencies. It is evident, therefore, that reflection will occur at that part of the frequency scale where the impedance of the repeating coil does not accurately match the impedance of the incoming line. Reflection often occurs at that part of the frequency scale where the attenuation of the equalizer is lowest, and hence reflected waves are readily transmitted through the equalizer to the transmission line.

According to a feature of this invention the impedance of the repeating coil is made of the proper value to terminate the incoming line at that part of the frequency range at which the equalizer loss is lowest, namely, at the higher frequencies, so that no reflection will occur at the higher frequencies. Then, even though reflection occurs at other frequencies, the reflected waves are highly attenuated by traversing the equalizer twice, thus reducing the reflection coefficient to a minimum for a desired maximum coil step-up ratio.

The features and advantages of the invention will be described in connection with the accompanying drawing, in which:

Fig. 1 is a diagrammatic illustration of a two-way amplifying repeater embodying the invention;

Fig. 2 shows curves illustrating the reduction in the reflection coefficient obtainable by means of the invention; and

Figs. 3^a and 3^b are circuit diagrams used in conjunction with the curves of Fig. 2 in describing the invention.

The two-way repeater of Fig. 1 comprises two one-way repeating channels RW and RE adapted to connect transmission line sections W and E. This repeater is of the general type disclosed in U. S. Patent No. 1,413,357 to P. A. Raibourn, issued April 18, 1922.

The currents incoming at the repeater from line section W are amplified in the channel RW and the amplified currents are delivered to the line section E. Similarly, the currents incoming from line section E are amplified in the channel RE and the amplified currents are delivered to line section W.

The currents incoming from the line section W are of higher frequencies than those incoming from line section E. Accordingly, the respective repeater channels are provided with frequency discriminating filters which direct the incoming currents to the proper channels. The repeater channel RW includes a high pass input filter HPIF, an amplifying structure WA and a high pass output filter HPOF. The repeater channel RE includes a low pass input filter LPIF, an amplifying structure EA and a low pass output filter LPOF.

The directional filters HPIF and HPOF are designed to transmit currents of the upper group of frequencies to be repeated by the amplifying structure WA and to suppress from transmission currents lower frequencies, while the directional filters LPIF and LPOF are designed to transmit currents of the lower group of frequencies to be repeated by the amplifying structure EA and to suppress currents of higher frequencies. These filters may be of the type disclosed in U. S. Patent No. 1,227,113 to G. A. Campbell issued May 22, 1917.

Since the attenuation of the transmission line sections W and E is a function of frequency, the carrier currents incoming at the repeater will vary in magnitude corresponding with the attenuation of the line section which they have traversed. When these currents are repeated into a succeeding line section the variation in magnitude at the receiving end of the second line section is proportionally much greater than for the first line section, and hence equalizers are usually employed at the repeater to equalize or compensate for the unequal attenuation of the incoming carrier currents.

In the channel RW, an attenuation equalizer WE is connected to the high pass input filter HPIF to equalize the differences of line attenuation at the upper group of carrier frequencies transmitted from west to east. The equalizer WE is coupled to the input circuit of the amplifier WA by means of a repeating coil T. Similarly, an attenuation equalizer EE is connected to the low pass input filter LPIF in the channel RE, this equalizer being connected to the input circuit of the amplifier EA by means of a repeating coil T_1. The equalizers WE and EE have transmission loss characteristics which are substantially complemental to the transmission loss characteristics of line sections W and E, respectively, so that all the waves in the output of each repeater channel will be at substantially the same transmission level. The equalizers WE and EE may be of the type disclosed in U. S. Patent No. 1,591,073, issued July 6, 1926, to O. J. Zobel, having a constant resistance characteristic impedance, and are designed to have the proper impedance to terminate the filters HPIF and LPIF, respectively.

In order to obtain the desired high gain at all the frequencies assigned to the channel RW, for example, the repeating coil T is designed to have the same high voltage transformation ratio at such frequencies. Similar conditions apply to the design of the repeating coil T_1 in the channel RE. In one specific instance, a repeating coil employed for this purpose was designed to have a voltage step-up ratio of 1:11. When the repeating coils are designed to have a high voltage transformation ratio over a wide band of frequencies, it has been found impossible at the same time to give the coils a characteristic impedance suitable for terminating the respective input filters, that is, a characteristic impedance which is constant with frequency. Accordingly, waves of certain frequencies will meet an impedance irregularity in the repeating coils T and T_1 and a portion of these waves will be reflected.

According to the invention the repeating coils T and T_1 are each designed to have the proper impedance for terminating the input filter to which it is connected at that part of the frequency band at which the equalizer is practically transparent, that is, at the higher frequencies. If, then, the coil impedance differs from what it should be at the other frequencies, any reflection introduced by the repeating coil due to impedance mismatching is reduced by the relatively high loss in the equalizer. This is due to the fact that the reflected waves must traverse the equalizer twice, whereas the signal traverses the equalizer but once, so that the reflected waves are highly attenuated. High resistance elements r and r_1 are connected in shunt to the primary windings of repeating coils T and T_1, respectively, to make the impedance of the coils correct to a first approximation.

Figs. 2, 3^a and 3^b illustrate how, by properly designing the impedance of a repeater input coil, the overall reflection coefficient considered as a function of frequency is reduced to a minimum for a desired maximum coil step-up ratio.

When a wave in traversing a circuit such as that shown in Fig. 3^a meets a change in impedance in the repeating coil T such that looking one way the impedance is Z_1 and looking the other way the impedance is Z_2, reflection of the wave occurs. The coeffiecient of reflection R is represented by

$$\left|R\right| = \left|\frac{Z_1 - Z_2}{Z_1 + Z_2}\right|$$

The coefficient of reflection under these conditions, when no loss element is employed in the circuit, is high, as shown by the curve A of Fig. 2.

When, as shown in Fig. 3^b, a loss element

E is inserted in the circuit between the line and the point where some reflection is to take place, the advantage gained from the reflection reducing standpoint at any frequency varies as twice the loss through the inserted element at that frequency. Thus,

$$\frac{|R| \text{ with equalizer}}{|R| \text{ with coil alone}}$$

varies as twice the loss through the equalizer. The coefficient of reflection when the equalizer E is employed between the line and the repeating coil T is materially reduced, as shown by the curve B of Fig. 2. In an actual installation a 3½ fold improvement in reflection coefficient has been obtained by means of this invention with the same repeater gain as has been obtained heretofore. Looking at the advantage of the invention from another viewpoint, if the same reflection coefficient heretofore obtained is not objectionable in certain installations, the gain can be increased materially by means of the invention, without changing the reflection coefficient.

While the invention has been described as applied to a repeater for use in multiplex carrier current signaling systems, it is evident that it may also be used in other situations and in other types of systems.

What is claimed is:

1. In a system for transmitting waves of different frequencies, a transmission line, means associated with said line causing waves of certain selected frequencies to be reflected, and a loss element between said line and said means to attenuate all of said reflected waves, said loss element having its highest transmission loss characteristics at the frequencies of said reflected waves and a lower loss at the other frequencies transmitted.

2. In a system for transmitting waves of different frequencies, a transmission line, means comprising a transformer associated with said line causing waves of certain selected frequencies to be reflected, said transformer having a high voltage transformation ratio substantially constant over the range of frequencies transmitted and a loss element in the path of said reflected waves, said loss element having its highest transmission loss characteristic at the frequencies of said reflector waves and a lower loss at the other frequencies transmitted.

3. In a system for transmitting waves of different frequencies, a transmission line, means associated with said line causing waves of certain selected frequencies to be reflected, and a loss element associated with said line and arranged to produce a greater loss for all the reflected waves than for the waves which are transmitted without reflection.

4. In a system for transmitting waves of different frequencies, a line over which said waves of different frequencies are received, means for reducing reflection effects due to impedance irregularities including a circuit comprising an electrical network upon which said waves are impressed, said circuit having a transmission loss characteristic which is high at certain frequencies and low at other frequencies, and a translating device comprising a transformer having a high voltage transformation ratio substantially constant over the range of frequencies transmitted connected to receive the waves from said circuit and having the same impedance as said circuit at frequencies at which said circuit has a low transmission loss and a different impedance at the other frequencies transmitted.

5. In a system for transmitting waves of different frequencies, a line over which said waves of different frequencies are received, means for reducing reflection effects due to impedance irregularities including a circuit comprising an electrical network upon which said waves are impressed, said circuit having a transmission loss characteristic which is high at certain frequencies and low at other frequencies, and a translating device connected to receive the waves from said circuit and having an impedance which varies throughout the range of transmitted frequencies but accurately matches the impedance of said circuit at the frequencies at which said circuit has a low transmission loss.

6. In a system for transmitting waves of different frequencies, a line over which said waves of different frequencies are received, means for reducing reflection effects due to impedance irregularities including a circuit comprising an electrical network upon which said waves are impressed, said circuit having a transmission loss characteristic which is high at certain frequencies and low at other frequencies, and means connected to receive the waves from said circuit comprising a repeating coil having a high transmission efficiency at all of said frequencies and having approximately the same impedance as said circuit at frequencies at which said circuit has a low transmission loss and a different impedance at the other frequencies transmitted.

7. In a system for transmitting waves of different frequencies, a line over which said waves of different frequencies are received, means for reducing reflection effects due to impedance irregularities including a circuit comprising an electrical network upon which said waves are impressed, said circuit having a transmission loss characteristic which is high at certain frequencies and low at other frequencies, and a repeating coil connected to receive the waves from said circuit and having substantially the same voltage transformation ratio at all of the transmitted frequencies, said repeating coil having an impedance which varies throughout the range of transmitted frequencies but matches the

impedance of said circuit at the frequencies at which said circuit has a low transmission loss.

8. In a wave transmission system employing waves of different frequencies, a line the transmission loss of which differs for different frequencies, an attenuation equalizer associated therewith and having a transmission loss characteristic substantially complemental to that of the line throughout the range of frequencies transmitted, and a translating device connected to said equalizer and having an impedance which matches the impedance of said line and equalizer only in the upper region of the transmitted frequencies.

9. In a wave transmission system employing waves of different frequencies, a line the transmission loss of which differs for different frequencies, an attenuation equalizer associated therewith and having a transmission loss characteristic substantially complemental to that of the line throughout the range of frequencies transmitted, an amplifier, and a transformer connecting said attenuation equalizer and amplifier and having an impedance which varies throughout the range of frequencies transmitted but matches the impedance of said equalizer at frequencies at which said attenuation equalizer has a low transmission loss.

10. In a wave transmission system, a line over which signaling waves are transmitted, a translating device from which waves of certain selected frequencies are reflected, and a loss element arranged to be traversed by the reflected waves a greater number of times than by said signaling waves, the loss introduced by said element being substantially proportional to the amount of reflection at the different frequencies.

11. In a system for transmitting waves of different frequencies, a transmission line, a repeater associated with said line and comprising a frequency discriminating filter, an amplifier and a repeating coil connecting said amplifier to said filter, and a loss element between said filter and said repeating coil having a transmission loss characteristic which is high at certain frequencies and low at other frequencies, said repeating coil having an impedance which varies throughout the range of frequencies transmitted by said filter but matches the impedance of said filter at frequencies at which said loss element has a low transmission loss.

12. The method of reducing cross-talk in signaling circuits which comprises reducing the reflection of waves in the upper region of the transmitted frequencies to a greater extent than in the lower region, attenuating reflected waves in said circuits a greater number of times than the effective signaling currents therein and attenuating the reflected waves in the lower region of the transmitted frequencies to a greater extent than in the upper region.

13. In a system for transmitting waves of different frequencies, a line the attenuation of which differs with the frequency of the transmitted waves, an attenuation equalizer connected to said line for variably attenuating the waves of the different frequencies in an inverse relation to the attenuation produced by said line, and a repeating coil connected to said equalizer, said coil having its impedance matched to that of the incoming circuit comprising the line and equalizer at the frequencies at which said equalizer has the lowest attenuation and mismatched at other frequencies, said repeating coil having its voltage ratio substantially constant over the range of frequencies transmitted and as high as is consistent with the permissible extent of mismatching of the impedance of said repeating coil with respect to the impedance of the incoming circuit, as determined by a substantially constant and negligibly small amount of reflection appearing on the line side of said equalizer throughout the transmitted range.

14. The method of reducing reflection effects due to impedance irregularities in a system for transmitting waves of different frequencies which comprises attenuating the waves in an inverse relation with respect to frequency, reflecting waves in the lower region of the transmitted frequencies to a greater degree than the other waves transmitted, and attenuating certain reflected waves after reflection in an inverse relation with respect to frequency.

15. The method of securing a high voltage transformation ratio over a wide band of frequencies without substantial reflection effects in a repeater for a system transmitting waves of different frequencies which comprises attenuating the waves in an inverse ratio to the line attenuation, making the reflection of waves a minimum in the region of the transmitted frequencies at which the line attenuation is high and attenuating the waves of other frequencies after reflection in an inverse ratio to said line attenuation.

In witness whereof, I hereunto subscribe my name this 30th day of August A. D., 1926.

CHARLES W. GREEN.