May 15, 1928. 1,669,589

H. H. BUTTNER

POWER LINE SIGNALING SYSTEM

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Fig. 1

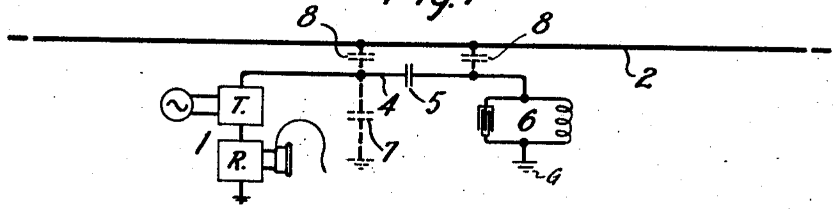

Fig. 2

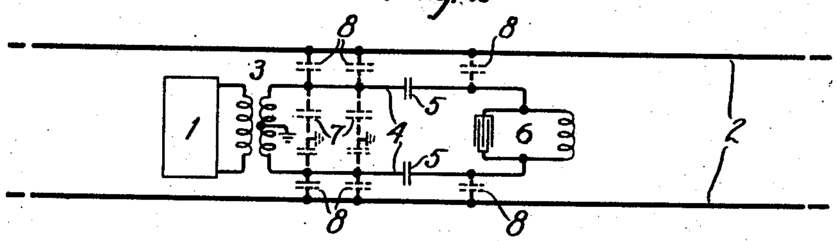

Fig. 3

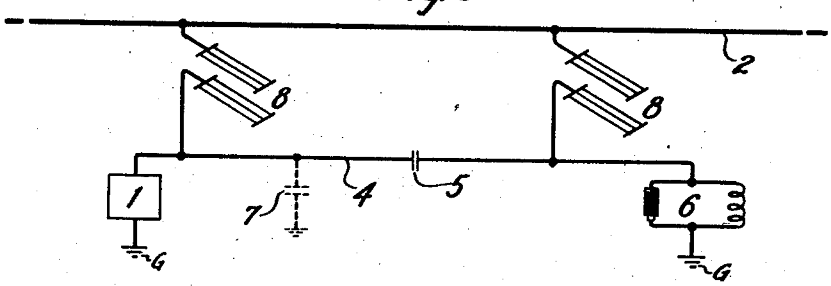

Fig. 4

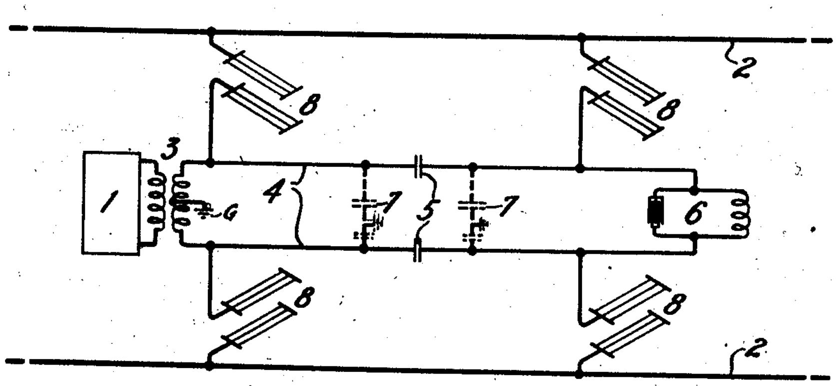

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Fig. 5

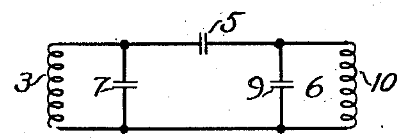


Fig. 6

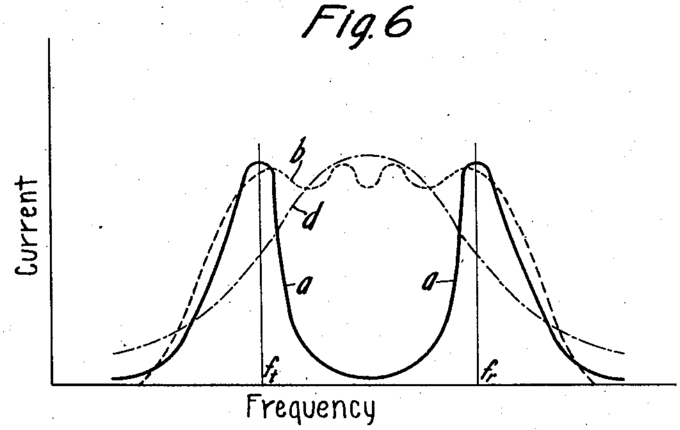


Fig. 7

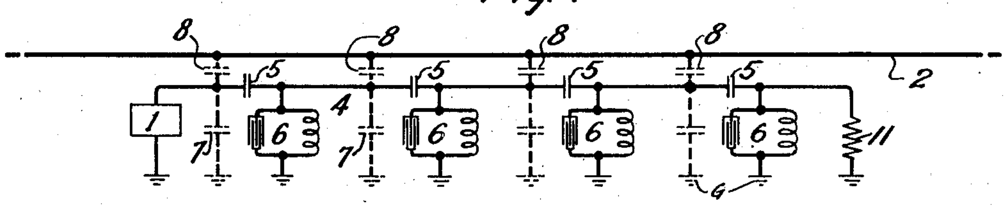
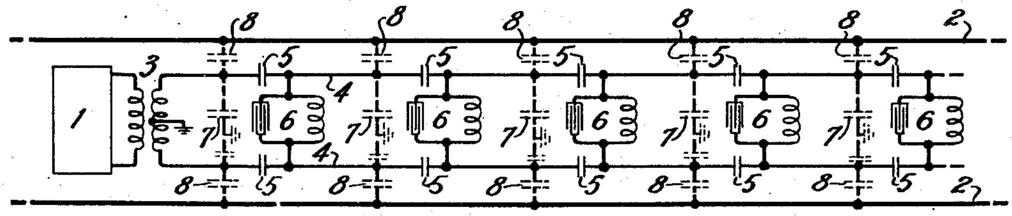


Fig. 8



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UNITED STATES PATENT OFFICE.

HAROLD H. BUTTNER, OF NEW YORK, N. Y., ASSIGNOR, BY MESNE ASSIGNMENTS, TO WESTERN ELECTRIC COMPANY, INCORPORATED, A CORPORATION OF NEW YORK.

POWER-LINE SIGNALING SYSTEM.

Application filed January 31, 1925. Serial No. 5,974.

This invention relates to communication by means of high frequency waves and more particularly to communication over power lines by superimposing the high frequency waves upon power currents traversing the power lines.

Heretofore, there has been employed in power line signaling systems an aerial consisting of a long wire in parallel relationship to the power line, or two separate aerials, one connected to the power line and one to the signaling apparatus, by means of which transfer of energy is obtained. In power line communication, it is advantageous to use different frequencies in transmitting and receiving, necessitating terminal apparatus capable of passing both frequencies.

When waves of frequencies somewhat widely separated are used for transmission and reception, the band of frequencies transmitted by the circuit including the aerial-power-line-conductor capacity must be sufficiently wide to include both frequencies. If this circuit is a flatly tuned circuit, there are two features of its operation which are capable of considerable improvement. One is to make the circuit more efficient at each of the two frequencies employed. The other feature which is characteristic of some, but not all, species of the invention as described hereinafter is that of making the circuit discriminate against waves of frequencies lying between the employed frequencies as well as those lying above the higher, and below the lower employed frequency.

It is an object of this invention to improve duplex telephone communication and other wave transmission over power lines and other transmission conductors.

Another object is to provide for more efficient coupling of signaling apparatus to a power line than heretofore employed.

A further object is to provide a coupling means for power line signaling adapted to transmit waves within the desired frequency bands and surpass waves of other frequencies.

A still further object is to provide a coupling means capable of passing both transmitting and receiving bands with a minimum amount of attenuation.

A feature of the invention consists in modifying the transmission characteristic of an electrostatic coupling circuit by means of special terminating impedance elements.

These objects and others which will be apparent as the nature of the invention is disclosed are accomplished by associating with the aerial wires coupling the signaling apparatus to the power line, a series of inductances and capacities which, in connection with the inherent capacity of the aerial wires, form a filter or other selective network capable of transmitting the desired frequency bands.

The aerial coupling the signaling apparatus to the power line, may be either of the form of a single long wire parallel to the power line and insulated therefrom or may consist of separate aerial structures, one of which is connected to the power line and the other to the signaling apparatus. In either case, a capacity coupling between the power line and the apparatus is obtained.

Although the novel features which are believed to be characteristic of this invention will be pointed out with particularity in the claims appended hereto, the invention itself, its objects and advantages, the manner of its operation and the mode of its organization will be better understood by referring to the following description taken in connection with the accompanying drawing wherein the same reference characters are used to designate corresponding parts in the various figures of which

Fig. 1 represents a form of this invention having a ground return system.

Fig. 2 is a modification of the system of Fig. 1 to a two-wire transmission system.

Fig. 3 is a modification of Fig. 1 wherein coupling aerials are employed.

Fig. 4 is a modification of Fig. 2 employing coupling aerials.

Fig. 5 is an equivalent circuit to that of Figs. 1 to 4.

Fig. 6 is a series of curves illustrating transmission characteristics of two forms of the invention.

Fig. 7 is an adaptation of the system of Fig. 1 designed to possess a modified transmission characteristic.

Fig. 8 is an adaptation of the circuit of Fig. 7 to a two-wire transmission system.

In the system shown in Fig. 1, signaling apparatus 1 is connected to power line 2 by means of an aerial 4 shown as a single wire parallel and adjacent to power line 2 but insulated therefrom. The signaling apparatus 1 comprises transmitting apparatus T and receiving apparatus R. Apparatus T and R may include circuits connected to the coupling network in parallel relation or in series relation. Apparatus T and R may also include selective circuits to separate the incoming and outgoing channels. A particular and preferred embodiment of transmitting and receiving apparatus is illustrated in the application of W. V. Wolfe, Serial No. 704,614, filed April, 1924. Aerial wire 4 includes series condenser 5 and is terminated in filter section 6 to obtain the desired transmission characteristic as will be hereinafter explained. Condensers 7 and 8 represent the distributed capacity of the aerial 4, to ground and to power line 2, respectively. The aerial capacities 8 are typical of capacity elements for coupling terminal elements and apparatus to the transmission line but the invention is not limited to the use of aerial capacities as oil condensers or equivalent elements may in some cases be employed.

In Fig. 2 signaling apparatus 1 is connected to power line 2 but insulated therefrom. In this and each succeeding figure the apparatus 1 is intended to indicate both transmitting and receiving circuits and devices. Aerial wires 4 are terminated in filter section 6. Series condensers 5 are inserted in the aerial as in Fig. 1. Condensers 7 and 8 represent the equivalent distributed capacity of the aerial 4 to ground and to power line 2, respectively.

The system shown in Fig. 3 is similar to that shown in Fig. 1, corresponding reference numbers being used to designate analogous parts. Capacity 8 of Fig. 1, the distributed capacity between the aerial wires 4 and power line 2, is obtained physically in Fig. 3 by coupling aerials 8, one of which is connected to power line 2 and the other to a signaling line 4. The signaling line 4 is terminated in filter section 6 similar to that shown in Fig. 1 and presents a system electrically equivalent thereto.

Fig. 4 shows the electrical equivalent of the system shown in Fig. 2 wherein capacities 8 are obtained by separate aerial structures instead of the distributed capacity of a single line in parallel relationship to the power line. The remaining parts of Fig. 4 are analogous to correspondingly numbered parts of Fig. 2.

There are certain advantages in the system shown in Figs. 3 and 4 as compared to that of Figs. 1 and 2. For example the strength of the power line is limited by certain mechanical requirements and by the cost represented in the long power line. There is more or less danger in connecting signaling apparatus to an aerial wire which is run parallel to a high tension power line although insulated therefrom as the power wire is liable to break during storms or for other reasons and come in contact with the aerial wire. This element of danger is largely eliminated in the system shown in Figs. 3 and 4 by the use of a separate aerial structure, which is relatively inexpensive as compared to a power line and may be made as strong as desired. The use of a large size wire in the aerial would not materially increase the cost of installation whereas the cost of a large wire for the power line, due to its great length, would be prohibitive. By using a separate aerial structure of great strength and associating therewith a second aerial connected to the signaling apparatus, the factor of safety is materially increased. Another feature is that the aerial-to-line capacity is more or less distributed whereas the aerial-to-aerial capacity is lumped.

An explanation of the operation of Figs. 1 to 4 can best be made by referring to the analogous circuit of Fig. 5 wherein inductance 3 corresponds to the inductance of terminal apparatus 1, including that of transformer 3 in Figs. 2 and 4. Capacity 7 corresponds to the distributed capacity represented as condensers 7 in Figs. 1 to 4, capacity 9 and inductance 10 correspond to tuned circuit 6, and capacity 5 is analogous to the correspondingly numbered capacities of Figs. 1 to 4.

This is a well known selective circuit having two degrees of freedom and has a transmission characteristic as shown by curve "*a*" of Fig. 6.

In Fig. 6 the transmitting frequency is indicated as f_t and the receiving frequency as f_r. In a practical system waves of frequencies of 80,000 and 100,000 cycles per second have been found convenient. If the coupling arrangements of Figs. 1, 2, 3, or 4 were used without the condenser 5 and circuit 6 the characteristic will be somewhat similar to the curve "*d*" (Fig. 6). When condensers and circuit 6 are added and the elements are properly proportioned a characteristic such as curve "*a*" (Fig. 6) is obtained. These curves are not drawn to scale and are intended to illustrate the invention as to principle but not as to quantitative results. Thus the curve "*a*" represents the characteristic of a system having two degrees of freedom wherein at two frequencies represented by the peaks of curve "*a*", the circuit will have a minimum amount of attenuation. This is especially advantageous in two-way communication as the peaks of the curve may be made, by proper design of the terminating circuit 6, to coincide with the transmitting and receiving frequencies used in the system.

A characteristic feature of this circuit is an aerial coupled to a transmission conductor by capacity coupling having a transmitting and receiving apparatus connected to one end of the aerial and a tuned terminating circuit connected to the other end. A condenser which divides the aerial into two parts is also used. Much greater efficiency can be obtained with a system of this kind than could be obtained where a coupling means is used having a single degree of freedom, wherein one or both signaling frequencies would lie outside of the minimum attenuation band.

The general principle employed in the system described above can be applied to produce a system having a band filter or other desired transmission characteristic by increasing the number of sections as shown in Figs. 7 and 8. The system shown in Fig. 7 is a modification of the system of Fig. 1 employing a plurality of filter sections containing circuits 6 and condensers 5 functioning analogously to the circuit 6 and condenser 5 of Fig. 1. The entire network is terminated in resistance 11 to obtain the desired characteristic. This resistance is typical of any one of several terminating networks which may be employed. In some cases no resistance or other terminating network need be used and the circuit may then be left open which is equivalent to a termination of infinite resistance.

Fig. 8 is an adaptation of the system of Fig. 2 to correspond to the system shown in Fig. 7 for two-wire communication. Correspondingly numbered parts have similar functions. In these two systems filter sections will be chosen to give band pass characteristics similiar to that shown in curve *b* of Fig. 6. The size and number of the irregular ripples of this curve may be controlled by changing the number of sections of the filter and the terminating impedances or both. The invention is not limited to the use of networks containing filter sections of the kind illustrated but may employ other types of section. The principles of design of such networks are set forth in U. S. patent to Campbell, 1,227,113, May 22, 1917 and in an article by Campbell in the "Bell System Technical Journal" vol. 1, No. 2 entitled "Physical theory of electrical wave filters".

The physical length of a system of this type is limited to a portion of the length of the transmitted wave as measured on the power line conductor. Current in each filter section will be in the same phase. If this current is applied to the transmission line at points a half wave length apart which would be at opposite potential no transfer would take place. The limiting case would be one half wave length above which any addition in the number of sections would decrease the signal strength. Maximum effectiveness is obtained by utilizing a portion of the power line equal to approximately one quarter wave length of the signal wave. The wave length referred to here is the wave length of a wave on the transmission line and not on the coupling network. The coupling network will in general be several wave lengths in electrical length but its physical length will in general be less than one-half a wave length on the power or other transmission line.

Although the principles of this invention have been illustrated by reference to particular forms of coupling means and particular sections, the invention is not limited to the use of these particular forms but is of general application in signaling systems employing other forms of coupling means and other filter sections within the scope of the claims.

What is claimed is:

1. A wave signaling system comprising a transmission line signaling apparatus and means for capacitatively coupling said line and said apparatus comprising an extended conductor electrostatically associated with said line and including a series condenser, and terminating impedances for said conductor, said terminating impedances forming in connection with said condenser and the distributed capacity of said conductor a wave filter adapted to pass freely waves of a plurality of different frequencies while attenuating waves of all other frequencies.

2. A system for duplex communication over power lines comprising a receiving circuit designed to operate on a predetermined wave frequency, a transmitting circuit designed to operate on a different wave frequency, means for capacitatively coupling said circuits to said power line comprising an aerial associated with said power line, and means including a terminating impedance for said aerial at the end remote from said circuits adapted to cooperate with the distributed capacity of the aerial in constituting said coupling means a wave filter selective to waves of both transmitting and receiving frequencies.

3. A system for duplex communication over power lines comprising a receiving circuit designed to operate on a predetermined wave frequency, a transmitting circuit designed to operate on a different wave frequency, means for capacitatively coupling said circuits to said power line comprising an aerial associated with said power line, and including a series condenser and means including a terminating impedance for said aerial at the end remote from said circuits comprising an inductance and a capacity in parallel adapted to cooperate with the distributed capacity of said aerial and with said series condenser in constituting said

coupling means a wave filter selective to waves of both transmitting and receiving frequencies.

4. A transmitting conductor and means for effecting transference of wave energy between said conductor and terminal apparatus comprising a plurality of conductive elements constituting electrostatic capacities, one electrode of each of which is in conductive relation to said conductor, said elements being spaced along said conductor.

5. A transmitting conductor and means for effecting transference of wave energy between said conductor and a terminal circuit comprising a plurality of electrostatic elements distributed along said circuit and separated by impedance elements.

6. A system in accordance with claim 5 in which the electrostatic elements consist of aerial members.

7. A system in accordance with claim 5 in which the impedance elements include electrical capacity elements.

8. An arrangement for transferring energy to or from a transmission circuit comprising electric capacities at physically separated points along said circuit each effective to effect the intertransfer of energy to or from said circuit, and a conductor including at least one impedance element connecting the electrodes of said capacities which are remote from said circuit.

In witness whereof, I hereunto subscribe my name this 29th day of January A. D., 1925.

HAROLD H. BUTTNER.