March 6, 1934.

M. E. STRIEBY

1,950,127

COMMUNICATION SYSTEM

Filed Feb. 25, 1932

2 Sheets-Sheet 1

FIG. 1

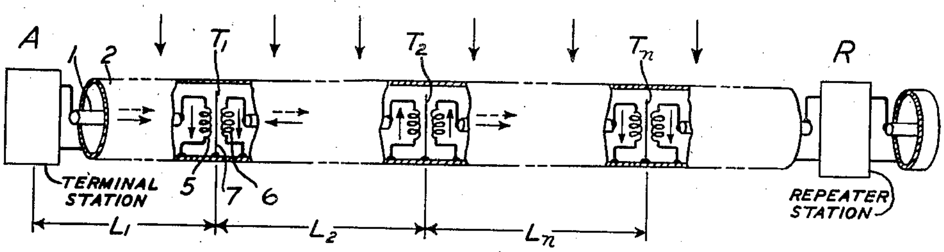

FIG. 2

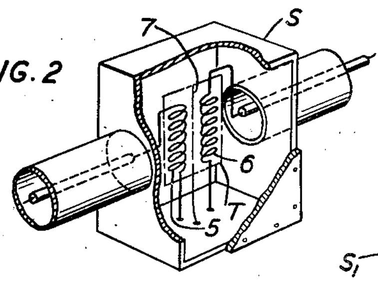

FIG. 3

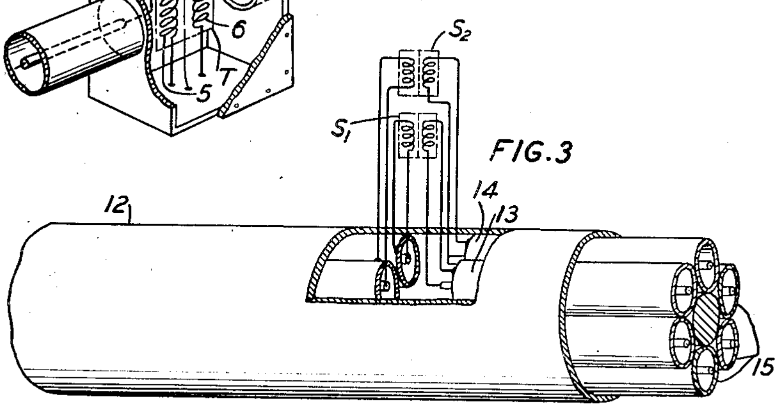

FIG. 4

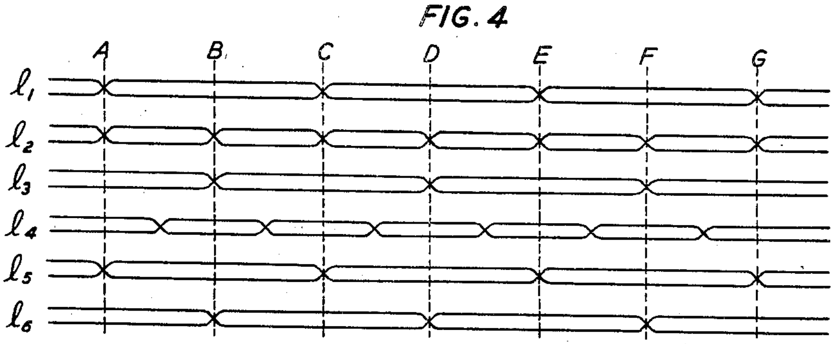

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FIG. 5

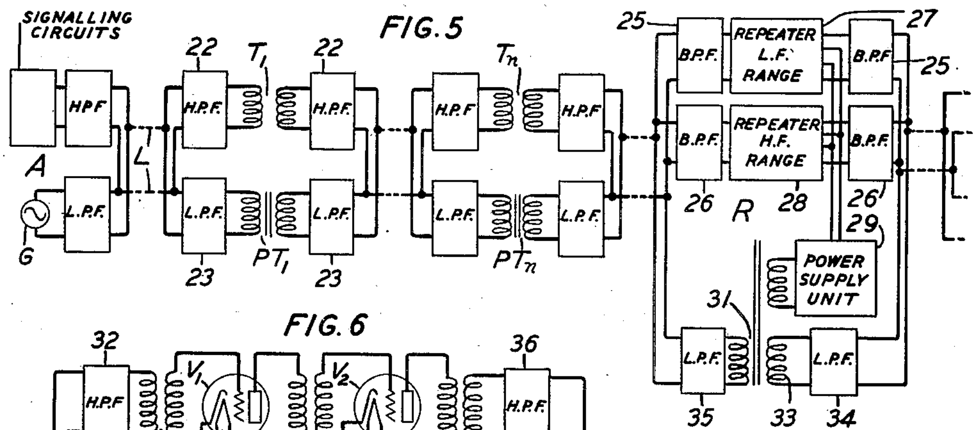


FIG. 6

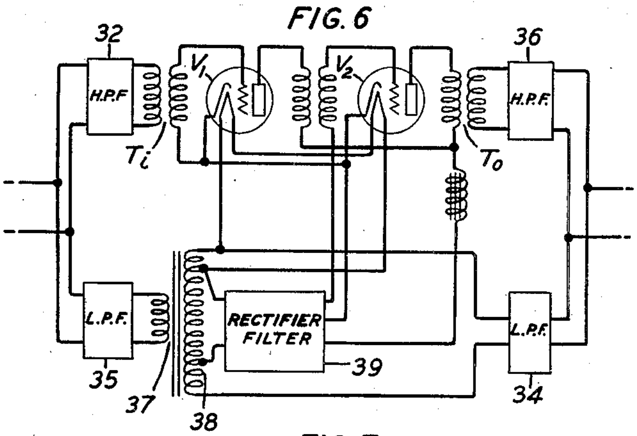


FIG. 7

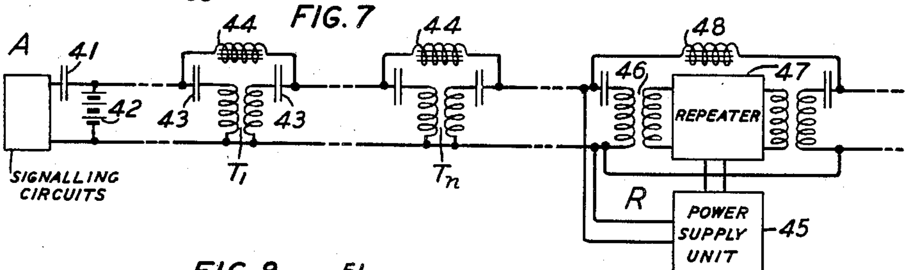
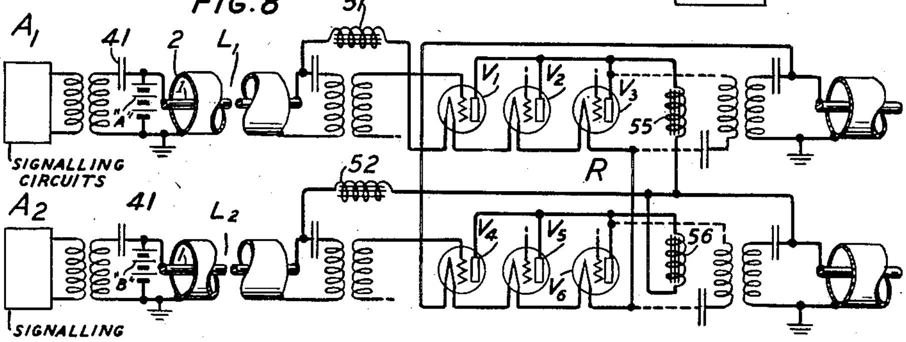


FIG. 8



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1,950,127

COMMUNICATION SYSTEM

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Application February 25, 1932, Serial No. 595,051

3 Claims. (Cl. 179—78)

This invention relates to conducting systems for the transmission of intelligence and more particularly to such systems wherein one conductor serves as a coaxial return for another.

An object of the invention is to reduce the disturbing effect of extraneous electric and magnetic fields on systems of the type to which the invention relates. Another and more particular object is to reduce the effect of signal induction between parallel conducting systems.

From another aspect, the object of the present invention is to make possible a reduction in the thickness of the return conductor of a coaxial system without permitting interference to become excessive.

A signaling line suitable for the transmission of frequencies of the order of megacycles per second has been found to be one comprising a central conductor and a tubular or shell-like return conductor maintained in coaxial relation with the first conductor and separated from it by a dielectric that is substantially gaseous. The outer conductor, since it completely surrounds the central conductor and is normally grounded, affords a high degree of shielding against external electric disturbances. External magnetic fields, because of the coaxial arrangement of the conductors, also have little effect on the system, at least at high frequency. Where the conductors are thick enough to be mechanically self-supporting the shielding may be so efficient, in fact, that the extent to which signals may be attenuated is determined not by the level of static and crosstalk as in other systems but only by the resistance noise of the conducting material and interference from other sources inherent in the system.

In some situations external sources of interference may be so powerful or so near the signaling line that the level of induced disturbance becomes objectionably high. Such a condition might be found, for example, where the transmission line passes in the immediate vicinity of a powerful radio broadcasting station. Where also a multiplicity of coaxial conductor pairs are brought together to form a cable, as disclosed in an application for patent bearing Serial No. 487,153 filed by H. W. Dudley on October 8, 1930, induction or crosstalk from one circuit to another becomes a serious consideration, and in some cases it determines the frequency range that may be utilized. Increasing the thickness of the outer conductor alleviates the difficulty, but as a practical matter it is not very feasible, since the flexibility of the cable is thereby reduced and the cost of the conducting material, already the major item of expense in a system of this type, is increased.

In accordance with the present invention it is proposed to reduce the effect of external fields on a coaxial conductor transmission line by electrically transposing the conductors of the pair at intervals along the line. Where a number of coaxial pairs are assembled as a cable, such electrical transposition is applied to the several circuits in accordance with a regular system, analogous to the system used for the physical transposition of open-wire lines. Since the outer conductor of a coaxial pair is normally grounded, an ordinary transposition of a signaling circuit would result in a short circuit. It is sufficient to achieve the effect of a transporition, however, that the phase of the signals in the central conductor be reversed at intervals, and for this purpose it is proposed to insert phase reversing devices, such as transformers, at the points where transpositions are desired.

A subsidiary object of the present invention is to provide a system wherein power for energizing the elements of repeating apparatus may be supplied over a pair of coaxial conductors in which electrical transposition is utilized.

The nature of the present invention will appear more fully in the following detailed description of several preferred embodiments. Reference will be made to the accompanying drawings, in which:

Fig. 1 represents a typical coaxial conductor system with transpositions in accordance with the present invention; Fig. 2 shows a modification of a detail thereof;

Fig. 3 represents a multi-circuit coaxial conductor cable; Fig. 4 shows a suitable scheme of transpositions therefor;

Figs. 5 and 6 show schematically a system for supplying alternating current to repeaters over a transmission line in which electrical transpositions are present; and Figs. 7 and 8 show similar direct-current systems.

Referring now to Fig. 1, there is shown a portion of a communication system embodying the present invention. At A is represented a terminal station which may be adapted to generate and receive carrier wave telephone or other signals ranging in frequency from perhaps five hundred kilocycles per second to five megacycles per second. Signals to and from the terminal station are transmitted over a line comprising a central conductor 1 and a hollow outer conductor 2, which are maintained in coaxial relation by means of a suitable separating structure. At intervals of several miles repeater stations R are inserted in the line. The particular nature of the terminal and repeater circuits and the specific type of coaxial conductor line employed is of no consequence as regards the present invention. Suitable embodiments are disclosed, for example in H. A. Affel, Patent 1,835,031, December 8, 1931.

The transmission line is divided into a plurality of sections L_1, L_2, L_n, etc., by means of transformers T_1, T_2, T_n, etc., which convey signals from one section to the next. Thus, the central conductor 1 of the first section L_1 is connected to one terminal of winding 5 of transformer T_1. The other terminal of winding 5 is connected to the outer conductor 2, which is at ground potential. Winding 6 of the same transformer is similarly connected to section L_2 of the line, one terminal being connected to the central conductor of that section and the other to the grounded outer conductor. The polarity of the windings of the several transformers, as indicated by the solid arrows, is such as to produce a reversal in phase of signal current in successive sections of line. That is, if current in the central conductor of section L_1, for example, were flowing in the direction of repeater R, as indicated by the solid arrows, the current in the central conductor of the next section L_2, would be caused to flow away from the repeater.

The neutralizing effect of the transposition on waves induced from external sources can readily be seen. If the several sections of line are affected by the same external source of disturbance, the waves induced in the central conductor will be in the same direction or sense in all of them, as represented by the dotted arrows. The disturbing waves induced in one section, as L_1, for example, are then transmitted to the adjacent section L_2, but reversed in phase because of the polarity of the transformer windings. As the waves induced in the latter section from the external source and those conveyed to it by the transformer are opposite in phase they tend to neutralize each other and their resultant effect in the circuit is diminished.

The number of transpositions required in each repeater section and their location will depend on several factors, including the nature, proximity, strength and position along the line of the disturbing sources. Generally, a given source of interference will affect only a relatively small portion of the line and hence only that portion may require transposition.

In Fig. 2 is shown one method for shielding the transformers against external disturbances. The transformer T is shown enclosed in a shielding container S which in effect is a mere enlargement of the outer conductor. Where it is feasible, the container may be dispensed with and the transformer located within the outer conductor itself. Preferably, a grounded shield is placed between the windings of the transformer.

In Fig. 3 is represented a cable 12 comprising a multiplicity of coaxial conductor pairs 15. Each pair may be associated with suitable terminal and repeating apparatus for transmitting carrier signals in a frequency band of, for example, fifty to five hundred kilocycles per second. A more detailed disclosure of cable and circuits is unnecessary here but reference is made to the patent application of H. W. Dudley, supra. At intervals along the cable, conductor pairs are interrupted and transformers are inserted to effect transpositions. Coaxial conductors are to be preferred for making the necessary connections. The transformers should give a unity impedance ratio and introduce as little loss as possible. As a specific example of a suitable type, the transformer may have a toroidal core built up of permalloy ribbon two mils thick and primary and secondary windings thereon of approximately one hundred turns each. An electrostatic shield may separate the windings.

In a multi-pair cable all of the pairs can not be transposed at the same point, since, while this would reduce interference from sources external to the cable, it would have no effect on inter-circuit induction or crosstalk. Instead, a regular system of transpositions is employed, wherein at any one point only two or three of the circuits, as 13 and 14, may be provided with transformers S_1, S_2, respectively. At each transposition point a suitable container or pot may be used to house the several transformers, similar, for example, to the structures used for loading coils.

A typical transposition system for a six-pair cable is shown in Fig. 4. Between the terminals A and G of a repeater section, one line, as l_1, may be transposed at only two points, while another, as l_2, may be transposed as many as five times. In general, the scheme provides that the number of transpositions in any one pair is half or twice that of adjacent pairs. The scheme can be extended, of course, as the number of pairs in a cable requires.

Referring now to Fig. 5, there is shown a transmission system including a terminal station A, a repeater station R, and a transmission line L connecting them, transformers T_1 T_n, etc., being provided at intervals along the line to effect transpositions. An alternating current generator G, which is connected to the line at station A, supplies current over the line to repeater R and to subsequent repeaters. A power supply unit 29 associated with each repeater is adapted to convert the alternating current received to a form suitable for energizing the vacuum tubes or other elements of the repeater.

At transposition points means are provided for shunting the power current around the signal transformers T_1, T_n, etc., since the latter are not adapted to transmit either large amounts of energy or power frequencies. This means may take the form of power transformers PT_1, PT_n, etc. connected effectively in parallel with the signal transformers. High-pass filters 22 and low-pass filters 23 of simple design may be connected in the leads of the two transformers to prevent detrimental inter-action. A similar filtering arrangement may be used at terminal and repeater stations. Thus, the signal input circuits at repeater R are connected to the preceding section of line through high-frequency filters 25 and 26, while the power supply unit 29 is connected to the line through low-pass filter 35. Power is supplied to the succeeding line section through winding 33 of power transformer 31 and low-pass filter 34.

The range of frequencies that a coaxial conductor line is capable of transmitting efficiently may be, as hereinbefore noted, from zero to five megacycles per second. Repeaters, as ordinarily designed, are not capable of amplifying effectively all frequencies of such a band. For carrier telephone systems, the lowest frequency of the band to be amplified by one amplifier can not practically be made much less than one-tenth the highest frequency. Where five megacycles per second is the highest frequency to be amplified, then, the lowest frequency for the same amplifier should not be less than approximately five hundred kilocycles per second. Repeater 28 of Fig. 5 and the associated band-pass filters 26 may accordingly be designed to amplify and pass this range of frequencies. The frequency range below this five hundred kilocycle lower limit may also be utilized if a suitable repeater is provided. Repeater 27 and its associated band-pass filters 25 are therefore designed to amplify and pass a band of from approximately fifty kilocycles per second to five hundred kilocycles per second. The line attenuation in this low-frequency range is much less than in the high-frequency range. The amplification required of repeater 27 is therefore less than that of repeater 28. Alternatively, if high gain is used, a 50–500 kilocycle repeater need be used at perhaps only alternate repeater stations. Where alternating current is not transmitted over the line to energize the repeaters, filters 25 and 26 may be of low-pass and high-pass types, respectively.

A typical repeater adapted to be supplied with alternating current power over the signaling line is represented schematically in Fig. 6. Power currents arriving over the line are separated by low-pass filter 35 and applied to the primary winding of power transformer 37. The terminals of the secondary winding 38 of transformer 37 are connected through a low-pass filter 34 to the next section of the signaling line. The secondary winding 38 is tapped at an intermediate point to supply a suitable voltage to rectifier-filter 39, which supplies current to the space paths of discharge devices V_1 and V_2. A low voltage tap is provided for the heater elements of the discharge devices. Incoming signal currents are selected by filter 32, which may be of the high-pass type, and applied to input transformer T_i, whence they pass through the amplifier, output transformer T_o and filter 36 to the outgoing line.

Where direct current is to be supplied over the signaling line to the repeaters the system shown in Fig. 7 may be used, or where two or more pairs of lines are present, that represented in Fig. 8. In the system shown in Fig. 7, a battery or other source of direct current 42 is connected across the line at the terminal station A. A blocking condenser 41 prevents short circuit of the battery by the terminal circuits. At transposition points, the transformers T_1, T_n, etc. used for transposition purposes are bridged by a choke coil 44 or other suitable device which will pass direct current to the exclusion of signaling frequencies. The return path for direct current is provided by one side of the signaling line, which may be continuous and grounded as in the system shown in Fig. 1. A choke coil 48 is similarly used at the repeater station R to convey direct current from one repeater section to another. Any suitable unit 45 may be used at the repeater station for applying the direct current diverted to the elements of the repeater.

If two or more signaling circuits are available, as in the cable system of Fig. 3, separate filament and anode supply circuits may be used. Thus, in Fig. 8 an "A" or filament supply battery is connected across line L_1 at the terminal station and a "B" battery across line L_2. At the common repeater station R, each line is provided with an individual amplifier, vacuum tubes V_1, V_2, and V_3 being associated with line L_1, and V_4, V_5 and V_6 with line L_2. Filament heating current for all tubes is supplied from line L_1. In the specific circuit shown, the central conductor 1 of the coaxial conductor line L_1 is connected through a choke coil 51 and the filaments of V_1 to V_6 connected in series, to the central conductor of the outgoing section of line. The filament circuit may include similar elements at succeeding repeater stations and it is eventually completed by connection to ground. Space current for all tubes is supplied over line L_2. A continuous direct-current path through the repeater is provided by choke coil 52 which connects the central conductor of one section to the central conductor of the next section. The grounded outer conductor provides the return path of this direct-current circuit. Space current for the vacuum tubes is obtained by connecting the anodes of each amplifier together and through a choke coil 55, 56, individual to the amplifier to the central conductor of line L_2. The signaling circuits of the amplifiers, which are shown incompletely, may be of suitable conventional design.

The present invention may of course be embodied in other forms than the ones described herein for purposes of illustration. It is therefore to be limited only by the scope of the appended claims.

What is claimed is:

1. A transmission system comprising a pair of coaxial conductors connected one as the return for the other, means for applying to said conductors bands of signaling waves occupying a wide range of frequencies, means for successively reversing the phase of said signaling waves throughout a region where said conductors are exposed to disturbing fields the outer of said conductors being so thin and the minimum signaling frequency being so low that excessive interference would be created in the lowermost of said signaling bands except for said phase reversing means, and a shielding structure electrically continuous with said outer conductor for enclosing each of said phase reversing means.

2. A combination in accordance with claim 1 in which said phase reversing means comprise transformers, the primary and secondary windings of said respective transformers being electrostatically shielded from each other.

3. In a multiplex carrier telephone transmission system, a cable comprising a multiplicity of pairs of coaxial conductors, the outer conductors of said pairs being insufficiently thick to prevent excessive mutual inductive effects between said pairs, signal repeaters at intervals along said cable, means for electrically transposing the conductors of each of said pairs at a plurality of points between said repeaters, the transposition interval for one pair of conductors being different from that of pairs adjacent to it in said cable, and respective shields electrically continuous with the outer conductor of each of said pairs for enclosing said electrical transposing means.

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