May 6, 1930. R. D. DUNCAN, JR 1,757,114

DUPLEX HIGH FREQUENCY TELEPHONE SYSTEM

Filed Dec. 23, 1925 2 Sheets-Sheet 1

Fig. 1.

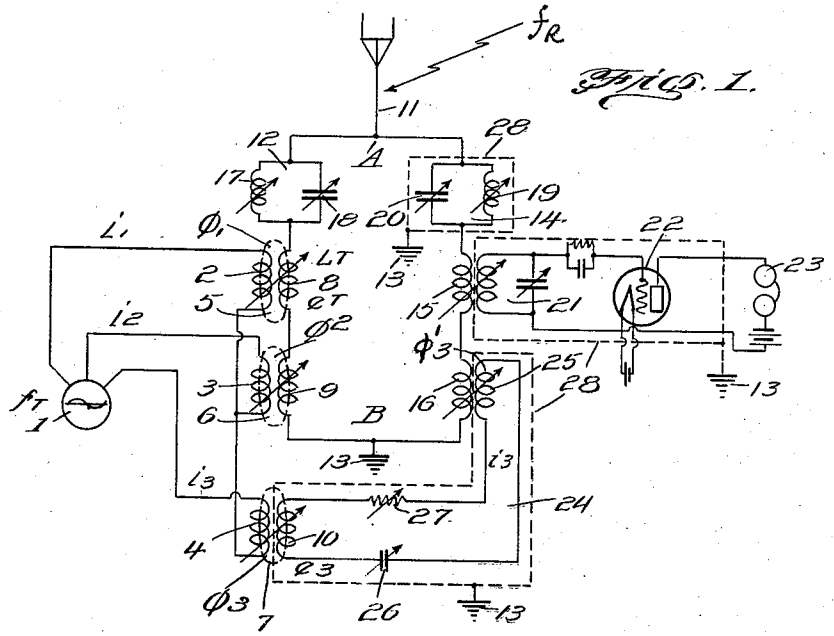
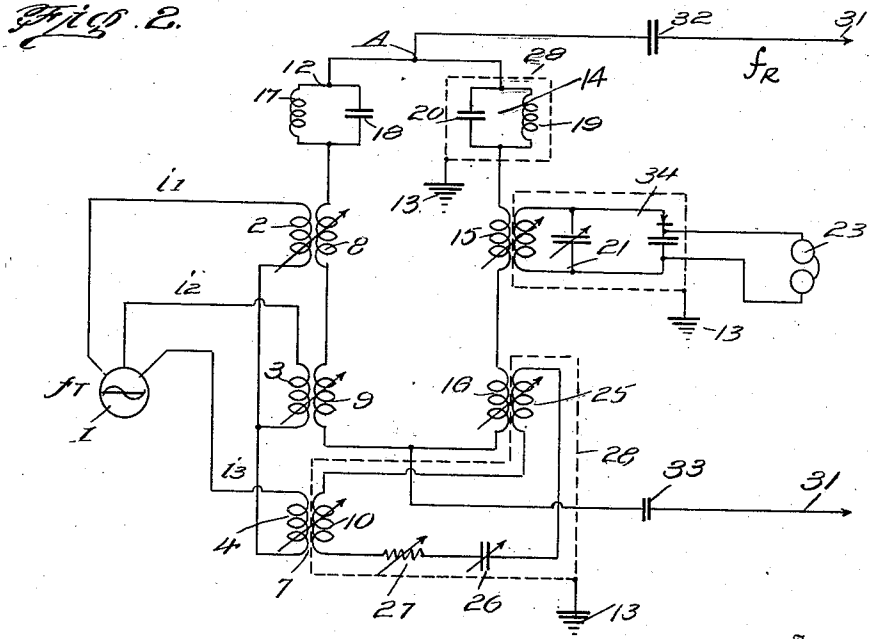


Fig. 2.



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Fig. 3.

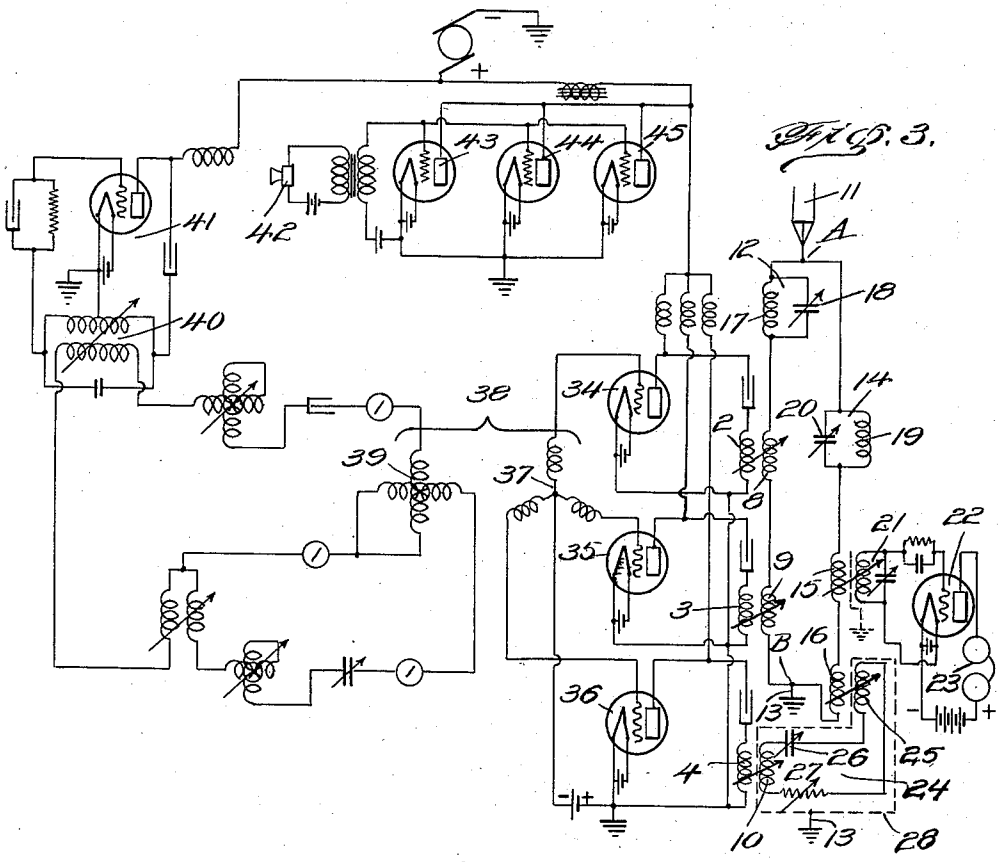
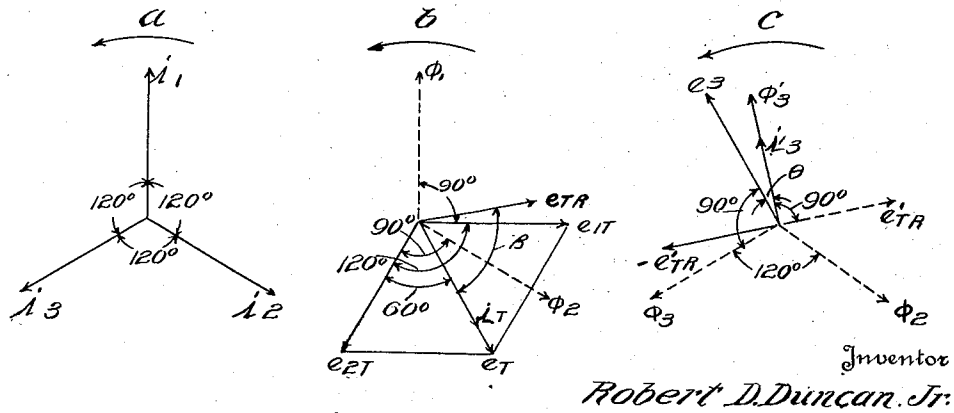


Fig. 4.



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UNITED STATES PATENT OFFICE

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DUPLEX HIGH-FREQUENCY TELEPHONE SYSTEM

Application filed December 23, 1925. Serial No. 77,290.

My invention relates broadly to electrical signaling and more particularly to a duplex high frequency telephone communication system.

One of the objects of my invention is to provide a practical circuit arrangement for the simultaneous operation of signal transmission and reception apparatus in a communication system at the same terminal without interference of the transmitting energy upon the local receiver system.

Another object of my invention is to provide a polyphase system of radio telephone communication where high frequency signaling energy is impressed upon the utilization circuit such as a line wire system or a radio antenna, which also connects with the receiving system for the simultaneous transmission and reception of modulated high frequency current, where the currents in one of the phases of the transmitting system are employed to eliminate currents introduced into the receiving circuit by the local transmitter, for preventing local interference.

Still another object of my invention is to provide a three phase high frequency current transmission system operating into a radiating system or carrier wave line wire system with a receiving apparatus connected in the same system for simultaneous operation on a frequency closely related to the transmission frequency, with means in the receiving apparatus for deriving energy from one of the phases of the transmission system for counteracting the local effects of the transmitter upon the receiver.

A further object of my invention is to provide a duplex radio telephone system in which simultaneous two way communication may be conducted on the same antenna without interference from side talk in the receiving system due to the local transmitter.

Heretofore in the art duplex systems of radio telephony on the same or on closely adjacent antennæ have been relatively complicated and have depended largely upon "bridge" or balanced circuits in which the effect of the transmitting circuit is neutralized or balanced in so far as it acts upon the receiving apparatus. Due to relatively high power of a normal high frequency transmitter and to the extreme sensitivity of the receiving equipment without such balancing circuits, even with the transmitting and receiving frequencies fairly widely separated, the intense magnetic and static fields established by the transmitting current tend to paralyze the receiving apparatus and render it practically impossible to simultaneously transmit and receive on the same or on closely adjacent antennæ.

By my present invention I provide a three phase high frequency generating system with connections for impressing a portion of the high frequency energy upon a utilization circuit. The receiving system is located closely adjacent the transmitting apparatus and a link circuit is provided between the transmitting system and the receiving system for impressing upon the receiving system a portion of the high frequency energy from the transmitting circuit. The receiving system has a normal voltage induced therein due to its direct connection with the transmitter. By virtue of the peculiar phase relations existing in a three phase system, the high frequency energy which is arbitrarily introduced into the receiving system from the transmitting system has its time phase in direct opposition to the time phase of the energy existing in the receiving circuit by action from the transmitting circuit as a result of which interfering currents in the receiving system are neutralized and the receiving circuit functions without interference from the local transmitting system. In this manner simultaneous transmission and reception on the same antenna or the same wire utilization circuit may be conducted without mechanical switching means between the transmitting and receiving apparatus.

In my Letters Patent 1,591,025, dated July 6, 1926, a method of duplex radio telephony, i. e., simultaneous transmission and reception is described, wherein the transmitting and receiving antennæ are separate but are closely adjacent, the method being based on the peculiar phase relations existing in a three phase high frequency current system. The present invention relates also to a system of

duplex high frequency telephony and employs three phase high frequency current for transmission but discloses circuit arrangements wherein the same antenna is employed for transmission and reception, which feature is of extreme advantage where space for the erection of antennæ is restricted such as on shipboard or on aircraft. The present system is also applicable to carrier current or wired radio operation over a line wire system, such as a pair of telephone wires or conductors for an electric power distribution system where in effect the transmitting and receiving antennæ are one and the same by virtue of the inherent constructions of the system.

The difficulties of obtaining a satisfactory duplex high frequency telephone system with the same or with closely adjacent transmitting and receiving antennæ, as herein set forth, are all overcome by the present invention.

My invention will be more fully understood from the specification hereinafter following by reference to the accompanying drawings, wherein:

Figure 1 shows diagrammatically the fundamental system of connection according to my invention for space radio operation on a single antenna; Fig. 2 is a modification of Fig. 1 showing the adaptation of my invention to a carrier wave line wire system; Fig. 3 shows the complete circuit connections for a duplex space radio system; and Figs. 4, *a*, *b*, *c*, are vector diagrams of the different currents, voltages and magnetic fluxes that are established in the transmitting and receiving circuits of the system of my invention.

Referring to Fig. 1, the numeral 1 represents a source of three phase high frequency current assumed to be modulated by the voice or otherwise by methods not shown and not here essential. Source 1 operates into three Y connected primary inductances (△ connection may be employed), 2, 3, 4 of transformers 5, 6 7. Inductively coupled to primary inductances 2, 3, are respectively, secondary inductances 8, 9, which are connected in series with each other and with the antenna 11, parallel tuned circuit 12, and ground 13. Connected between points AB, i. e., in parallel with circuit 12, inductances 8 and 9, is series circuit composed of parallel tuned circuit 14, and inductances 15, 16. Circuits 12 and 14 respectively, are composed of inductance 17, capacity 18, and inductance 19, capacity 20. Inductively coupled with inductance 15 is receiving circuit 21, and electron tube detector 22, containing telephone receivers 23 in its plate circuit. Inductively coupled to primary inductance 4, and to inductance 16 is circuit 24 made up of inductances 10 and 25, variable capacity 26 and variable resistance 27. Circuits 19, 21 and 24 are shown to be shielded by metallic shielding 28, grounded at 13, a preferred feature of this invention. An equivalent of antenna 11 is shown in dotted lines as a closed circuit made up of inductance 29, and capacity 30.

The circuits shown in Fig. 2 are similar to those of Fig. 1, with the exception that antenna 11 is replaced by carrier wave transmission lines 31 which are connected with points AB through capacities 32, 33.

In Fig. 3 I have shown a complete radio transmitting and receiving system embodying the principles of my invention, in which an electron tube three phase high frequency generator of the kind more particularly described in my co-pending application Serial No. 61,019, filed October 7, 1925, and my Letters Patent 1,578,881, dated March 30, 1926. Reference is made to the said co-pending applications for a complete description of the three phase high frequency current generator. For the purpose of explaining the operation of the duplex system of the present application it will be sufficient to observe that a single phase high frequency current generator of any suitable type, illustrated here by reference character 41 as of the self-excited electron tube type, is connected as illustrated by reference character 40 to the tuned system 39 which is coupled through the Y connected inductance system 37 with electron tube high frequency power amplifiers 34, 35 and 36, the output circuits of which impress polyphase high frequency signaling energy on the transmitting antenna system 11, through coupling coils 2—8 and 3—9. Energy delivered from amplifier circuit 36 is impressed upon the link circuit 24 through coupling coils 4—10, and is in turn impressed upon the receiving system through coupling coils 25—16. Modulation of the system is secured through parallel connected tubes 43, 44 and 45, controlled from microphone 42, connected in the input circuit of the amplifier. The receiving system is coupled to the antenna circuit through inductances 15—21, as described in connection with Fig. 1.

The operation of circuits of Figs. 1 and 2 is as follows:

Referring to Fig. 4 and Fig. 1, three phase high frequency currents i_1, i_2, i_3, are generated by three phase source 1 and have the relationship represented in vector diagram *a* of Fig. 4 where they are displaced in time phase by 120°. The vectors are, in accordance with convention, assumed to rotate in a counter-clockwise direction. Current i_1 establishes magnetic field φ_1 shown vectorially in Fig. 4ᵇ, in time phase with i_1 and which links inductances 2 and 8 as indicated by a dotted line in Fig. 1. Magnetic field φ_1 induces a driving voltage e_{1T} in inductance 8, lagging in phase as shown in Fig. 4ᵇ by 90°. The same is true with magnetic field φ_2 linking inductances 3, and 9, as shown in dotted lines in Fig. 1, produced by current i_2, which in-

duces a second driving voltage e_{2T} in inductance 8 and lagging behind the magnetic vector φ_2 by 90° as shown in Fig. 4[b]. In a normal balanced system $i_1=i_2$, $\varphi_1=\varphi_2$, and hence $e_{1T}=e_{2T}$. The resultant driving voltage existent in the transmitting branch of the antenna circuit is the vector sum of e_{1T} and e_{2T} or e_T, shown in Fig. 4[b], which due to the 120° phase relation is equal in amplitude to e_{1T} or e_{2T} and lags the former or leads the latter by 60°. Now the antenna circuit 11, composed of the inherent antenna inductance and capacity 29 and 30 together with circuit 12, and inductances 8 and 9, is adjusted to be in resonance with the transmitting frequency f_T of source 1, and hence the transmitting current i_T which will exist under the action of driving voltage will be substantially in phase with e_T, as shown in Fig. 4[b]. Parallel tuned circuit 12, which may or may not be required, is adjusted for resonance to the receiving frequency f_R which is different from the transmitting frequency f_T. If f_R is greater than f_T, circuit 12 will have the properties of an inductance at frequency f_T; if f_R is less than f_T, circuit 12 will behave as capacity at frequency f_T. In either event with the proper adjustment of inductance 17, and capacity 18 of circuit 12, the effective reactance of circuit 12 at frequency f_T will be small compared with reactance of inductances 8 and 9, and hence the voltage e_{TR} established between points A—B of the antenna circuit will lead the transmitting current i_T by an angle B, shown in Fig. 4[b] to be slightly less than 90°, since for efficient operation the resistances of inductances 8, 9, will be low in comparison with their reactances. Now voltage e_{TR} is impressed directly across the receiving branch of the antenna circuit composed of circuit 14, and inductances 15 and 16, and will, unless balanced out, produce interference in the local receiving circuit 21—22. Circuit 14 made up of parallel connected inductance 19 and capacity 20 is adjusted for resonance at the transmitting frequency f_T, and hence will offer a very high impedance (infinitely high in the ideal case) at this frequency. Under this condition the major portion of the transmitting current i_T will pass into the elevated portion 11 of the antenna and be available for radiating signals; only a fraction of the current i_T will be diverted from the antenna back to the ground connection 13, through the receiving branch 14, 15, 16. Experience has shown that however perfect it is practically possible to make the rejecting properties of parallel tuned circuit 14, with relatively high transmitting powers and sensitivities of the local receiving circuits, the small fraction of the transmitting current which flows back to the ground through the receiving branch is sufficient to produce serious interference with the local receiver and render simultaneous transmission and reception practically impossible even with widely separated values of f_T and f_R. To still further reduce this "residual" interference, use is made of the third phase of source 1 in the following manner. Current i_3 establishes magnetic field φ_3 in phase with i_3, but lagging behind φ_2 by 120°, as shown in Fig. 4[c], which links inductances 4 and 10 as shown in dotted line in Fig. 1. Magnetic field φ_3 induces a driving voltage e_3 in inductance 10 of circuit 24 as shown in Fig. 4[c] lagging φ_3 by 90°. Circuit 24 by virtue of adjustments of inductances 10, 25, and variable capacity and resistance 26 and 27, is preferably adjusted to be slightly off resonance, here shown in an inductive direction, so that the current i^1_3 established by voltage e_3 lags e_3 by an angle θ, as shown in Fig. 4[c]. Current i^1_3 establishes a magnetic field φ^1_3 in phase with i^1_3 and which links inductances 25 and 16 as shown in dotted lines in Fig. 1. Magnetic field φ^1_3 induces a driving voltage e^1_{TR} in inductance 16 lagging φ^1_3 by 90° as shown in Fig. 4[c]. The amplitude of e^1_{TR} is variable and is determined by the intensity of current i_3, the degree of coupling at inductances 4, 10 and 16, 25, and variable resistance 27.

It will be noted that the voltage e^1_{TR} substantially coincides in phase with e_{TR}; a 180° reversal in phase may therefore be obtained by having the couplings at inductances 4—10, and 16—25 reversed with respect to each other, in which condition the balancing or neutralizing voltage $-e^1_{TR}$ is obtained which is substantially opposite in phase to e_{TR} and may be made equal in amplitude therewith. Interfering currents in the receiving branch of the antenna may therefore be completely balanced out. The shielding of currents 14, 21 and 24 has been found preferable as electric fields are thereby prevented from acting upon the circuits so shielded and a more complete balancing out of interference obtained.

The receiving wave of frequency f_R impinging upon the elevated portion of the antenna will establish currents therein of that frequency. Two paths are presented for the passage of these currents, the transmission branch 12, 8, 9, and the receiving branch 14, 15, 16. Now the complete receiving antenna circuit 29, 30, 14, 15, 16 is tuned to resonance for frequency f_R and hence offers a low impedance to currents of this frequency. Parallel tuned circuit 12 is adjusted to resonance for receiving frequency f_R and hence the transmission branch containing circuit 12 will offer an exceedingly high impedance to currents of frequency f_R. Therefore, the major portion of the receiving current will flow through the receiving branch 14, 15, 16 and affect in the desired manner the receiver circuit 21, 22.

By the methods and circuits just disclosed simultaneous radio telephone transmission and reception on the same antenna system may be conducted with suitable transmitting

and receiving frequencies without either complete paralyzing of the local receiving apparatus by the local transmitter or giving rise to excessive and disturbing side tones. In fact, the absence of side tones may be so complete, that the operator will be unable to hear any of his own conversation, which for many reasons is often an undesirable condition so that the balance obtained at link circuit 24 may be arbitrarily disturbed so as to yield side tones of the required intensity.

I have illustrated only one method of modulation which may be employed in the transmitting system, but it will be understood that grid modulation or other arrangements of circuits may be provided for effecting the transmission of signals. It will also be understood that I may employ other arrangements of detector circuits and that a crystal detector may be used in lieu of the tube detector illustrated herein, or various arrangements of amplification systems may be provided at the receiver for reproducing the desired signals.

The complete freedom from disturbing side tones is brought about by the doubly branched antenna circuit and the introduction of a neutralizing voltage into the receiving branch for obtaining duplex operation. The phase relations of the currents in the system described herein as distinct from other systems employing a double branched antenna and a neutralizing voltage obtained by elaborate phase displacing circuits, are automatically fixed by the three phase source and the system accordingly lends itself towards extreme simplicity and stability in operation. The variable features of the link circuit and the circuits 12 and 14 permit adjustments to be made in order to adjust for departures from more or less ideal conditions in the system.

While I have described my invention in certain particular embodiments I desire that it be understood, that modifications may be made and that no limitations upon the invention are intended other than are imposed by the scope of the appended claims.

What I claim as new and desire to secure by Letters Patent of the United States is as follows:

1. In a simultaneous transmission and reception system of radio telephony, the combination of an antenna-ground system, two branch circuits connected in parallel, one of said branch circuits containing a parallel tuned circuit, said parallel connected branch circuits connected in series with said antenna-ground system, a signal receiving system, said signal receiving system connected with said branch circuit containing said parallel tuned circuit, a source of three phase high frequency electrical energy, said second branch circuit connected with two phases of said three phase source, said parallel tuned circuit of one of said branch circuits adjusted substantially to resonance for the frequency of said three phase source, a linking circuit connected with the third remaining phase of said three phase source and with said branch circuit containing said parallel tuned circuit, said combination providing means for eliminating interfering signals produced in said receiving system by said source of three phase high frequency energy.

2. A radio telephone transmitting and receiving system comprising in combination a source of modulated three phase high frequency current, at least one inductance electrically associated with each phase of said source and interconnected in a three phase manner, a single antenna system, a pair of branch circuits disposed in parallel with said antenna system, said circuits containing a plurality of inductances, two of said inductances being inductively coupled with two of said first mentioned inductances, a signal translating and responsive means associated with one of the inductances in said antenna system, a link circuit containing at least two inductances in series connection, one of said link circuit inductances inductively coupled to the remaining of said three first mentioned inductances, the remaining of said link circuit inductances inductively coupled with another inductance adjacent said signal translating and responsive means, said link circuit being adjusted to establish in said signal translating and responsive means a current for neutralizing the effects of said source.

3. A radio telephone transmitting and receiving system comprising in combination a transmitting system having a source of three phase high frequency current, a plurality of electron tube circuits corresponding in number to the number of phases of said source, an input circuit for each of said electron tube circuits, inductances in each of said input circuits electrically associated with each phase of said three phase source, an output circuit for each of said electron tube circuits, said output circuits each containing an inductance, an antenna system, a pair of branch circuits disposed in parallel with said antenna system, one of said circuits being inductively coupled to two of said output inductances, independent inductances in said antenna system, means for effecting telephonic modulation of the high frequency energy existent in said electron tube circuits, a signal translating and responsive means electrically associated with one of said independent inductances, a link circuit containing a plurality of inductances, said link circuit inductively coupled to the third of said output inductances of said electron tube circuits and to another of said independent inductances, the adjustment of said transmitting and receiving antenna

systems and of said link circuit by virtue of the opposing phase relations of the voltages established in said antenna system by the current in said transmitting system.

4. A radio telephone communication system comprising in combination a common antenna system, a pair of branch circuits connected in parallel thereto, a source of unmodulated three phase electrical energy, means for impressing energy from two phases of said three phase source upon one of said branch circuits, means for impressing energy from the third remaining phase of said source upon said other branch circuit for neutralizing the effects in said last named branch circuit of the high frequency electrical energy transmitted by said common antenna system, and means interposed between said three phase source and said means for impressing energy from said source upon said antenna systems for effecting telephonic modulation of said three phase high frequency electrical energy.

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