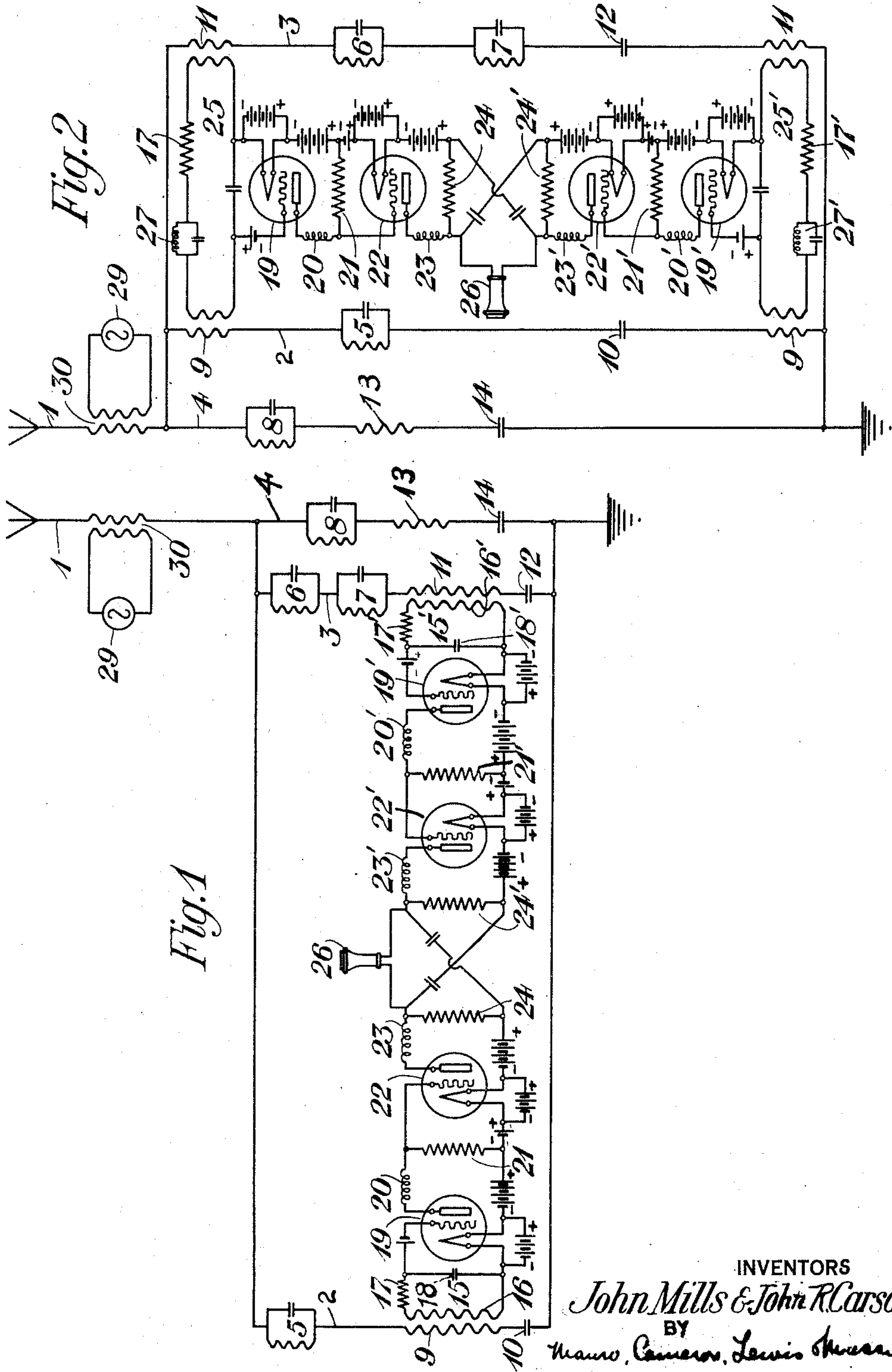


J. MILLS AND J. R. CARSON.
WIRELESS SYSTEM.
APPLICATION FILED OCT. 6, 1915.

1,309,538.

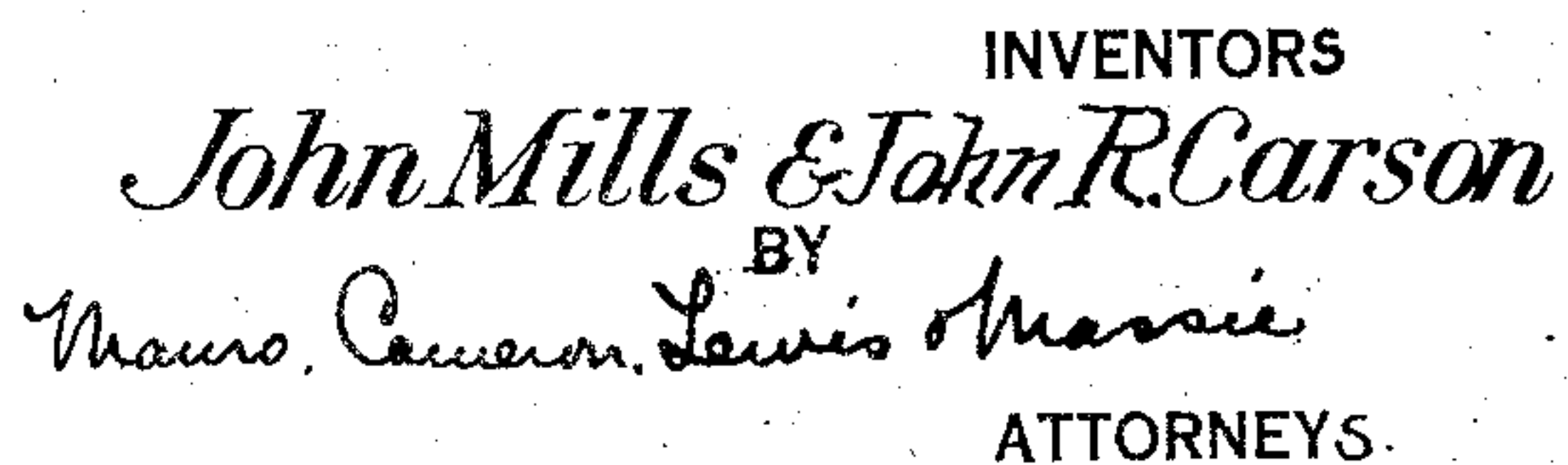
Patented July 8, 1919.
2 SHEETS—SHEET 1.



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1,309,538.

2 SHEETS—SHEET 2.



UNITED STATES PATENT OFFICE.

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WIRELESS SYSTEM.

1,309,538.

Specification of Letters Patent.

Patented July 8, 1919.

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To all whom it may concern:

Be it known that we, JOHN MILLS and JOHN R. CARSON, residing at Wyoming, in the county of Essex and State of New Jersey, and at New York, in the county of New York and State of New York, respectively, have invented certain Improvements in Wireless Systems, of which the following is a specification.

10 This invention relates to a wireless system and more particularly to a wireless system which is designed for duplex operation. Its object is to provide means for protecting the receiving instrument of a wireless system
15 from disturbing oscillations and, in particular, to embody such protective means in a system designed for duplex operation, whereby the receiving instrument is protected both against static disturbances and
20 disturbances arising from the transmitting portion of such duplex system.

It is well known that in wireless telegraphy and telephony the magnitude of the transmitted current is enormously greater
25 than the received current, their ratio sometimes being of the order of one million to one. This enormous ratio renders inapplicable to wireless systems duplex methods which have been successfully employed in
30 wire telegraph and telephone systems.

It is further well known that static or atmospheric interference not only constitutes a serious menace to the successful commercial operation of wireless systems, but also that
35 its elimination presents a very difficult problem. This difficulty inheres in the fact that the natural or characteristic oscillations, set up in a receiving system by a static disturbance, are of substantially the frequency to
40 most strongly affect the receiving device, and that, therefore, static interference cannot be tuned out by a change of wave length, as can persistent interference from a foreign sending station. As regards the elimination
45 of static interference, this invention does not attempt to reduce or eliminate the radio-frequency natural oscillations, but, by interposing detectors between a receiving device and the seat of said radio-frequency
50 oscillations, resultant low frequency oscillations are developed which by a combination of circuits are balanced out with respect to said receiving device. In the several embodiments of the invention in duplex systems, it is contemplated that the system be
55 resonantly responsive to two frequencies,

one of which is that of the signals to be received and the other is that at which signals are transmitted.

The invention may best be understood by 60 reference to the accompanying drawings in which Figures 1 and 2 are diagrams showing two different embodiments of the invention, and Figs. 3, 4 and 5 are diagrams showing
65 different embodiments of the invention in a receiving system with duplex features omitted.

Referring to Fig. 1, 1 is an antenna for the radiation and reception of energy, said antenna containing the primary of an oscillation transformer 30, which couples said
70 antenna with the transmitting apparatus, conventionally represented by a high frequency generator 29. The antenna system has a plurality of branches in parallel, said
75 antenna being grounded through three parallel branch circuits 2, 3 and 4. The branch circuit 4, which may be termed the transmission branch circuit, is tuned to resonance at the transmission frequency, and said branch
80 circuit therefore offers a very low impedance to currents of said frequency. Branch circuit 4 contains a tuning inductance 13, a tuning condenser 14, and an anti-resonant set 8 which is tuned to anti-resonance at the
85 reception frequency. The branch circuit 2, which may be termed the reception branch circuit, contains a tuning condenser 10, a coupling coil 9, and a set 5 which is adjusted for anti-resonance at the transmission
90 frequency. By means of said tuning condenser and said coupling coil the circuit consisting of the antenna 1 in series with the branch circuit 2 is tuned to resonance at the
95 frequency of reception. It will thus be understood that circuit 2 offers a very high impedance to the transmission currents and is adjusted for maximum response to the signals to be received. Branch circuit 3, which
100 may be termed the auxiliary branch circuit, contains a coupling coil 11, a tuning condenser 12, and two sets 6 and 7, the first of which is anti-resonant to the reception frequency and the second of which is anti-resonant to the transmission frequency. The branch circuit
105 3, therefore, offers a very high impedance both to current of transmission and current of reception wave length. It is evident that the organization thus far described has a plurality of degrees of freedom and that as a
110 whole it is resonantly responsive to two frequencies one of which is the frequency of

transmission and the other of which is the frequency of reception. It is further evident that the circuit consisting of the antenna in series with branch 2 is resonant at the reception frequency, while the circuit consisting of the antenna in series with branch 4 as well as branch 4 itself is resonant at the transmission frequency. It follows from the principles of electro-dynamics that there is a third frequency at which branch 3 is most responsive, since the system as a whole has three degrees of freedom.

A receiving device, conventionally represented by a telephone receiver 26, is connected in a symmetrical manner both to branch 2 and branch 3 through amplifiers 22, 22', preferably of the vacuum tube type, detectors 19 and 19', also preferably of the vacuum tube type, and the loosely coupled oscillation circuits 15 and 15'. The same characters, with and without primes, refer to corresponding, similar elements, those without primes, denoting elements connected to the branch 2, and those with primes denoting corresponding and similar elements connected to the branch 3. The oscillation circuit 15 contains a coupling coil 16, a condenser 18, and a resistance element 17, and is tuned to the frequency of reception. The circuit 15' correspondingly contains the elements 16', 18' and 17' and is tuned to the frequency to which the branch 3 is responsive. 20, 23, 20', 23' represent high inductance impedance elements, while 21, 24, 21', 24' represent non-inductive resistance elements.

The operation of the organization shown in Fig. 1 will now be explained. Considering first the phenomena of transmission, it has been already stated that branch 4 offers a very low impedance to the transmission currents, while branches 2 and 3 are substantially anti-resonant at the transmission frequency; it therefore follows that practically all the transmission current flows through the branch 4, and only a very small fraction thereof through branches 2 and 3. However, owing to the enormous ratio of the transmitted and received currents, the fraction of the transmission current flowing through the branch 2, if only one part in one hundred thousand of the total transmission current, will still be much greater than the current excited by electromagnetic waves from the communicating station. It will be seen then, that, in spite of its high impedance to the transmitted current, the oscillation circuit 15 may be excited more strongly by the said transmission current than by the relatively very small reception current to which 15 is tuned to respond. Except for the branch 3 and its associated apparatus, it may well be that, in spite of careful design and sharp anti-resonance, the currents set up in the receiver 26 by the transmission current, will be prohibitively large. One of the functions

of branch 3 and its associated apparatus is, however, to substantially eliminate the transmission interference in a manner now to be explained. Since branches 2 and 3 both contain elements or sets which are anti-resonant at the transmission frequency, they offer substantially the same impedance to the transmission currents. Therefore approximately equal fractions of the transmission current flow through branches 2 and 3, and these fractional currents are of substantially the same phase. The oscillation circuits 15 and 15' are, therefore, excited by equal induction from branches 2 and 3, respectively, and the effects of the current in circuits 15 and 15' after translation and amplification oppose and may be made to substantially neutralize with respect to the receiver 26. When this condition is attained, it is evident that no current corresponding to the transmission current flows through the receiver 26, and therefore the organization satisfies the fundamental condition for duplex operation, namely freedom from transmission interference.

As regards now the phenomena attending the reception of signals from the communicating station (not shown), it is evident that, by virtue of the anti-resonance of branches 1 and 3 to the reception frequency, the system is essentially the same as though branches 1 and 3 were removed, leaving the antenna grounded through branch 2 alone. As has already been stated, the circuit consisting of the antenna in series with branch 2 and the oscillation circuit 15 are separately tuned to the reception frequency. Therefore circuit 15 oscillates strongly in response to the received signals, while circuit 15' oscillates very feebly. The current, then, corresponding to said received signals and flowing through the receiver 26, is essentially independent of the presence of branch 3 and its associated apparatus as well as of branch 4, and hence the arrangement shown is such as to satisfy the condition of efficient reception of signals.

The operation of the organization shown in Fig. 1 in reducing static interference is as follows: When the receiving system as a whole is excited by a static disturbance it oscillates in its characteristic or natural modes of damped oscillations. The predominant oscillation excited by the static disturbance in circuit 15 is practically determined as regards periodicity and damping by the electrical constants of said circuit, that is by the values of its inductance, capacity and resistance elements. Similarly the corresponding oscillation of circuit 15' is determined by the electrical constants of said circuit. The predominant oscillations occurring in circuits 15 and 15' will be of different frequencies, since said circuits are tuned to different frequencies; but such os-

cillations may be made to have the same
 damping factors by assigning suitable
 values to the inductance and resistance ele-
 ments of said circuits. If the said damping
 5 factors are proportioned for equality, the
 voltages impressed on resistances 24 and 24'
 will be of similar form and practically in-
 dependent of the frequency of the natural
 10 oscillations, owing to the translating action
 of the detectors 19 and 19' and the high
 inductive impedance of the inductance ele-
 ments 20, 23, 20', 23'. If the voltages im-
 pressed on resistances 24 and 24' are equal
 15 and similar, the resultant current in the
 receiver 26 is zero. These voltages may be
 made equal in a number of ways, such as
 by proportioning the relative amplifying
 powers of the amplifiers 22 and 22', or the
 20 relative values of the resistance elements 24
 and 24', or the relative values of the induc-
 tances 9 and 11. As regards static elimina-
 tion, the embodiment of the invention shown
 in Fig. 1 contemplates having the receiv-
 25 ing device operatively connected to two par-
 allel antenna branches, the said receiving
 device being so connected to said parallel
 branches that the high frequency natural
 oscillations, after translation by detectors
 or after translation and amplification, op-
 30 pose and substantially neutralize with re-
 spect to said receiving device. It will be
 understood further that, while the receiv-
 ing device is operatively connected through
 detectors, the order of translation and am-
 35 plification is immaterial, and, indeed, that
 though amplifiers are desirable they are not
 absolutely essential.

It should be observed that in order that
 static interference shall be substantially elim-
 40 inated it is essential that the oscillation
 circuits 15 and 15' shall have practically the
 same time factors in order that the natural
 oscillations executed by said circuits shall
 have the same damping. To this end it is

45 necessary that $\frac{R}{L} = \frac{R'}{L'}$ when R and L are
 the resistance and inductance respectively
 of circuit 15 and R' and L' the resistance
 and inductance respectively of circuit 15'.

50 A second embodiment of the invention is
 shown in Fig. 2, which will be readily
 understood from the foregoing explanation
 of the organization shown in Fig. 1. As
 regards the antenna 1, the branches 2, 3
 55 and 4, the detectors, the amplifiers, and the
 receivers, the arrangement of Figs. 1 and 2
 are identical. The difference between the
 two structures is that in Fig. 2 the oscilla-
 tion circuits 25 and 25', corresponding to
 60 oscillation circuits 15 and 15' of Fig. 1, are
 inductively coupled to both branches 2 and
 3. The advantage of this arrangement lies
 in the fact that since, as already explained,
 65 fractional parts of the transmission current
 of essentially the same amplitude and phase

flow through branches 2 and 3, the resultant
 induced voltages in circuits 25 and 25' may
 be made very small, said resultant voltages
 being differential effects which substantially
 vanish when currents of equal amplitude 70
 and the same phase flow through branches
 2 and 3. Further the initial rush of cur-
 rent in branches 2 and 3, consequent upon
 a static disturbance, oppose with respect to
 both oscillation circuits, and the resultant 75
 oscillations in said circuits are retarded and
 reduced in amplitude.

If particularly strong protection is re-
 quired from transmission interference, the
 oscillation circuits 15 and 15' of Fig. 1 and 80
 25 and 25' of Fig. 2 may include sets which
 are anti-resonant to the transmission wave
 length, as shown in Fig. 2, in which 27 and
 27' represent sets anti-resonant to currents
 of the transmission frequency. 85

Certain features of the invention, as re-
 gards static elimination, are not limited to
 a combination designed for duplex opera-
 tion. Fig. 3 shows one embodiment of the
 invention in a receiving system alone. It 90
 will be understood by reference to the draw-
 ings that the structure shown in Fig. 3 is
 the same essentially as that shown in Fig. 1
 with the omission in Fig. 3 of component
 parts whose functions relate to duplex oper- 95
 ation: Such component parts are the trans-
 mitting system proper, branch circuit 4 and
 the anti-resonant sets 5, 7 and 8 of Fig. 1.
 As in Fig. 1 branch circuit 2 is the reception
 branch circuit and the branch circuit 3 is 100
 the auxiliary branch circuit whose function
 is the elimination of interference. A minor
 and non-essential structural difference be-
 tween the two organizations is the mode
 in which the receiver 26 is coupled to the 105
 output side of amplifiers 22 and 22'. In
 Fig. 3, said receiver is shown as differ-
 entially coupled by repeat coils 28 and
 28', preferably designed for operation at
 telephonic frequencies. The operation of 110
 the organization shown in Fig. 3 in elimi-
 nating static interference is precisely the
 same as that of the organization shown in
 Fig. 1 heretofore described.

By omitting the duplex features of Fig. 2, 115
 the structure becomes that shown in Fig. 4.
 The operation of the system shown in Fig.
 4 and the protection afforded the receiving
 instrument against static disturbances will,
 therefore, be readily understood from the 120
 foregoing description of Fig. 2. The re-
 ceiver 26 is operatively coupled by means
 of repeater coils 28 and 28' as in Fig. 3.

Fig. 5 shows another embodiment of the
 invention as a receiving system which does 125
 not differ in principle from those shown in
 Figs. 3 and 4. Its specific difference from
 the structures illustrated in Figs. 3 and 4
 consists in coupling the oscillation circuits
 35 and 35', corresponding to the oscillation 130

circuits 25 and 25' of Fig. 4, to the antenna branch 31 by means of coupling coils 38 and 39 instead of to the parallel branches 32 and 33. The operative connection of receiver 26 to said oscillation circuits 35 and 35' is identically the same as that shown in Figs. 3 and 4. The antenna system shown in Fig. 5 has two degrees of freedom by virtue of the parallel branches 32 and 33 and therefore there are two frequencies to which said antenna system is resonantly responsive. One of said frequencies is adjusted by tuning to coincide with the frequency of the signals to be received and oscillation circuit 35 is tuned to this same frequency. Oscillation circuit 35' is tuned to the other of said frequencies of the antenna system. As heretofore stated, oscillation circuits 35 and 35' are made to have the same damping factors by giving suitable values to the resistance elements 37 and 37', and are loosely coupled to the antenna 1. The operation of the system in eliminating interference, particularly that due to natural disturbance will be understood from the description and explanation hereinbefore given. This arrangement is preferable to that shown in Figs. 3 and 4 in that both oscillation circuits are excited by the same impulsive current in the antenna upon the incidence of a static disturbance, and, therefore, the relative magnitudes of the natural oscillations set up in oscillation circuits 35 and 35' are invariable.

What is claimed is:

1. In a wireless duplex system, the combination of a transmitting branch circuit, a receiving branch circuit, an auxiliary branch circuit, a receiving device connected to said receiving branch circuit and said auxiliary branch circuit, and means for rendering said receiving device unresponsive to interfering oscillations of said circuits.

2. A wireless duplex system comprising a transmitting branch circuit, a receiving branch circuit, an auxiliary branch circuit, a translating device connected to said receiving branch circuit, a second translating device connected to said auxiliary branch circuit, and a receiving device differentially connected to both of said translating devices.

3. A wireless duplex system comprising an antenna; a transmitting, a receiving, and an auxiliary branch circuit through which said antenna is connected to ground; an oscillation circuit coupled to said receiving branch circuit; a second oscillation circuit coupled to said auxiliary branch circuit; a detecting device connected to said first named oscillation circuit; a second detecting device connected to said second named oscillation circuit; and a receiving device differentially connected to both of said detecting devices, said oscillation circuits including electrical constants of such values that the said receiving device is practically unaffected by oscil-

lations other than those it is desired to receive.

4. A wireless duplex system resonantly responsive to two frequencies, one of said frequencies being the frequency of the signals to be received and the other of said frequencies being that of the transmitted signals, said system comprising an antenna; three parallel branch circuits through which said antenna is connected to ground, the first of said branch circuits offering a low impedance to currents of the transmission frequency and a high impedance to currents of the reception frequency, the second of said branch circuits offering a high impedance to currents of the transmission frequency and being adjusted for maximum response to the signals to be received, the third of said branch circuits offering a high impedance to currents of both said frequencies; an oscillation circuit connected to said second named branch circuit; a second oscillation circuit connected to said third named branch circuit; a detecting device connected to said second named branch circuit through said first named oscillation circuit; a second detecting device connected to said third named branch circuit through said second named oscillation circuit; and a receiving device differentially connected to both said detecting devices, said oscillation circuits including electrical constants of such values that said receiving device is practically unaffected by transmission currents and by natural oscillations.

5. A wireless duplex system resonantly responsive to two frequencies, one of said frequencies being the frequency of the signals to be received and the other of said frequencies being that of the transmitted signals, said system comprising an antenna; three parallel branch circuits through which said antenna is connected to ground, the first of said branch circuits being substantially resonant to currents of the transmission frequency and substantially anti-resonant to currents of the reception frequency, the second of said branch circuits being substantially anti-resonant to currents of transmission frequency, and the third of said branch circuits being substantially anti-resonant to currents of both said frequencies; an oscillation circuit connected to said second named branch circuit; a second oscillation circuit connected to said third named branch circuit; a vacuum tube detector connected to said first named oscillation circuit; a second vacuum tube detector connected to said second named oscillation circuit; a vacuum tube amplifier connected through said first named detector to said first named oscillation circuit; a second vacuum tube amplifier connected through said second named detector to said second named oscillation circuit; and a receiving

device differentially connected to both of said amplifiers, said oscillation circuits including electrical constants of such values that said receiving device is practically unaffected by said transmission currents and by natural oscillations of said system as a whole.

6. A wireless duplex system resonantly responsive to two frequencies, one of said frequencies being the frequency of the signals to be received and the other of said frequencies being that of the transmitted signals, said system comprising an antenna; three parallel branch circuits through which said antenna is connected to ground, the first of said branch circuits being substantially resonant to currents of the transmission frequency and substantially anti-resonant to currents of the reception frequency, the second of said branch circuits being substantially anti-resonant to currents of transmission frequency, the third of said branch circuits being substantially anti-resonant to currents of both said frequencies; an oscillation circuit containing resistance, inductance and capacity elements, said oscillation circuit being inductively coupled to said second and third branch circuits and being tuned to the frequency of reception; a second oscillation circuit containing resistance, inductance and capacity elements, said second oscillation circuit being inductively coupled to said second and third branch circuits and being tuned to the frequency to which said third branch circuit is responsive; a vacuum tube detector connected to said first named oscillation circuit; a second vacuum tube detector connected to said second named oscillation circuit; a vacuum tube amplifier connected through said first named detector to said first named oscillation circuit; a second vacuum tube amplifier connected through said second named detector to said second named oscillation circuit; and a receiving device differentially connected to both said amplifiers.

7. A wireless system comprising an an-

tenna circuit having parallel branches, two oscillation circuits each coupled to both of said branches, a detecting device connected to one of said oscillation circuits, a second detecting device connected to the other of said oscillation circuits, and a receiving device differentially connected to both of said detecting devices, said oscillation circuits including electrical constants of such values that the said receiving device is practically unaffected by oscillations other than those it is desired to receive.

8. A wireless duplex system comprising an antenna; a transmitting, a receiving, and an auxiliary branch circuit through which said antenna is connected to ground; an oscillation circuit coupled to both said receiving branch circuit and said auxiliary branch circuit; a second oscillation circuit coupled to both said receiving branch circuit and said auxiliary branch circuit; a detecting device connected to said first named oscillation circuit, a second detecting device connected to said second named oscillation circuit; and a receiving device differentially connected to both of said detecting devices, said oscillation circuits including electrical constants of such values that the said receiving device is practically unaffected by oscillations other than those it is desired to receive.

In testimony whereof, I, JOHN MILLS, have signed my name to this specification in the presence of two subscribing witnesses, this 30th day of September, 1915.

JOHN MILLS.

Witnesses:

A. W. HAVENER,
C. E. MORGAN.

In testimony whereof, I, JOHN R. CARSON, have signed my name to this specification in the presence of two subscribing witnesses, this 2d day of October, 1915.

JOHN R. CARSON.

Witnesses:

GEORGE E. FOLK,
FRED'K S. ROBINSON.