Nov. 16, 1926. 1,606,795

K. S. JOHNSON ET AL

MULTIPLEX SIGNALING

Filed Jan. 11, 1924 2 Sheets-Sheet 1

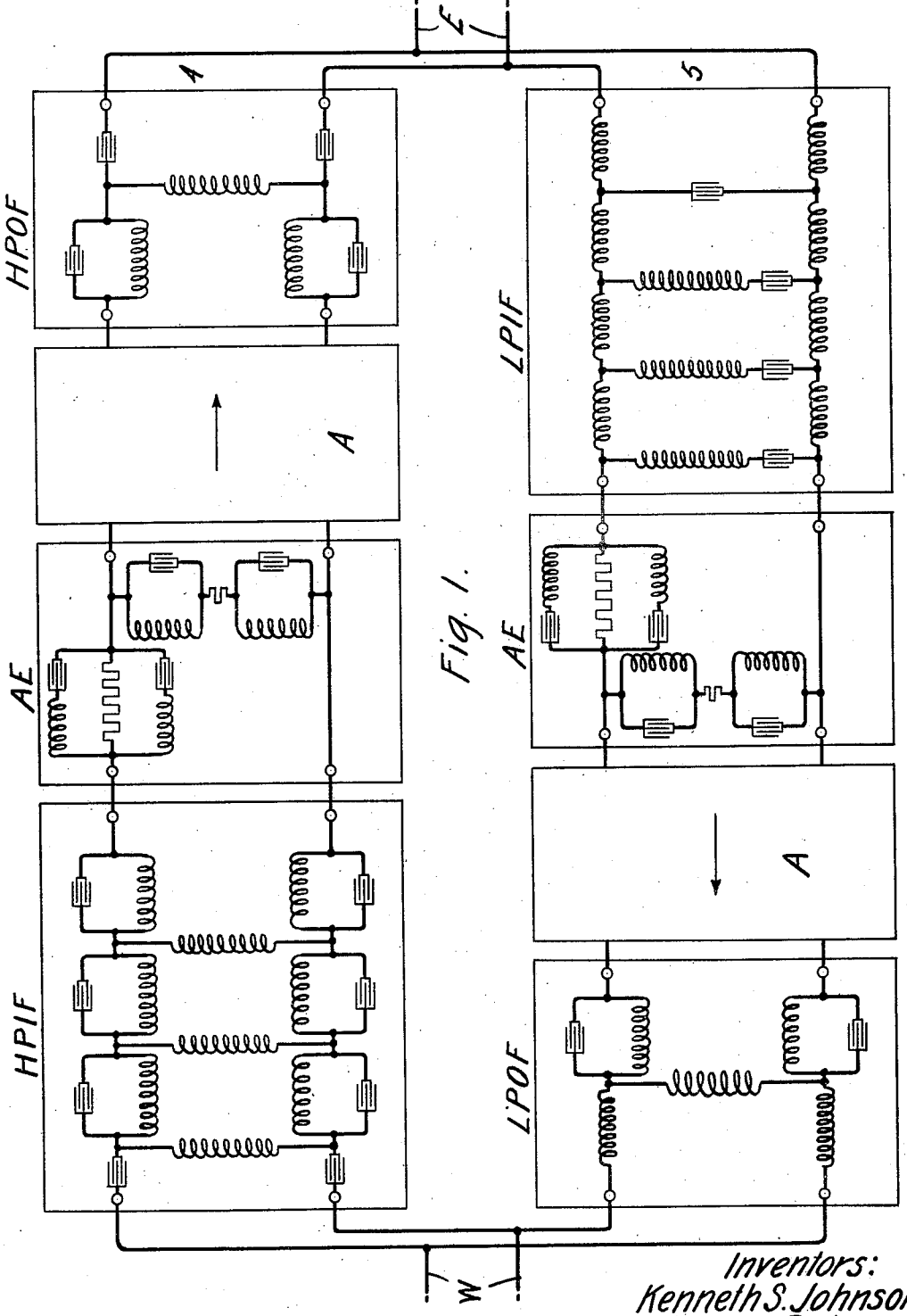


Fig. 1.

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Fig. 3.

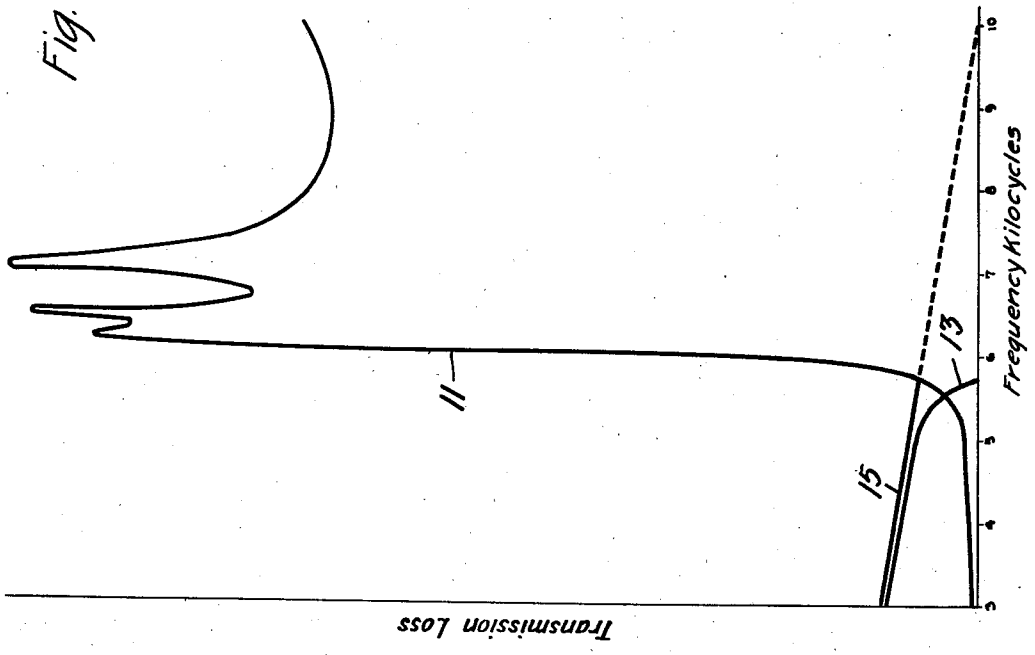
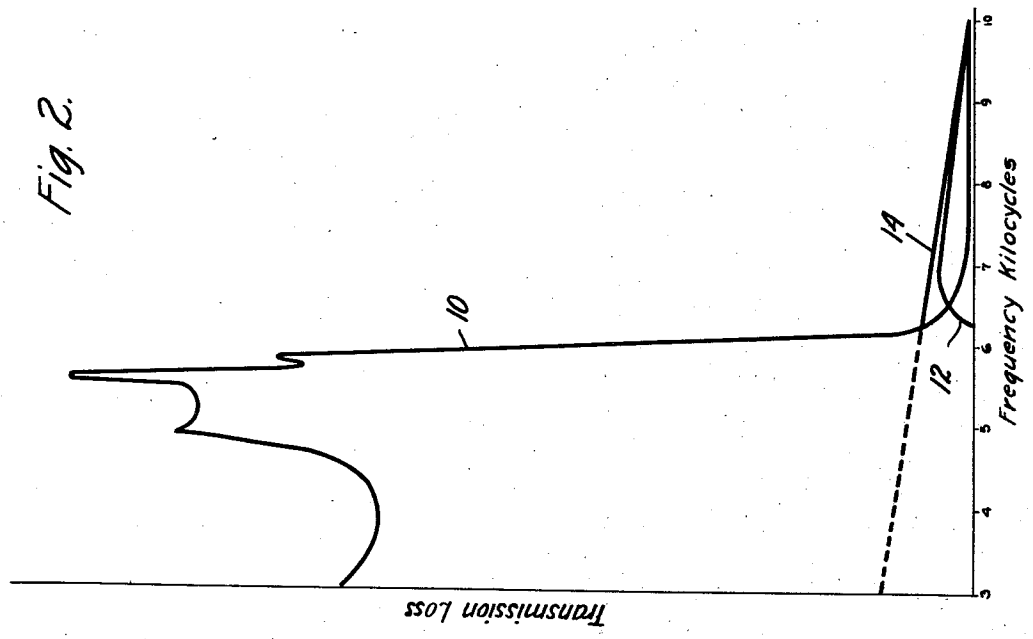


Fig. 2.



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UNITED STATES PATENT OFFICE.

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MULTIPLEX SIGNALING.

Application filed January 11, 1924. Serial No. 685,677.

This invention relates to multiplex signaling and particularly to filtering systems for use therein.

It is an object of the invention to provide a new and improved means for compensating for the unequal attenuation of the different waves in the transmission medium of a multiplex signaling system.

Another object of the invention is to provide means whereby the frequency spacing required between oppositely directed groups of frequencies is materially reduced, thereby rendering available considerable frequency space for additional communication channels.

In multiplex signaling systems in which the transmitted energy is in the form of waves or oscillations modulated in accordance with the signals to be transmitted, a plurality of such waves, each of a distinctive frequency, are transmitted over the same line. Due to the inherent attenuation of the transmission line and its associated apparatus, however, it is necessary to amplify these oscillations. This may be accomplished by providing a repeater system in which oppositely directed waves are transmitted at different frequencies, the repeater being so arranged that all of the waves transmitted in one direction will be amplified by a single one-way repeater and all of the waves transmitted in the opposite direction will be amplified by another one-way repeater.

In such systems, particularly those employing long line conductors, it is well known that the waves of higher frequencies are less perfectly transmitted than those of lower frequencies. The wider the range of frequencies transmitted the greater is the distortion due to the poorer transmission or greater attenuation of the high frequencies relative to the low.

If a repeater of the above mentioned type is used for a large range of frequencies on a line possessing unequal attenuating properties, it is desirable to associate with the repeater some means for equalizing or compensating for the distortion due to such attenuation. In general, it is desirable to introduce the means of correction for the line attenuation at the repeater since the correcting means introduces a loss which may be made up by the repeater. Heretofore, to meet these requirements, attenuation equalizers and filters have been employed which have each been separately designed with respect to their particular functions, and in practice considerable frequency margin has been thought necessary between the oppositely directed carrier waves.

In accordance with a feature of the invention a carrier signaling system is provided with a repeater comprising grouping filters to separate oppositely directed groups of frequencies, and attenuation equalizers. The grouping filters each comprise a plurality of sections separated by an amplifier which thus divides the sections into two groups. The attenuation equalizers are so designed that when combined with the filters and the line, the transmission efficiency of the entire circuit is essentially constant over the transmitted range of frequencies. The combined filter and equalizer then act as a filter having attenuation characteristics over the transmission range complementary to those of the transmission line, and at the same time having high attenuation over the attenuated range. By this arrangement, the frequency spacing required between oppositely directed groups of frequencies can be materially reduced.

Other features and advantages of the invention will be apparent from the consideration of the following description taken in connection with the accompanying drawing, in which:

Fig. 1 is a diagrammatic illustration of a two-way amplifying repeater connecting two line sections of a carrier transmission line, constructed in accordance with the invention.

Figs. 2 and 3 are curves illustrating the attenuation of the various parts of the system of Fig. 1.

The system shown in Fig. 1 is particularly adapted for multiplex carrier wave transmission in which a plurality of modulated carrier waves, each of which represents an individual message, may be simultaneously transmitted. The transmissions in the two directions are obtained by currents of different frequency ranges. For example, line section W may supply only currents of frequencies higher than 6,000 cycles to section E, and section E in turn may transmit only

currents of frequencies lower than 6,000 cycles to section W. The two repeating paths or branches 4 and 5 of the repeater are each equipped with a filter to suppress currents of the frequencies transmitted by the other branch, thus effectively preventing singing.

Each branch 4 and 5 includes an amplifier A, preferably of the highly evacuated three element electron discharge type, for amplifying the current supplied to that branch. In order to secure faithful repetition, these amplifiers and their circuits are designed in well known manner to produce as little intermodulation or other distortion of the different frequency currents as possible. The branch 4 also includes a high pass input filter section HPIF, an attenuation equalizer AE and a high pass output filter section HPOF, while the branch 5 includes a low pass input filter section LPIF, an attenuation equalizer AE and a low pass output filter section LPOF. In accordance with the invention disclosed in Patent No. 1,413,357 to P. A. Raibourn, April 18, 1922, the amplifiers A are interposed between the input and output filter sections in each of the branches so that part of the filter sections are connected to the input circuit of the amplifier and the remainder of the sections are connected to its output circuit. As pointed out in the Raibourn patent all the sections cooperate to selectively transmit currents of the desired range of frequencies to the exclusion of currents of other frequencies.

The filter sections HPIF, HPOF, LPIF and LPOF may be of the general type disclosed in British Patent No. 186,198, and may be of the composite wave filter type as discussed in part 3 of an article on the Theory and design of uniform and composite electric wave-filters, by Otto J. Zobel, in the Bell System Technical Journal of January, 1923. These filters consist in general of a plurality of sections having series and shunt reactances designed, according to well known laws, for the range of frequencies of the currents which the filters are to transmit. Filters of this type are known as suppression filters and are particularly advantageous where a sharp cut-off between frequencies in the transmitted and suppressed ranges is desired. The filter section HPIF is of the high pass type and is adapted to suppress frequencies below a definite limit, while filter section LPOF is of the low-pass type and is adapted to suppress frequencies above a definite limit.

Since the attenuation of a transmission line is a function of the frequency, the carrier currents at the receiving end of the line will vary in magnitude corresponding with the attentuation of the line which they have traversed. Where these currents are repeated into a succeeding line the variation in magnitude at the receiving end of the second line is proportionately much greater than for the first line, and hence equalizers have been devised for use at repeater points which effectually decrease the amplification of the repeater for the lower frequencies. In the present system the equalizers AE are included in the repeater network between the amplifiers A and the input filters HPIF and LPIF, respectively. The addition of these equalizers introduces a loss in the transmission range of the filters in repeater paths 4 and 5.

If curves 10 and 11 of Figs. 2 and 3, representing the characteristics of the high and low pass filters, respectively, were each extended vertically to the frequency axis, it would be possible by means of the grouping filters to separate oppositely directed frequencies which approached within a few cycles of each other. In practice, there must always be left a substantial frequency margin between oppositely directed transmissions on account of the gradual cut-off which a filter has and which is indicated particularly by the curved lower portions of the characteristics 10 and 11. Even if, for instance, the filter cut-offs were made so close to each other that the lower curved portions of characteristics 10 and 11 overlapped, there would still be a region common to the transmission ranges of both filters within which the filters would be ineffectual to separate the frequencies and this frequency interval could not therefore be utilized.

In accordance with the invention, the attenuation equalizer is made to have a characteristic which combines with the lower curved portion of the filter characteristic 10 or 11 to give a resultant characteristic for each repeater path comprising an attenuation equalizing portion and a frequency suppression portion, with such a sharp cut-off between the two frequency regions that the practical frequency margin necessary to be left between the oppositely directed transmission is materially reduced.

The attenuation equalizers AE are preferably of the type which have a constant resistance characteristic impedance as disclosed in an application of O. J. Zobel, Serial No. 580,769, filed August 9, 1922, according to which a network of this type having any desired attenuation-frequency characteristic may be designed. In the present case, the filter sections HPIF and HPOF of branch 4 are designed to pass currents of frequencies above about 6,000 cycles and to effectively suppress currents of frequencies below 6,000 cycles, as represented by the characteristic curve 10 of Fig. 2. The filter sections LPIF and LPOF of branch 5 are designed to pass currents of frequencies below 6,000 cycles and to effectively suppress

currents of frequencies above 6,000 cycles as indicated by the characteristic curve 11 of Fig. 3. The curve 12 of Fig. 2 represents the required characteristics of the attenuation equalizer AE of branch 4, which, when combined with the characteristic of the network represented by the curve 10, will give an over-all characteristic represented by the full line portion of the straight line 14. Similarly, the required characteristics of the attenuation equalizer AE of branch 5 are represented by the curve 13 of Fig. 3. The characteristics of this equalizer when combined with the characteristic of the network represented by the curve 11 will give an over-all characteristic represented by the full line portion of the straight line 15. In order that the attenuation equalizer of branch 4 may possess the characteristic represented by the curve 12, it is evident that the attenuation of this equalizer must be substantially zero at two points, namely at 6,400 cycles and at 10,000 cycles. The general method of constructing such an equalizer is described in the above-mentioned Zobel application. If then, one of the series arms of the equalizer is made resonant at 6,400 cycles and one of the shunt arms is made anti-resonant at 6,400 cycles, the series arm will offer zero impedance and the shunt arm will offer infinite impedance to the passage of currents of this frequency, thus causing no attenuation for currents of 6,400 cycles. The other series arm is made resonant at 10,000 cycles and the other shunt arm is made anti-resonant at 10,000 cycles, thus causing no attenuation for currents of 10,000 cycles. The series resistance arm of the equalizer is of such a value as to determine the maximum loss given by the equalizer, or in other words to determine the peak of the curve 12. The attenuation equalizer of branch 5 may likewise be designed to give the characteristics represented by the curve 13.

While the invention has been shown and described in connection with a multiplex carrier transmission system, it will be understood that it is not to be limited to such a system.

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 scope and spirit of the invention as defined in the following claims.

What is claimed is:

1. In a wave transmission system employing waves comprised in different frequency ranges, a line the attenuation of which differs for different frequencies, filters for separating oppositely directed groups of frequencies, and means for compensating for the distortion due to attenuation, said compensating means including networks each having a characteristic which corrects for the non-linear characteristic of a respective filter over part of the range of the transmitted frequencies, and said compensating means and said filters having combined characteristics which correct for the non-uniform attenuation of said line.

2. In a wave transmission system employing waves comprised in different frequency ranges, a line the transmission loss of which differs for different frequencies, means for separating oppositely directed groups of frequencies, and means for compensating for the distortion due to the variable transmission loss, said separating and compensating means having combined loss characteristics over the transmission range complementary to those of the transmission line, said separating means and said compensating means each having by itself a loss characteristic materially different from a loss characteristic complementary to that of the line throughout at least a portion of the frequency range over which their combined transmission loss is complementary to that of the line.

3. In a wave transmission system employing waves comprised in different frequency ranges, a line the transmission loss of which differs for different frequencies, and a network comprising grouping filters to separate oppositely directed groups of frequencies and attenuation equalizers, said network having characteristics over the transmission range complementary to those of the transmission line and having high attenuation over the suppression range, said grouping filters and said attenuation equalizers each having by itself a loss characteristic materially different from a loss characteristic complementary to that of the line throughout at least a portion of the frequency range over which their combined transmission loss is complementary to that of the line.

4. A wave transmission system employing waves comprised in different frequency ranges, a line the transmission loss of which differs for different frequencies, and a repeater in said line including means for separating oppositely directed groups of frequencies and an attenuation equalizer, said separating means and said attenuation equalizer having combined transmission characteristics over the transmission range complementary to those of the transmission line, said separating means and said attenuation equalizer each having by itself a loss characteristic materially different from a loss characteristic complementary to that of the line throughout at least a portion of the frequency range over which their combined transmission characteristic is complementary to that of the line.

5. A wave transmission system employing waves comprised in different frequency

ranges, a line the transmission loss of which differs for different frequencies, and a network comprising means for amplifying all of said waves substantially uniformly, grouping filters to separate opposite directed groups of frequencies and attenuation equalizers, said network having characteristics over the transmission range complementary to those of the transmission line, said grouping filters and said attenuation equalizers each having by itself a loss characteristic materially different from a loss characteristic complementary to that of the line throughout at least a portion of the frequency range over which their combined transmission loss is complementary to that of the line.

6. In a wave transmission system employing waves comprised in different frequency ranges, a line the transmission loss of which differs for different frequencies, a filter for freely transmitting waves comprised in a certain frequency range and for suppressing the transmission of waves of frequencies outside said range, the attenuation of said filter varying over an appreciable frequency interval in a manner markedly different from that of said line, and an attenuation equalizer associated with said filter, said attenuation equalizer and said filter having a combined transmission characteristic complemental to that of the line throughout the range of free transmission of said filter and a said attenuation equalizer having a transmission characteristic which varies in a manner to compensate for the difference in variation of the attenuation of said filter and said line over the said appreciable frequency interval.

7. In a wave transmission system, employing waves comprised in different frequency ranges, a filter for freely transmitting waves comprised in a certain frequency range and for suppressing the transmission of waves of frequencies outside that range, said filter having a non-linear transmission loss characteristic in the neighborhood of the cut-off frequency, and means for compensating for the nonlinear loss characteristic of said filter in the neighborhood of the cut-off frequency.

8. In a wave transmission system employing waves comprised in different frequency ranges, a line having non-uniform attenuation at different frequencies, a filter for freely transmitting waves comprised in a certain frequency range and for suppressing the transmission of waves of frequencies outside said range, said filter having a non-linear transmission characteristic in the neighborhood of the cut-off frequency, and an attenuation equalizer for compensating for the wave distortion produced by the non-uniform attenuation of said line, said attenuation equalizer having a transmission loss characteristic which substantially corrects for the said non-linear portion of the characteristic of said filter in the neighborhood of the cut-off frequency.

In witness whereof, we hereunto subscribe our names this 10th day of January A. D., 1924.

KENNETH S. JOHNSON.
MAURICE B. LONG.