May 10, 1927. 1,627,718

P. WARE

RADIOTELEPHONY

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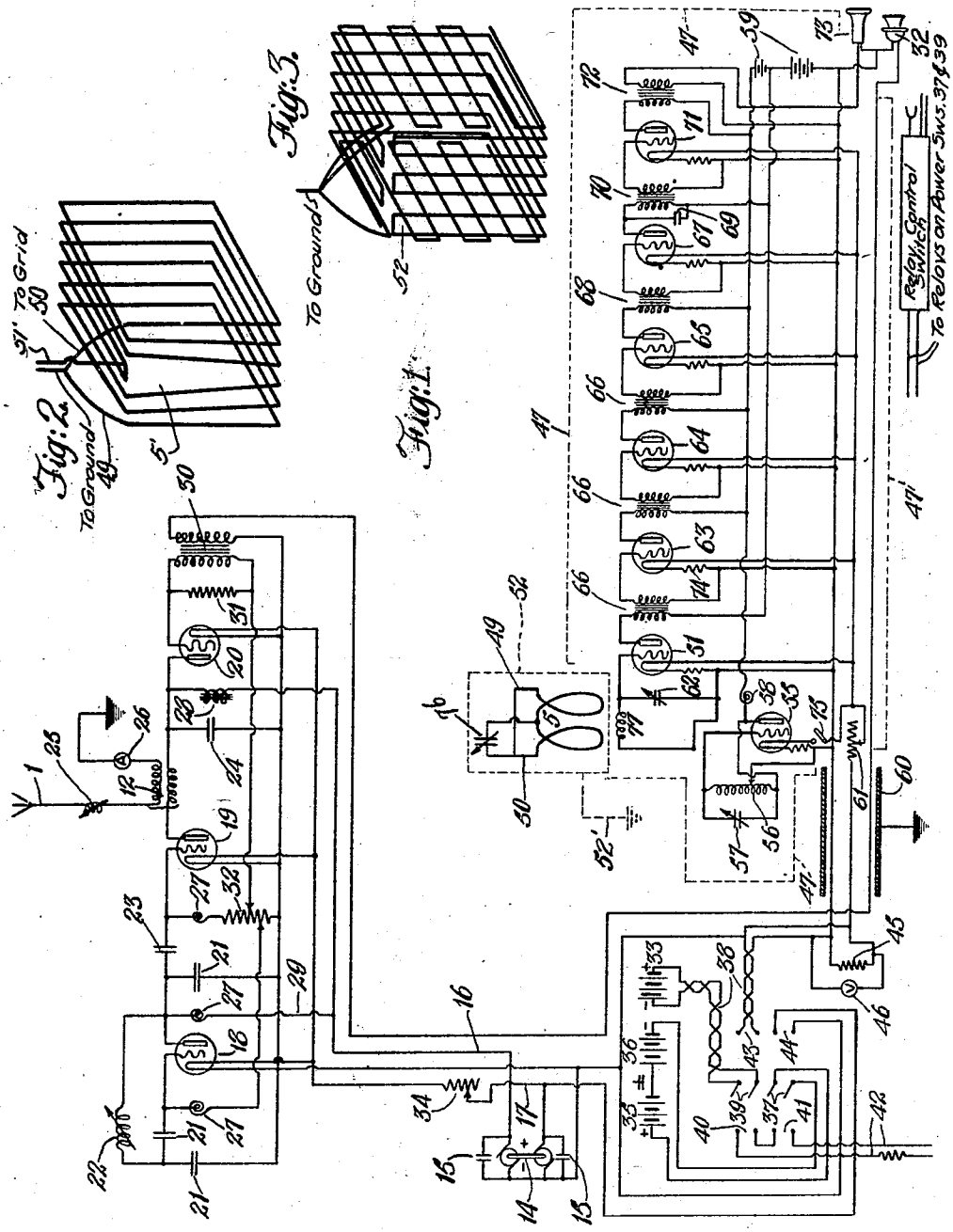

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By his Attorney J. D. Worster

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UNITED STATES PATENT OFFICE.

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RADIOTELEPHONY.

Application filed September 3, 1921. Serial No. 498,339.

This invention relates to duplex or two-way radio communication, more particularly to communication by telephone, wherein communication can be had over considerable space, without manipulation of switches or varying circuit conditions as between sending and receiving, in a manner similar to present day wire telephone communication.

The invention employs at a station a power radiating element or antenna separate from the element receiving incoming oscillations, herein shown as a loop which has especial advantages in the system herein disclosed over an ordinary antenna for receiving, as will be hereafter pointed out.

The objects of the invention generally are to enable separate transmitting and receiving elements to be installed within reasonable distance of each other, as in the same building, without causing the receiving system to be paralyzed by the powerful transmitting system, while maintaining the necessary sensitiveness; to provide an efficient system wherein power losses are reduced to a minimum; and also to provide a system which will require no radio skill to operate and which can be easily set up and used in outlying districts or where space is limited without requiring a large fixed plant or ground area. Such a system is herein provided wherein the transmitting element can be on the roof of a building and the receiving loop element either on the same roof, or within one of the rooms, without interfering one with the other and each station operated by automatically or manually controlled batteries and a dynamotor, the batteries being chargeable when the system is not in operation from any suitable source of power.

So far as I am aware, there is no system as above outlined at present on the market or available in the art, notwithstanding that there is an enormous field for such a system either for telephonic communication in districts without any electrical communication at all or where present wire telephones and telegraphs are more expensive or too restricted in operation, or where it is desired to extend the present radius of communication of wire telephones by radio. The circuits of this system are so arranged that they can be attached to ordinary wire telephone circuits, which has heretofore been a difficulty in duplex radio extensions of wire telephones.

In carrying out the invention, both the transmitting and receiving circuits are improved in various particulars, together with novel means confining the various currents to their own proper circuits, and for shielding and protecting the receiving equipment from undesirable coupling with adjacent metallic objects such as pipes, frames of buildings, fixtures, etc., which might carry transmitter high frequency energy.

Any suitable source of power may be used for transmitting, but as shown herewith, a storage battery and dynamotor, having suitable means for eliminating its ripple, are provided. The transmitter includes master oscillator, power amplifier and power modulator vacuum tubes, the circuit containing such tubes being preferably loosely coupled through an adjustable output transformer to the transmitting element radiating continuous carrier wave oscillations. The telephone transmitter is adjacent the telephone receiver, as in wire telephony, and is connected in circuit with the primary of a modulation transformer whose secondary is connected with the power modulator and remainder of the transmitting circuit. An important feature of this transmitting system is that it is free of operating adjustments, being set once for all and operating without skilled attention under intended conditions.

Although an ordinary receiving antenna may be used with such a transmitting system, a loop receiving element has a number of advantages, especially for duplex operation. The improved loop receiving arrangement in conjunction with the transmitting high frequency circuit localized adjacent the antenna as disclosed herein, has the additional advantage, however, of permitting much more closely situated sending and receiving equipment under conditions encountered in practice than has heretofore been possible to obtain. A preferred arrangement is to localize the transmitting high frequency equipment in a weather proof box at the antenna, as on the roof of a building. The transmitting vacuum tubes should be in a separate ventilated but burglar proof compartment of this box. The loop receiver

and its associated radio frequency circuits may also be out of doors, but it is of advantage to locate it indoors, especially if a storage battery is used to heat the receiving tube filaments and it is desired to locate this storage battery at the position of the transmitting storage battery, as herein provided, because if the receiving circuit is located near the battery position there will be less power loss in the connecting lines and consequently a smaller battery is required than otherwise.

By a novel system of shielding and the utilization of a loop of small size I am able to install the receiving set in an ordinary room without affecting its sensitiveness or permitting it to be affected by induction from the local transmitter, as through the frame of the building, pipes, and other metallic objects. The receiving system contains a loop with its flat side approximately toward the antenna to pick up a minimum of transmitter energy, and pointing to the distant station and is preferably of the heterodyne type, as shown, wherein local oscillations derived from the transmitter, or preferably from a separate local oscillator, are of such difference in frequency from the voice modulated incoming oscillations as to produce a voice modulated signal beat frequency, which is preferably out of audibility frequency, this beat frequency being amplified by one or more amplifiers, and finally demodulated or translated into the desirable voice frequencies in the telephone receiver.

I have found that a small electrostatically shielded loop of novel form can be installed in a room with the receiving tubes, transformers, etc., inside the loop for compactness if desired, without being affected by adjacent pipes, columns, gas meters, etc., with successful results, thus providing a high frequency duplex telephonic communication system through space, using a desk telephone set automatically controlling the power unit from the desk set hook and completely eliminating all operating adjustments, throw-over switches or the like.

The matter of efficiency is important in automatically controlled systems of this character, which must operate for considerable time without attention, because thus far only the smaller sizes of vacuum tubes have been developed to operate on reasonably low plate voltages that are satisfactory for this service.

In this system, the transmitting high frequency is isolated to the transmitting radiating system, eliminating the customary lead-in wires, as on the roof, if the installation is made on and within a building, while a novel system of sheathed cables connecting the several units effectively prevents interferences.

The accompanying drawing shows a diagram of a preferred form of the invention, wherein—

Figure 1 shows a complete diagram of the invention,

Figure 2 is a diagram of a suitable oppositely wound loop, and

Figure 3 shows the loop shield.

Referring to Figure 1, the upper part of the figure represents the transmitting unit, left hand lower part of the figure is the power unit, and the right hand lower part the receiving unit. The transmitter apparatus is supplied with power from a dynamotor and storage battery, which is charged from a suitable source of supply, and controlled by a main switch having one position for sending and receiving, and another for charging.

The power supply switches 37 and 39 (Fig. 1) may be manually operated, if desired, or automatically operated through holding relays coacting with the switches biased by gravity or spring means to normally remain open. The holding relays may be controlled from a remote relay control switch 39′ provided with a switch hook, as shown, and so arranged as to close the holding relay circuits when the receiver 73 is lifted from the hook, or to open said circuits when the receiver is replaced thereon. The antenna 1 is loosely coupled by output transformer 12 to the high frequency power circuit of tube 19. 14 is the dynamotor with condensers 15, and its output side supplies high voltage power to the master oscillator 18, amplifier 19 and modulator 20. 21 are condensers, 22 an adjustable inductance for setting the frequency, 23 is a coupling condenser of proper capacity to drive the power amplifier tube 19, and 24 is a blocking condenser. The modulation system is a constant current one, wherein the sum of the currents to the modulator and amplifier tubes 20, 19, is constant at voice frequencies. 25 is an adjustable tuning inductance to tune the antenna to resonance as indicated by ammeter 26.

Transformer 12, instead of functioning like the usual oscillation transformer between a closed primary supply circuit and an antenna circuit, is similar to a power transformer where the primary current drops very low on open circuit. This is effected by a high primary impedance at the band or range of operating frequencies when the secondary is detuned or open-circuited, thus protecting tube 19 from destruction, if the antenna breaks or becomes detuned. In addition, the secondary fits loosely over the primary and the coupling is finely adjustable. This avoids the use of taps on the secondary to adjust the antenna load for maximum plate circuit efficiency in tube 19, regardless of antenna characteristics within reasonable limits. This avoids variation of

efficiency in using taps, and can be set at the time of installation to get the best output. A readjustment is required, of course, if the antenna changes its characteristics, but in practice this is only necessary over quite long periods of time. A further advantage of the loose coupled secondary is that in conjunction with the master oscillator-power amplifier, circuit radio frequency chokes in the cable between the transmitting unit and power unit, are not found to be necessary to confine the transmitter high frequency to the antenna circuit. It is very desirable, of course, to eliminate these chokes especially those in series with the filament lines because of the great power loss.

The positive terminal of the dynamotor 14 is connected to the plates of the tubes 19 and 20 through the voice frequency reactance 28 by the wire 16 and to the plate of tube 18 through the high frequency choke 27 by the branch wire 29. 30 is a modulation transformer having high resistance 31 across its secondary to improve the modulation. The resistance 32 acts as a grid leak unit for independently regulating the grid-filament operating potentials of all three transmitting tubes 18, 19, 20 and obviating a separate battery to make the grids negative. The primary of transformer 30 is in series with battery 33 and telephone or other source of speech 32. 34 is a resistance for regulating the filament currents of tubes 18, 19, 20 as supplied by batteries 35, 36 connected to switch points 37. The leads 38 of battery 33 are twisted as shown for a purpose hereafter to be described, and lead to switch points 39. The points 40, 41 are for charging all the batteries in series, when connected with the respective points 37, 39 from suitable power source 42. The switch points 39 close on points 43 and points 37 on points 44, when the system is in operating condition.

The batteries 35, 36 operate the dynamotor 14 and heat the filaments of tubes 18, 19, 20 and battery 33 operates the telephone transmitter 32 and heats the filaments of the receiving tubes. All of the batteries discharge at the same rate because shunt resistance 45 is adjusted to increase the discharge rate of the battery 33 up to that of batteries 35, 36. 46 is a voltmeter to indicate the condition of charge of the batteries, at constant load, and is a certain indicator, inasmuch as the batteries always discharge at the same rate. A mark on the dial indicates the operating point below which the batteries should be charged.

For eliminating commutator ripple, the armature of dynamotor 14 is skew slotted, as about three-quarters of the slot pitch, which in conjunction with condensers 15 and choke 28, completely smooths out the ripple in the dynamotor output current so that it is not heard in the local receiving set.

The receiving filament wires 38 are twisted as shown, to prevent low frequency induction in the receiving set from the wires connected to batteries 35, 36, which run the dynamotor.

The receiving unit is equipped with a comparatively small loop aerial which may be of the ordinary type but is preferably of one of the forms shown in Figs. 1 and 2. The loop 5, Fig. 1, is double with each half wound in the opposite direction and may be connected as indicated in circuit with a variable tuning condenser 76 and loosely coupled through the coil 77 to the input circuit of the detector 51. If the loop 5′ (Fig. 2) which is also double oppositely wound, is used instead of the loop 5, the free ends 49′ and 50′ of this loop are connected together and grounded, and the mid-point of the coil is joined to the lead 51′ which establishes a connection to the grid of the detector tube 51 of the receiver unit. The receiver loop (5 or 5′) is shielded from local transmitter oscillations by any suitable means, but preferably by the electrostatic, open circuited shield or cage 52, Fig. 3. This shield consists of a special form of cage or coil of conductive material adapted to entirely surround the loop and be slightly spaced from it. The preferred construction comprises groups of spaced, parallel conductors connected in series with one end only of each group connected to the common grounded conductor 52′. This arrangement provides an open circuited metallic cage surrounding the loop on all sides and serves to shield it from local transmitter energy without impairing its effectiveness for the reception of incoming signals. As indicated by the dotted lines in Fig. 1, the shield 52 may enclose the loop 5 and its tuning condenser 76, the remainder of the receiving equipment being enclosed in the metal box 47 provided with suitable openings to bring in the connections from the transmitter and power units and those from the desk telephone set.

The local oscillator 55 comprises a tube with inductance 56, variable capacity 57 to change its frequency, and receives plate circuit power through the radio frequency choke coil 58 from battery 59. The filament current comes from battery 33 through switch points 39, 43, wires 38 in grounded metal covered conductors 60, and adjustable resistance 61. The loop circuit is tuned by variable capacity 76 to the frequency of the incoming signal and is coupled to detector circuit through coil 77. Coil 77 also receives local oscillations from nearby circuit of tube 55 to form an intermediate heterodyne beat frequency in the output circuit of detector 51. This beat frequency is amplified by tubes 63, 64, 65 coupled by transformers 66. This intermediate frequency is then rectified by tube 67 coupled to the output circuit

of tube 65 by transformer 68. 69 is an intermediate frequency by-pass condenser across the primary of transformer 70 which couples tube 67 to audio frequency amplifier tube 71, the transformer 70 and tube 71 constituting an audio frequency stage of amplification. Transformer 72 adapts the output of tube 71 to telephone receiver 73. The filaments of tubes 55, 51, 63, 64, 65, 67, 71 are heated by battery 33, while both parts of the battery 59, in series, supply plate current to tubes 55, 63, 64, 65, 71, and one part supplies plate current to tubes 51, 67. All of the receiving tubes employ filament grid-bias resistances 74 as shown to regulate the grid potentials.

The use of the local oscillator 55 to heterodyne with the incoming signal frequency is of advantage in that it avoids the necessity of employing a predetermined difference between the incoming and outgoing frequencies, but the transmitter frequency can be employed with a proper frequency difference by cutting out oscillator 55 as by switch 75, and making the proper transmitter frequency adjustments. The main difficulty, however, in using the transmitter to heterodyne the incoming carrier wave, is in arranging the sending and receiving high frequency equipment to give the proper amplitude of local oscillations in tube 51 to produce maximum amplification, whereas by employing the local oscillator 55 the degree of coupling between the local oscillator circuit and 51 is such as to give maximum heterodyne amplification, and is fixed, no matter what are the conditions of installation of the equipment. Another advantage in employing the separate receiving oscillator is that the receiving set will function whether or not the transmitter is going. This permits the station to be in condition for receiving a call when the transmitter is off. And still another advantage is that by excluding the transmitter radio frequency out of the receiver the latter can be connected by well-known methods to an ordinary wire telephone system, without howling. The amplification of the beat frequency and then re-detection, is of advantage because of greater efficiency and quietness than either high frequency or audio frequency amplification will afford. This applies particularly to short wave reception. For the longer waves, however, straight radio-frequency amplification is quite satisfactory for this system.

As shown in Figure 1, conductors connecting the receiving unit with the power and transmitting units are enclosed in metal sheathing to prevent the passage of high frequency currents. If the wires to telephone set 32, 73 are short no metal covering is necessary on them. In practice this provides a very compact and convenient receiving element capable of being installed on a roof, with suitable weather proofing, or in a room of a building with the transmitter set and the antenna on the roof at one side, without one interfering with the other. This is by reason of localizing the transmitter high frequency apparatus adjacent the antenna, which may either be run in connection with a ground as shown, or have a counterpoise, and controlling the transmission from wherever it is convenient to locate the operating position. If the transmitting and power units are separated some distance, and the connecting conductors pass near the receiving unit, it will also be found necessary to enclose these conductors in metal sheathing preferably grounded. The object of grounding, of course, is to prevent transmitter radio frequency energy from passing through the sheathed conductors. The shielded receiving loop is at one side pointing at the distant station with one side approximately toward the the antenna to pick up little or no energy from the transmitter. In this connection, it is important to note that the master oscillator transmitting circuit with loosely coupled output transformer, or other means for confining the high frequency transmitter power to its own radiating circuit, in conjunction with the metal sheathed cables between the various units, effectively prevents paralysis of the receiving loop system by the transmitter, even when located in and on the same building. Small loops in general and especially of the form disclosed herein are very desirable for receiving, in that they pick up much less induction, etc., in operating positions such as factories, than do antenna-ground systems. Loosely coupling the receiving set to the loop increases the selectivity, and is found desirable in locations where there is considerable interference from other stations and induction. In using loose coupling, as between the tuned loop and a secondary coil, care should be taken to avoid any stray capacity coupling. A preferred arrangement is to mount the little secondary coil 77 outside of the loop shield, together with the rest of the receiving equipment in a metal box, but this loose coupling can be anywhere in the high frequency circuits between the loop and the telephone receiver.

Should there be found to be interference with the receiver from a very powerful local transmitter the receiving and sending elements can be further separated, but can still be much closer together and give duplex communication, as with wire telephones, than has heretofore been possible with other systems proposed, which have required considerable separation of transmitter and receiver, and expansive land and construction.

After this system is once adjusted upon installation, no further operating adjust-

ments are found necessary, excepting over long periods of time.

A power unit consolidated for both sending and receiving is believed to be new operating, as herein shown and described. If desirable a specially designed motor-generator could be built to run on the available source of power and supply suitable power to run the equipment, but storage batteries have the advantage of rendering the communication independent of power supply interruptions.

What I claim is:

1. In duplex radio telephony, relatively powerful means for radiating outgoing oscillations and means for receiving incoming oscillations located in such proximity that the receiving means tends to be paralyzed by the outgoing oscillations, a telephone receiver connected to be responsive to the incoming oscillations and an adjacent telephone transmitter connected to control the outgoing oscillations, means for supplying power to operate the sending and receiving systems, said receiving means including an antenna provided with an open circuited metallic shield.

2. In duplex radiotelephony, the combination of a sending element and a radio transmitter connected thereto, an antenna provided with an open circuited metallic shield, a radio receiver connected thereto, means for supplying power to the system, and a telephone transmitter and receiver.

3. In duplex radiotelephony, the combination of a transmitting elevated element, a radio transmitter connected thereto, means for setting the frequency of outgoing oscillations independently of the radiating circuit characteristics, a loop receiving circuit, a shield including an open circuited conductive member associated with said loop, a power supply, and a telephone transmitter and receiver.

4. In duplex radiotelephony, the combination of a radiating element, a radio transmitter circuit connected thereto, said transmitter circuit including a master oscillator, an amplifier and a modulator, means for inductively coupling the transmitter to said element, a radio receiving circuit having a loop antenna, an open circuited conductive shielding member enclosing said loop antenna, a source of power operatively connected to the transmitter and receiver circuits, and a telephone transmitter and receiver operatively connected to the respective circuits.

5. In duplex radiotelephony, the combination of a radiating element, a radio transmitter connected thereto, a loosely coupled output transformer, said transmitter comprising an oscillator, an amplifier and a modulator tube, a grid leak regulating resistance unit, a loop receiving circuit having the loop thereof enclosed by a plurality of independent conductive shielding members and the remainder of said circuit enclosed in a single conductive shielding member for preventing local paralysis of the receiving circuit by the transmitter, a source of power, and a telephone transmitter and receiver.

6. In duplex radiotelephony, the combination of a radiating element, a radio transmitter connected thereto, a loosely coupled output transformer having adjustable secondary and high impedance primary when the secondary circuit is detuned, said transmitter comprising an oscillator, an amplifier and a modulator tube, a grid leak regulating resistance unit, a loop receiving circuit having means including a grounded, open circuited, conductive shield for preventing local paralysis of the receiving circuit by the transmitter, a source of power, and a telephone transmitter and receiver.

7. In duplex radiotelephony, the combination of a radiating element loosely coupled to a transmitter, said transmitter including a master oscillator, a consolidated power unit for the system, a receiving unit having a loop antenna, shielding means for preventing electrostatic coupling between said antenna and adjacent metallic objects, means for loosely coupling the antenna to the receiving circuit from the outside of said shielding means, the conductors passing between the power and receiving units being shielded, and a telephone transmitter and receiver.

8. In duplex radiotelephony, the combination of a radio transmitter and a radiating element, a double oppositely wound receiving loop having a receiving set coupled thereto, a consolidated power unit containing dynamotor and storage batteries for energizing both the receiver and transmitter, sheathed conductors passing between the transmitting, power and receiving units, the conductors in the power unit which go to the receiving unit being twisted in a manner to prevent dynamotor noises in the receiving set, and a telephone transmitter and receiver.

9. In duplex radiotelephony, the combination of a transmitter and a radiating element, a shielded loop positioned so as to prevent local paralysis of the receiving set connected thereto, a consolidated power unit comprising storage batteries and a dynamotor, the dynamotor armature being skew slotted, condensers shunted across both the input and output side of the dynamotor, the high voltage circuit containing a low frequency choke coil, and a telephone transmitter and receiver.

10. A duplex radio telephone station comprising separate transmitting and receiving elements, means for preventing local paralysis of the receiving set by the transmitter,

the receiving set consisting of a double, oppositely wound loop, two detectors, a local oscillator and a multi-stage amplifier arranged to amplify an inaudible frequency.

11. In duplex radio telephony, a transmitting set and a radiating element, a receiving set in the field thereof positioned for reception from a distant station and for minimum collection of local transmitter energy, and a grounded, open circuited shield enclosing said receiving set for preventing paralysis of the receiver by the local radiating element.

12. A duplex radio telephone station comprising a master oscillator power amplified transmitting circuit, a radiating element loosely coupled thereto through an output transformer, a separate receiving set comprising a local oscillator, a receiving loop shielded from the transmitter oscillations, amplifying and telephone detecting means, a telephone transmitter controlling the outgoing oscillations through a power modulator, a power unit supplying the transmitting and receiving circuits, and means for preventing the transmitting power from affecting the detection of the received signal oscillations.

13. In duplex radio telephony, the combination of a radio transmitter unit having a radiating antenna, a radio receiving unit having a loop antenna, a common power supply for both said units, switch means for controlling the supply of power to each unit, relay means including a switch hook for remotely controlling the switch means, a telephone transmitter and receiver operatively connected to the transmitting and receiving circuits, said receiver coacting with said switch hook in such manner as to cause said relay means to open or close said switch means.

14. The combination with a relatively powerful source of oscillations and a radiating element therefor for transmitting, of a loop receiving element adjacent said element and within the field thereof positioned relatively to said element as to receive a minimum of local transmitter energy, amplifying and detecting means connected to said loop, and means for shielding the receiving system from local transmitter high frequency oscillations from said radiating element including an open circuited wire cage surrounding said loop receiving element.

15. In radio telephony, the combination of a separately excited power amplifying circuit delivering continuous carrier wave oscillations to a radiating element through an output power transformer, a loop receiving element positioned to pick up a minimum of local transmitter energy and tuned to receive a different incoming frequency, a power supply, and grounded, open circuited shielding means for preventing local paralysis of said element.

16. A duplex radio telephone station consisting of transmitting, power and receiving units, the transmitting unit having means for generating outgoing modulated oscillations controlled by a telephone transmitter and an oscillator for setting the frequency independently of antenna circuit characteristics, the receiving unit consisting of a shielded loop, detector and amplifier and telephone receiver, the units being connected by power supply and control wires and means for preventing high frequency oscillations from passing through said wires, a switch hook for said receiver, and switching means operated by said hook for energizing or deenergizing the transmitting and receiving circuits simultaneously when the receiver is removed from or replaced on said hook.

17. In a duplex radiotelephone system including a transmitting set, a loop receiving set and a common source of power supply for both said sets, the method of operating said system without paralyzing the receiving set by local transmitted energy which consists in balancing out said transmitted energy in the power supply circuit and in the loop circuit, shielding the receiving circuit in a closed circuited metallic conductor and shielding the loop circuit in an open circuited metallic conductor.

Signed at New York in the county of New York and State of New York this 26th day of August A. D. 1921.

PAUL WARE.

CERTIFICATE OF CORRECTION.

Patent No. 1,627,718. Granted May 10, 1927, to

PAUL WARE.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 3, line 17, before the words "The positive" insert the words "27 are radio frequency choke coils"; page 4, line 88, strike out the article "the" second occurrence; page 6, line 15, claim 12, for the word "amplified" read "amplifier"; and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 31st day of May, A. D. 1927.

Seal.

M. J. Moore,
Acting Commissioner of Patents.

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