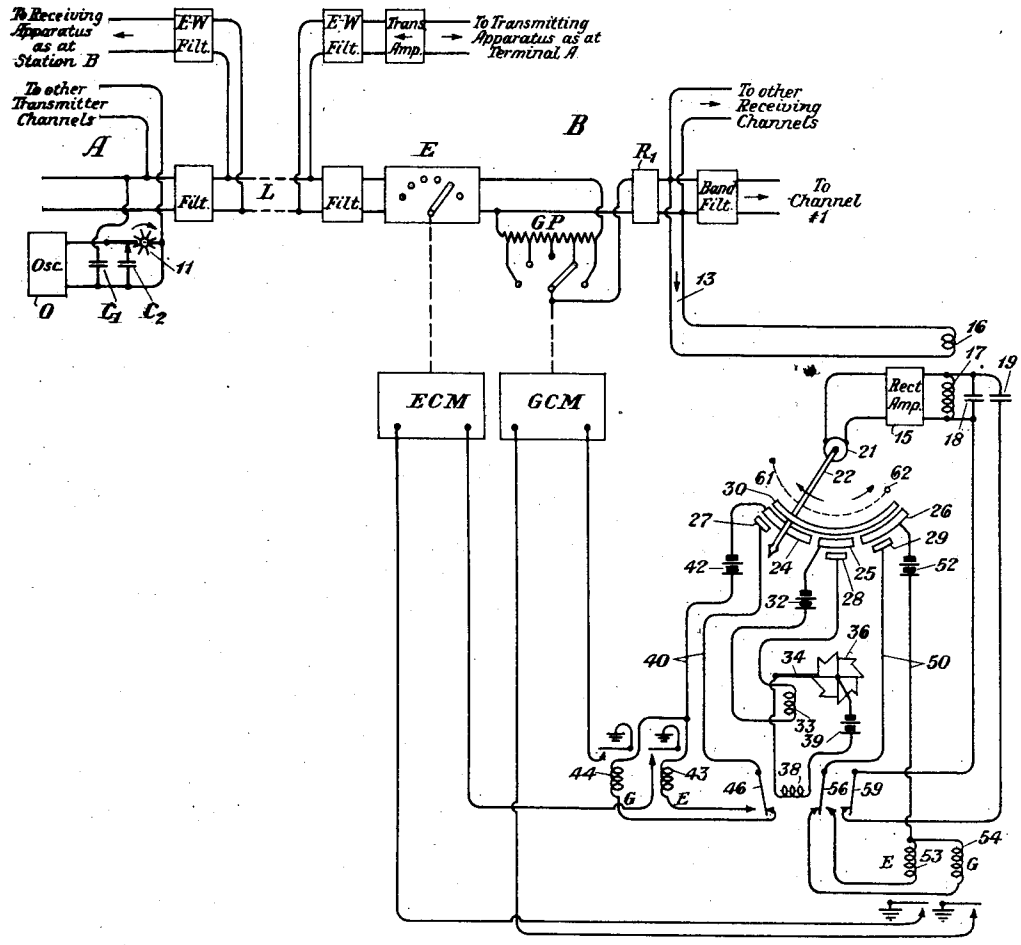
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EQUALIZATION FOR CARRIER SYSTEMS

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## EQUALIZATION FOR CARRIER SYSTEMS

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This invention relates to the equalization of carrier systems so that all channels will be brought to substantially a common transmission level, the common level being maintained constant with changes in transmission conditions.

In a transmission system employing line conductors, the attenuation of the current varies with frequency, the attenuation increasing as the frequency goes up. This becomes a very series matter in a multiplex carrier system, as the channels having the higher carrier frequencies will be much more attenuated than the channels transmitting at lower carrier frequencies. If, in such a system, the attenuation is plotted against frequency, the resultant curve will, within reasonable frequency limits, approximate a straight line having a slope depending upon the character of the circuit and the existing transmission conditions. This slope varies with different transmission conditions, and the variation in slope will, moreover, be different for different types of circuits.

The need of compensation so that the transmission at a given frequency is maintained at a desired level, and further compensation so that all channels are brought at all times to that level, and means for accomplishing this, are given in the patent of Green, No. 1,743,132, January 14, 1930. More specifically, in that application use is made of two pilot frequencies existing on the pilot line at all times, one of these being used to control the gain introduced by repeaters, and the two together being used differentially to correct for changes in the slope of the attenuation characteristics of the line.

This invention is an improvement on the method and means of the application referred to and has for its object the simplification of the circuit arrangements and the elimination and consolidation of certain of the otherwise necessary apparatus. More particularly in my invention I make use of two pilot frequencies, but instead of sending these out on the pilot line continuously, I send them alternately. In view of this, there need be but one oscillator at the transmitting end, this oscillator being adapted to have its frequency changed periodically in any predetermined manner. Also, at the further terminal of the transmission line or at the intermediate repeater stations, it is sufficient to have one receiving circuit for both of these frequencies, the receiver at any one station being alternately altered, as by tuning, to be receptive for the one pilot frequency or the other. By suitable switching mechanism, then, it is possible to operate on gain control mechanism or on equalization control mechanism at one time or another, depending upon which particular pilot frequency is being received at the moment.

The figure of the accompanying drawing shows a circuit arrangement for carrying out my invention. Referring more particularly to this drawing, there is shown a transmitting station A and an intermediate repeater station B, the two being connected by a transmission line, this line continuing to subsequent repeater stations. At the station A, there will be associated apparatus for transmitting messages over the transmission line L and apparatus for receiving messages coming over this same line. Also, at this station, there is connected to the line an oscillator O the frequency of which may be altered periodically in any suitable manner, such as, for example, by connecting and disconnecting the condenser $C_2$ in parallel with the condenser $C_1$. This change may be produced in any desired manner, such as by the rotation of a make-and-break device 11 which in turn may be operated by clock mechanism. The frequency at which this change occurs may be varied over a wide range, but might very well be of the order of once in five minutes. As a result, there is impressed on the line L alternately two frequencies $f_1$ and $f_2$, preferably located rather far apart but within the frequency range over which signaling is carried on in the various message channels identified with the line L.

At the station B, transmitting apparatus is associated with the line as at the station A. In addition, in the transmission line itself, there is introduced a potentiometer GP which controls the gain of the repeater $R_1$. Also in the input circuit of the repeater

$R_1$ there is introduced an equalizer E by means of which an adjustable loss may be introduced, which is a function of the frequency. By suitable adjustment, then, of the potentiometer GP, it is possible to bring the level of transmission at a given frequency $f_1$ to any desired value, and, by adjustment of the equalizer, it is possible to bring the level of all frequencies in the desired frequency band to the same level, all as described in the above-mentioned patent of Green.

Associated with the output of the repeater $R_1$ is a branch circuit 13 associated with the rectifier-amplifier 15. This association may be obtained in any of a number of ways, and, in the drawing, is shown as an inductive coupling from the coil 16 to the coil 17. Associated with the coil 17 are condensers 18 and 19, the one of these, 18, being permanently connected in parallel, yielding a circuit tuned to the frequency $f_1$ of the oscillator O. The condenser 19 is connected in parallel to 18 periodically in a manner hereafter described, and, when so connected, yields a circuit tuned to the frequency $f_2$.

Associated with the output of the rectifier 15 is a galvanometer 21, of any suitable form such as the well known D'Arsonval galvanometer. The pointer 22 of this galvanometer will take up a position depending upon the size of the current flowing through the galvanometer 21, and, as it changes its position, may pass over strips 24, 25 and 26, which bars are movable and adjacent to contacts 27, 28 and 29. Adjacent to the pointer 22 is a bar 30 which, by some independent mechanism, may be pressed against the pointer 22 which in turn bears on the contact strips 24, 25 or 26 to close contact with 27, 28 or 29, depending upon the position of the pointer 22.

Associated with the contact members 25 and 28 is a relay circuit including the battery 32 and relay 33. The armature 34 of this relay engages with a ratchet wheel 36 to step this around for a purpose to be described later.

The contact members 24 and 27 are associated with a relay circuit 40 including the battery 42 and the relays 43 and 44, these latter being connected in parallel. The circuit also includes a switching member 46 constituting an armature of a relay 38 which latter is included in circuit with the battery 39 and the ratchet wheel 36.

In a similar manner, the contact members 26 and 29 are associated with a relay circuit 50 including the battery 52 and the parallel relays 53 and 54, and including, also, a switching member 56 which constitutes a second armature of the relay 38. Finally, a third armature 59 of the relay 36 is used for connecting and disconnecting the condenser 19.

The relays 44 and 54 are used for controlling the gain control mechanism GCM which in turn is associated in any suitable manner with the potentiometer GP. The relay 44 operates on the potentiometer in a manner to increase the gain of the repeater, and the relay 54 operates to decrease this gain. Similarly, the relays 43 and 53 control the equalization control mechanism ECM to step the equalizer E in the one direction or the other.

The ratchet wheel 36 has its alternate teeth or segments connected to a common point, and by means of the battery 39 is used to control the relay 38. Thus, when the armature 34 is in contact with one of the segments just referred to, circuit for battery 39 will be closed and the relay 38 is operated. On the other alternate segments, however, circuit 39 will be broken.

The limits of motion of the pointer 22 are determined by stops 61 and 62, the stop 61 corresponding approximately to the position of the needle for zero current through the galvanometer, whereas the stop 62 corresponds to approximately the maximum current which it is intended shall flow through the galvanometer. With this maximum current, the pointer 22 is still above the member 26 and in position to contact with that member upon the motion of the bar 30. The member 24, however, is fore-shortened so that the needle 22 is not in a position to contact with it if the current through the galvanometer falls below a certain specified minimum.

The method of operation of the circuit will now be given. Consider the circuit to be adjusted initially for proper gain and proper equalization. In this invent, the current of either frequency $f_1$ or $f_2$, as taken off by the branch 13, is of such a magnitude as to give galvanometer current which will bring the needle 22 over the member 25 and periodically it will be pressed against the member 25 to close contact with 28, and thus the circuit of relay 33 will be closed. Each of these closures will cause the ratchet 36 to be moved one step and thus alternately opens and closes the circuit of relay 38. This operation changes the tuning, whereupon the needle goes to zero and awaits the next frequency. During this wait, nothing occurs, however, in the circuits 40 or 50.

If, now, some change in the line occurs so that the attenuation for the frequency $f_1$ increases, then the current through the galvanometer 21 is below normal during the reception of this frequency $f_1$. It may be that it falls off sufficiently to bring the needle 22 above the member 24. Let us consider this to occur while the relay 38 is operated, in which case the condenser 19 is connected in circuit and the input of the rectifier 15 is adjusted for reception of the frequency $f_1$. Upon pressure of the bar 30 the circuit 40 is closed at 24 and 27 to make contact through

the relay 44 which then operates GCM to step up the gain of the potentiometer GP. It will be noted that during this time the circuit 50 can not be operated. As long as the needle 22 remains above the member 24, there will be an operation of the relay 44 and a corresponding stepping up of the potentiometer each time that the bar 30 moves down to close contact between 24 and 27, and, with each step thus made, the current through the galvanometer 21 increases and finally the needle comes above the member 25. Upon the next movement of the bar 30, contact is made to operate the relay 33 which then moves the ratchet 36 one step forward, disconnecting the relay 38 and releasing its armatures. Upon this movement, the condenser 19 is disconnected and the input of the rectifier 15 is now in tune for the frequency $f_2$. If the frequency $f_1$ is still being given by the oscillator O, the current in the galvanometer will fall to practically zero value, and no operation of the circuits will occur. In due course, however, the frequency of O will be changed to $f_2$ and substantial current will now flow through the galvanometer 21, bringing the needle over, let us say, the member 24. If it stays over this member for an appreciable time, contact will be made through the pressure bar 30, thus closing the circuit 40 through the relay 43, thus stepping the equalizer control mechanism in such a direction as to increase the gain over the transmission line as a whole for the frequency $f_2$, and step after step of this change will occur until the current for this frefrequency $f_2$ brings the pointer 22 over the member 25, whereupon the ratchet 36 will be moved another step to operate the relay 37 and make it possible to close circuits for the relays 44 or 54 which control GCM. In the event, however, that the gain for this frequency $f_2$ is already too large, the pointer 22 will quickly move over the member 26, and, in due course, the pressure bar 30 will close the circuit 50 through the relay 53 which will then operate on ECM in the reverse direction to decrease the gain for this particular frequency.

From the above, it is seen that through the mechanism as thus described it is possible to control the gain either upwards or downwards for the frequency $f_1$, bringing this to a predetermined desired level and also to equalize the gain for the frequency $f_2$ either by upward or downward adjustment to bring it to the same level as the gain for the frequency $f_1$. If these two frequencies are chosen at appropriate points in the total frequency range over which equalization is desired, then the departure from the desired gain for all the frequencies in this band will be substantially zero.

It should be noted that no synchronization is required between the operation at the transmitter which changes the frequency from $f_1$ to $f_2$, and the motion of the ratchet 36. This is made possible by the fact that no adjustments at the station B will take place if the current through the galvanometer is below a certain specified minimum, and the current will be below this minimum until the transmitting oscillator changes over to the frequency for which the rectifier 15 is at the time tuned. This circuit will therefore await the proper change at the oscillator O and will then resume operation and adjust the current in the galvanometer 21 to the normal value, operating, now, upon equalization if the previous adjustment was a gain, or vice versa. When this value is reached, the cycle of operation will be repeated.

Another advantage of having a minimum value of current below which the needle 22 makes no contacts is that of protection of the apparatus from false signals, it being assumed that these false signals would never attain a value comparable to those necessary for the operation of the mechanism as a whole.

While reference has been made to the control mechanism for one pair of wires only, it is to be understood that if there are a plurality of such pairs of wires, each having a repeater $R_1$, the gain of which is to be controlled, the one set of controls GCM and ECM may be used for all such repeaters.

This invention has been described specifically with reference to carrier frequency signaling but it is equally applicable for signaling in the normal telephone range, the two pilot frequencies selected being suitably placed in the speech range.

It will be evident that many modifications and changes may be made in the details of this circuit without departing from the spirit of the invention. For instance, instead of using relays, it would be possible to carry out the changes with motor apparatus, but it is to be understood that these and other variations come within the scope of this invention.

What is claimed is:

1. In a multi-frequency transmission system, a transmission line, the method of equalization of the transmission over a range of frequencies, which consists in transmitting two pilot frequencies alternately, observing the amplitudes of these after transmission, adjusting the gain for all frequencies in accordance with and by one of these observations, and adjusting the frequency equalization in accordance with and by the other observation to make the transmission equivalent of the system the same at all frequencies.

2. In a multi-frequency signaling system, a transmission line, means for transmitting over the line a plurality of pilot frequencies in sequence, means at a repeater point for observing the amplitude of the received pilot frequencies, and means controlled by the in-

coming pilot signals for introducing gain or loss in proportion to these amplitudes to bring the level of transmission for the different frequencies to a desired value.

3. In a multi-frequency signaling system, a transmission line, means for transmitting over the line a plurality of pilot frequencies in sequence, means at a repeater point for observing the amplitude of the received pilot frequencies, and means controlled by the pilot signals for introducing gain for all frequencies in accordance with the amplitude of one of the pilot frequencies, and for introducing equalization in proportion to another observed amplitude.

4. In a multi-frequency signaling system, a transmission line, means for transmitting over the line two pilot frequencies alternately, means at a repeater point for observing the amplitude of the received pilot frequencies, and means for introducing gain for all frequencies in accordance with the amplitude of and controlled by one of the pilot frequencies, and means for introducing equalization in proportion to and controlled by the other observed amplitude.

5. In a multi-frequency signaling system, a transmission line, means for transmitting alternately over the line two pilot frequencies, means at a remote point on the line for receiving these, a gain control mechanism, and an equalization control mechanism, and means for automatically controlling these alternately in proportion to the amplitude of and by the received pilot frequencies.

6. In a multi-frequency signaling system, a transmission line, means for transmitting alternately over the line two pilot frequencies, means at a remote point on the line for receiving these, a gain control mechanism, and an equalization control mechanism, and means for automatically controlling these alternately in proportion to the amplitude of the received pilot frequencies, the one mechanism being operated on and by receipt of the one pilot frequency, and the other on and by receipt of the other pilot frequency.

7. In a multi-frequency signaling system, a transmission line, means for transmitting alternately over the line two pilot frequencies, both in the signaling range, a receiver at a remote point on the line adapted to selectively receive one pilot frequency at a time, a gain control mechanism, and an equalization control mechanism, and circuits automatically controlled by the pilot signals for operating upon one mechanism or the other, depending upon the pilot frequency being received.

8. In a multi-frequency signaling system, a transmission line, means for transmitting alternately over the line two pilot frequencies, both in the signaling range, a receiver at a remote point on the line adapted to selectively receive one pilot frequency at a time, a gain control mechanism, and an equalization control mechanism, and circuits automatically controlled by the pilot signals for operating upon one mechanism or the other, depending upon the pilot frequency being received, and means for automatically shifting the receiver circuit to the other pilot frequency when proper adjustment has been made for the first frequency.

9. In a multi-frequency signaling system, a transmission line, means for transmitting alternately over the line two pilot frequencies, both in the signaling range, a receiving circuit adjusted at one time to effectively receive one pilot frequency, a galvanometer associated with the receiving circuit giving deflections in proportion to the amplitude of the received pilot frequency, and comprising three sets of contacts; one for increasing gain; one for decreasing gain; and one for shifting the receiver to the other pilot frequency when adjustment in accordance with the first pilot frequency has been made.

In testimony whereof, I have signed my name to this specification this 1st day of July, 1929.

ALLEN CARPE.