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TRANSMISSION SYSTEM

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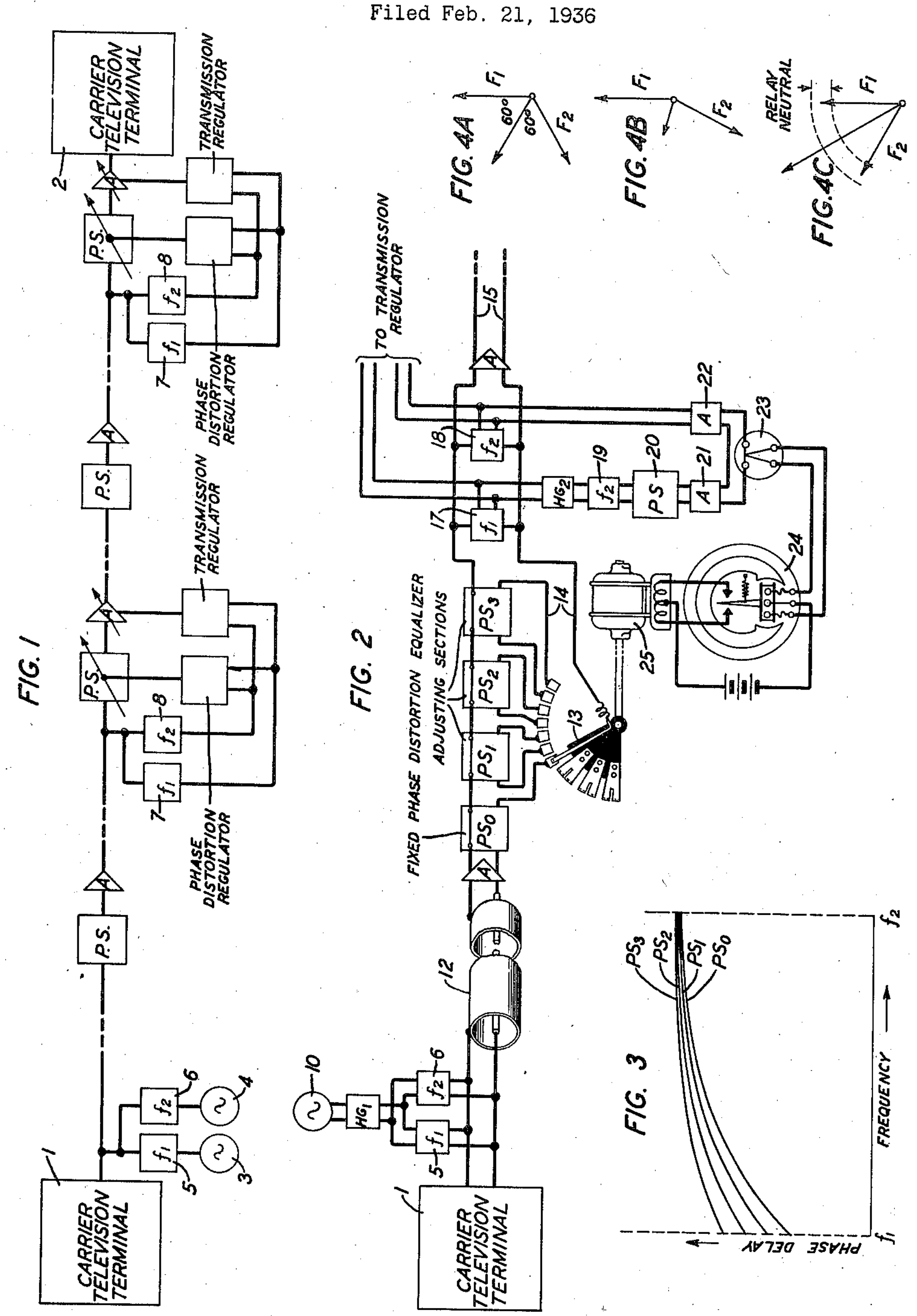

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TRANSMISSION SYSTEM

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This invention relates to wave transmission systems and more particularly to electric wave systems in which a wide frequency range is transmitted.

It is a well known phenomenon that in many transmission systems waves of different frequencies are not propagated at the same velocity. Thus, in the transmission of carrier frequency waves over a long non-loaded line the higher frequencies travel at greater velocity than the lower frequencies, this giving rise, if uncorrected, to perceptible and in some cases serious distortion of the signals. Means have been devised heretofore for differently retarding waves of different frequencies transmitted over a conducting system so as to equalize their times of transmission and to permit waves of all frequencies to arrive at a given point of the system in their proper time relation.

In the transmission of certain types of signals, and particularly, for example, television signals, it is necessary that distortion of this character, phase distortion as it is known, be kept at a very low value. So stringent is this requirement that means are needed not only to equalize the initial velocities over the frequency band but also to compensate for the variations of velocity that accompany slight changes in the characteristics of the transmitting medium such, for example, as changes in the resistance and capacitance of a transmission line with changes in temperature.

An object of the present invention is to correct automatically for variations in the velocity of transmission and so prevent phase distortion in a transmission system.

A more particular object is to provide a variable phase distortion correction system that does not require a pilot wire circuit or other physical transmission medium paralleling the signal transmission circuit or medium.

In another and specific aspect, an object of the invention is to provide a system in which phase distortion correction is effected under the control of waves that are subjected to velocity variations similar to those of the signals under correction.

A feature of the present invention resides in the use of a comparison wave that is utilized to detect relative changes in the velocities of propagation of the signal waves.

Another and more specific feature of the invention is the use of two pilot waves of different frequencies, the relative propagation velocities of which vary in a manner correlated with the variations in the phase distortion of the signal waves.

In accordance with the present invention as embodied in a typical illustrative wire transmission system, either or both of two pilot waves are transmitted over a line that is subject to substantially the same variation in transmission characteristics as the line carrying the signal waves. In the preferred form, both of the pilot waves and the signal waves are transmitted over the same line, one pilot wave lying immediately above the signal band and the other immediately below it in the frequency spectrum. At a phase distortion correcting point, for example, a repeater or terminal station, means are provided for comparing the times of transmission of the two pilot waves and for varying the signal phase distortion correction at that point in such sense and magnitude as to equalize the times of transmission of the two pilot waves or otherwise to bring the pilot waves into some predetermined time or phase relationship indicative of equal times of transmission.

The nature of the present invention and other objects and features thereof will appear more fully in the following description of a typical illustrative system embodying the invention. Reference will be made to the accompanying drawing, in which:

Fig. 1 shows schematically the manner of application of the invention to a high frequency wire line system;

Fig. 2 shows in greater detail the means employed at a correcting point; and

Figs. 3, 4A, 4B, and 4C are diagrams illustrative of the manner of operation of the correcting means.

Referring now to Fig. 1, there is represented schematically a one-way wide-band high frequency transmission system comprising terminal stations 1 and 2 and an interconnecting transmission line in which signal amplifiers are provided at suitable intervals. The signal waves applied to the line at terminal 1 and received at terminal 2 may comprise, for specific example, a band of carrier television signals 900 kilocycles in width and lying between 100 and 1000 kilocycles per second in the frequency spectrum utilized in signaling over the line.

At each line repeater is a signal amplifier A, and at two of them are phase distortion correctors PS of the fixed type to which reference has hereinbefore been made. At the mid-line repeater and at the repeater associated with the receiving terminal station 2 are provided adjustable phase distortion correctors. These are operated by means of the respective automatic regulators indicated in Fig. 1. The latter, in turn, are controlled by means of waves generated by sources 3 and 4 and applied to the line at terminal 1 through respective filters 5 and 6, these waves being, in the embodiment illustrated, both transmitted over the line to filters 7 and 8 associated with the automatic regulators.

Assuming that the wave sources 3 and 4 generate waves of constant frequencies f_1 and f_2, respectively, f_1 lying immediately below the signal spectrum and f_2 immediately above it, changes in phase distortion occurring in the transmission line, being reflected in changes in the relative velocities of propagation of the two waves f_1 and f_2, may be detected at the repeater stations and caused to effect a compensating change in the phase distortion correction. An automatic regulator suitable for performing these functions is shown in Fig. 2.

Although the pilot waves utilized for operating the regulators have been illustrated as generated by separate sources provided for this specific purpose, this is not an essential feature of the present invention. Transmission systems known heretofore have employed two pilot waves for automatic regulation of attenuation and these same pilot waves may be utilized for effecting the objects of the present invention as indicated in Fig. 1. Again, one or more carrier waves utilized in the carrier terminal may be applied to the transmission line and used as pilot waves. In all of these specific examples, one wave subject to substantially the same velocity variations as signals of one frequency or to velocity variations correlated in known manner therewith is compared with another wave that is subject to velocity variations substantially the same as or correlated with, velocity variations of signals of another frequency, whereby relative changes in the velocity at different frequencies within the signal band can be detected and the resulting phase distortion compensated.

Fig. 2 illustrates a preferred embodiment of the invention and shows in detail the nature of the variable phase distortion equalizer and its associated control circuits.

Briefly, the wide band of carrier television signals produced at terminal 1, together with the two pilot waves, are transmitted over the coaxial conductor line 12 to the repeater station, where both signals and pilot waves are amplified, passed through one or more sections of an adjustable phase distortion equalizer and out through leads 14 and 15 to the next section of transmission line or to other circuits of the repeater. The two pilot waves are impressed across respective filters, 17 and 18, which are designed to present such high impedance to the signal circuit that the energy levels of the signal and pilot waves are not substantially affected; the one of lower frequency is converted by a harmonic generator or frequency converter to the same frequency as the other pilot wave, and the two waves of equal frequency are passed through respective amplifiers 21 and 22 of constant output.

The waves from the constant output amplifiers 21 and 22, being of the same frequency, differ only in phase. Variations in their phase relation, arising from variations in the relative velocities of transmission of the pilot waves in the transmission line, are detected by combining the waves in thermocouple 23 or other suitable detecting means. The voltage developed in the thermocouple is then utilized to control the reversible motor 25 which operates to change the number of phase distortion equalizer sections in the signaling circuit of the repeater. With the proper number of equalizer sections in circuit, the waves applied to the thermocouple return to some predetermined phase relation and the adjusting operation ceases until further changes in the transmission characteristics of the line occur.

Referring now more specifically to the pilot wave generating means associated with terminal station 1 of Fig. 2, the source 10 is, or may be, an oscillator of some constant and relatively low frequency. Its output is applied to a harmonic generator HG_1 and two harmonics thereof are selected by the respective filters 5 and 6 and applied to the transmission line 12. In the embodiment of the invention chosen for purposes of illustration, the frequency f_1 of one pilot wave may be immediately below the lower limit of the signaling band, for example 60 kilocycles per second, and the frequency f_2 of the other may be immediately above the signaling band, for example, 1020 kilocycles per second. The pilot frequencies may be more closely spaced, if desired, and this will be particularly advantageous where less than the entire signaling frequency range requires distortion correction or where this frequency range is divided into spaced bands of lesser width for independent correction.

Signal and pilot waves arriving at the repeater station are passed through a preliminary amplifier and through one or more of the tandem-connected phase distortion equalizer sections PS_0, PS_1, PS_2, etc., depending on the position of the contact arm of switch 13, and thence through leads 14 and another amplifier to output circuit leads 15. The phase delay-frequency characteristics of the equalizer sections are represented in Fig. 3, the ordinate indicating the cumulative phase delay (in units of time) at the output terminals of the respective sections. These characteristics are such that when added to the phase delay in the line, the total phase delay or time of transmission is the same at all frequencies in the transmitted band under correction.

It will be apparent from Fig. 3 that with increase of frequency the phase delay in the transmission is less subject to variation. The upper pilot wave, if of sufficiently high frequency, therefore approximates, and from a practical standpoint frequently may be considered as, a reference wave unchanging in velocity of propagation or, more broadly stated, as a comparison source of a frequency perfectly fixed relative to the lower pilot wave source.

Filters 17 and 18 connected across the leads 14 are each adapted to select one of the pilot waves passing through those leads. The voltage of the pilot wave of lower frequency f_1 is applied to a harmonic generator HG_2 and the harmonic, the seventeenth in the specific embodiment described, equal in frequency to the other pilot frequency f_2, is selected by means of filter 19. Following filter 19 in circuit is a phase shifter 20, the purpose of which will be explained shortly, and an amplifier 21. A similar amplifier 22 is connected to the output terminals of filter 18. These two amplifiers are designed to have equal constant outputs regardless of changes in the amplitudes of the respective input waves. Suitable amplifiers of this type are well known in the art.

The output circuits of the amplifiers 21 and 22 are connected in series with each other and with the heater element of thermocouple 23. The respective output voltages being constant and equal, the electromotive force developed in the thermocouple depends only on the phase relation between these two output voltages and varies from zero when the two voltages are in opposition with respect to the series heater circuit to a maximum value when they are in phase. It will be apparent, therefore, that with a progressive change in the relative velocities of transmission of the two pilot waves the thermocouple output voltage tends to vary periodically between zero and a maximum value. Actually, however, the concurrent introduction of phase distortion equalization precludes so wide a range of variation.

The voltage output of thermocouple 23 is applied to the armature of a biased double-contact relay 24, the contacts of which are so connected in the field circuit of direct current motor 25 as to permit reversible control of its operation. The drive shaft of motor 25 is connected, through a speed reducing mechanism if required, in operable relation with the contact arm of switch 13 in such manner as to permit the contact arm to be driven in either direction across its associated contactor segments. Any other suitable phase difference detector, motor and motor control means may be employed alternatively.

Phase shifter 20, designed to establish a "normal" phase relation between the two waves applied to the thermocouple 23 may be adjusted while the phase distortion introduced by the transmission system is at some average value requiring that, for example, two equalizer sections be connected in the repeater to compensate it. Preferably, the adjustment is such that under these normal conditions the two waves applied to the thermocouple are 120 degrees out of phase, as indicated in Fig. 4A. The vector resultant that effects operation of the biased relay is then midway between the minimum value that is approached in Fig. 4B and maximum value approached in Fig. 4C. Relay 24 is so biased that under the normal conditions represented in Fig. 4A its armature stands midway between the two associated contacts and the motor is at rest.

Upon an increase of the relative delay of the low frequency pilot wave, the phase relations represented in Fig. 4B may be reached. Thereupon the armature of relay 24 moves to complete the motor field circuit through one of its associated contacts, the motor drives the contact arm of switch 13 clockwise to add additional sections of the phase distortion equalizer, until the phase distortion is corrected and the phase relations indicated in Fig. 4A again obtain. Thereupon the armature of relay 24 assumes its neutral position and the system comes to rest. Relay 24 is insensitive enough to provide a neutral zone, as shown in Fig. 4C, to avoid incessant reversal of the motor when slight uncompensated distortion is present.

Upon a decrease of the relative low frequency delay, a similar series of operations is initiated resulting in the removal of one or more equalizer sections from circuit. It will be obvious that the three "adjusting sections" shown in Fig. 2 are only representative of a larger number that might actually be required. In some instances, the several adjusting sections may have identical delay-frequency characteristics.

In Fig. 2 leads from filters 17 and 18 are indicated for connection to an automatic transmission regulator. For details of the transmission regulation system, reference is made to E. I. Green Patent 1,743,132, January 14, 1930, the disclosure of which is to be deemed incorporated in this specification.

It is to be understood that the systems herein described and illustrated are only specific embodiments of applicant's invention, and that other and widely different systems may embody applicant's invention and the several novel features thereof as they are defined in the appended claims.

What is claimed is:

1. In the transmission of waves occupying a wide frequency range, the method which comprises subjecting a pilot wave to varying transmission conditions correlated with those conditions to which said wide band of waves is subject, comparing a characteristic of said pilot wave with a reference wave, and utilizing relative changes in said characteristic to modify phase distortion within said wide band of waves.

2. In a system subject to variations in phase distortion, the method which comprises transmitting through said system two pilot waves of different frequencies and utilizing the variations in the relative velocities of propagation of said pilot waves to regulate the phase distortion correction in said system.

3. In combination, means for transmitting a band of waves through a medium from a first point to a second point, and an instrumentality at said second point responsive to changes in relative velocities with which waves of different frequencies are propagated through said medium.

4. In a transmission system subject to variations in phase distortion, means for transmitting over said system two pilot waves of different frequencies, and means responsive to variations in the relative velocities of propagation of said pilot waves.

5. A signaling system comprising a transmission line, means for transmitting thereover signal waves occupying a wide frequency band, means for transmitting over said line two pilot waves, one immediately above and the other immediately below said wide frequency band, phase distortion correcting means at a point in said line, means at said point for selecting said pilot waves and converting them to waves of the same frequency, means for comparing the phases of said last-mentioned waves, and means responsive to said last-mentioned means for adjustably controlling said correcting means.

6. A combination for detecting difference in phases of two waves comprising means for fixing the respective amplitudes of the said waves, means for vectorially combining said waves of fixed amplitude, means responsive to the vectorial resultant wave produced by said last-mentioned means, and phase changing means operative on one of said waves to maintain said resultant wave within prescribed amplitude limits.

7. In combination, two sources of waves of the same frequency and of variable phase relation, constant output amplifiers each connected to a respective one of said sources, and means responsive proportionally to the vectorially combined outputs of said amplifiers.

8. In combination, a transmission system carrying signals occupying a frequency range of a width suitable for television transmission, means for transmitting over said system two pilot waves of initially fixed relative phase and amplitude, means for adjusting phase delay distortion cor-

rection and attenuation equalization in said system, and means operating under the control of said pilot waves for controlling said adjusting means.

9. A system comprising a conducting line subject to temperature changes, means for transmitting over said line signals occupying a frequency range of the order of megacycles in width, means for concurrently transmitting over said line two waves having respective frequencies such that the variations in velocity of propagation of said waves with variation in temperature are comparable with the maximum and minimum velocity variations respectively of waves within said frequency range, means for adjustably compensating for velocity variations throughout said frequency range, and means operated under the control of said two waves for adjustably controlling said compensating means.

10. In a system for the transmission of signals occupying a wide frequency range, means for transmitting over said system a wave subject to velocity variations similar to those to which said signals are subject, and response means for comparing a condition of said wave after transmission over said system with a similar condition of a reference wave, said response means and said condition being such that the response is indicative of changes in the velocity of propagation of said first-mentioned wave.

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