L. A. HAZELTINE.
SHIELDING RADIO APPARATUS.
APPLICATION FILED NOV. 1, 1917.

1,379,184. Patented May 24, 1921.

Fig:4.

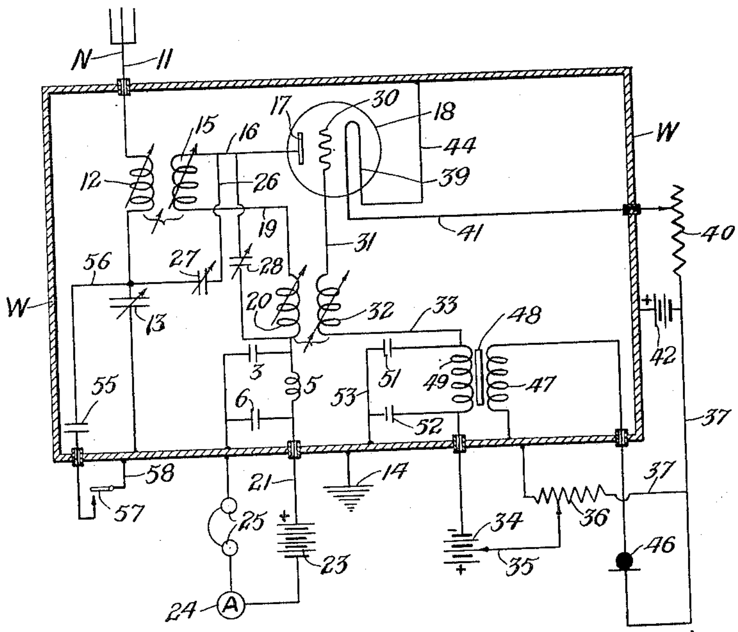


Fig:1.

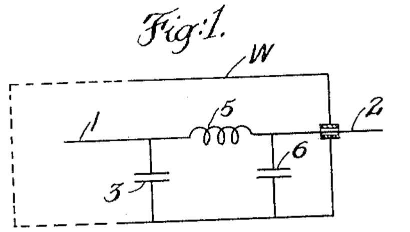


Fig:2.

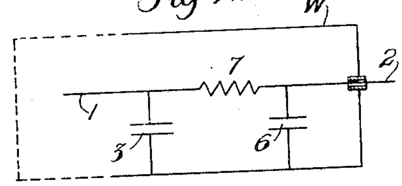
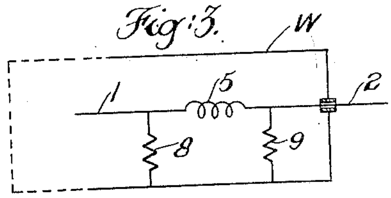


Fig:3.



INVENTOR
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BY
ATTORNEY

UNITED STATES PATENT OFFICE.

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SHIELDING RADIO APPARATUS.

1,379,184. Specification of Letters Patent. Patented May 24, 1921.

Application filed November 1, 1917. Serial No. 199,742.

To all whom it may concern:

Be it known that I, Louis A. Hazeltine, a citizen of the United States, and a resident of Hoboken, in the county of Hudson and State of New Jersey, have invented certain new and useful Improvements in Shielding Radio Apparatus, of which the following is a specification.

This invention relates to radio apparatus and has particular reference to means for eliminating the disturbing effects on the tuning caused by movements of the human body, or of other conducting or insulating bodies, in the immediate neighborhood of radio sending and receiving apparatus. It is sometimes sought to reduce such effects by providing the adjusting devices with long handles, but such expedients are not satisfactory in general, and are of little or no use in sending and receiving systems employing oscillations which are to be kept in or very near synchronism in order to operate.

This invention comprises a shielding arrangement interposed between the radio frequency circuits and apparatus and the audio frequency and direct current apparatus, and so connected to each circuit that radio frequency currents will be isolated from the audio frequency circuits through a path or paths of relatively low impedance without diverting the audio frequency or direct currents from their normal path. In its broad aspect, the invention comprises an impedance in series between high frequency apparatus, such as the plate circuit of an audion, and low frequency or direct current apparatus, such as a telephone receiver, combined with a shunting capacity across the impedance for carrying the high frequency current away from the low frequency apparatus. Thereby, the conditions in the high frequency circuit are not subject to variations introduced by the added capacity, impedance, etc., introduced by the low frequency apparatus, thereby permitting of better tuning. For special conditions, such as portable apparatus for telephony or telegraphy, such a circuit is combined with a screen containing most of the apparatus, and may be in the form of a grounded sheet metal or mesh box partially or wholly inclosing the apparatus and circuits to be protected, and having apertures through which pass the outside wires and adjustment rods for interior apparatus. This system effectually prevents radio frequency currents from flowing in the telephone receivers, batteries and other audio frequency or direct current apparatus which is electrically connected to the radio frequency circuit, and at the same time does not shunt away the audio frequency or direct currents that should flow from one side of the screen to the other through the same wires.

For removing the deleterious effects of body movements on the antenna system, the antenna circuit is provided with a series coil and condenser and the antenna is made of such dimensions relative to the wave length to be employed, that a potential node will exist at the point where the antenna circuit is nearest the operator's position, and such portion of the antenna circuit including the series coil and condenser is placed within the screen aforesaid. The antenna circuit may be grounded through the screen, or may be connected to a counterpoise ground of such dimensions as to give a potential node on the counterpoise near the operator's position.

In the accompanying drawings,

Figure 1 is a diagrammatic representation of the shielding means,

Fig. 2 is a modification,

Fig. 3 is a further modification, and

Fig. 4 shows one station of a sending and receiving apparatus embodying the invention.

Referring to Figs. 1, 2 and 3, W represents a conducting screen which may be in the form of a copper or aluminum sheet metal box entirely inclosing the internal parts from the external parts, or only partially inclosing such parts on the side at which the external disturbances occur. 1 represents a radio frequency conductor connected to radio frequency apparatus within the screen. and 2 is a wire passing out of the screen through a bushing to any suitable audio frequency apparatus, and coupled within the screen to the radio conductor 1 in any suitable way, as by impedance 5. Between the radio conductor and the screen is connected a condenser 3, which shunts most of the radio frequency current entering wire 1, causing it to flow to the screen instead of out through wire 2. To insure that none of the radio frequency will pass to wire 2, a series inductance 5 is inserted between wires 1 and 2 and beyond condenser 3, and another condenser 6 is inserted between the inner portion of wire 2 and the screen. Any radio frequency current which might pass inductance 5 will be shunted to the screen by condenser 6, and this arrangement might be continued by additional inductances between wires 1 and 2 and condensers connected to the screen, but one inductance and one condenser is usually sufficient.

In Fig. 2, a non inductive resistance 7 is used instead of the inductance 5, and in Fig. 3, non inductive resistances 8, 9, are used instead of the condensers 3, 6. The arrangement of Fig. 1 is preferable, but all three arrangements satisfy the general requirements that the shunt paths 3, 6, or 8, 9, shall have relatively low impedance for the radio frequency currents as compared with the direct path 1, 2, and that the latter path shall have a relatively low impedance for audio frequency or direct currents compared with the shunt paths, 3, 6, or 8, 9.

In Fig. 4, the invention is embodied in a synchronous telephone or telegraph set for simultaneous sending and receiving in which the screen W incloses a radio frequency detector, tuning apparatus, and sending source, while the audio frequency receiving and sending devices, together with batteries and their adjusting devices are outside and readily accessible. With this apparatus radio communication by either telephone or telegraph has been had without interference due to movements of the operator, etc.

The antenna circuit 11 is externally connected to an antenna or other oscillator, and leads through an insulating bushing into the screen, thence to a series coil 12 which is variable for tuning, then to a variable series condenser 13, and is then connected to the screen at its lower terminal, and the screen may be grounded as at 14. The antenna is chosen of such dimensions relatively to the wave length to be employed, that a potential node may exist at the point N for example nearest the operator's position. For use with undamped waves as in the system herein shown, a straight vertical oscillator has a high decrement, power factor, and radiation resistance, and hence radiates more energy than other types, of given height, besides giving a voltage node near the operator, or ground, when oscillating at its natural frequency. This is accomplished by placing the series coil 12 and condenser 13 in the antenna circuit within the screen. Upon proper adjustment, it will be found that the frequency of the antenna circuit will not be affected by necessary movements of the operator's head, hands, etc., in adjusting and operating, thus showing that a potential node exists externally of the screen at or adjacent to the point, such as N, nearest the operator. The antenna should operate at or near its own natural frequency, so that the lead 11 entering the screen has a node at this point.

The screen should preferably be located near the ground so as to avoid a long ground wire. If the wire is long, it should have in series with it at the ground end a coil or condenser, or both, similar to 12, 13, so that a potential node will exist at the portion nearest the operator's position.

In cases where a counterpoise ground is used instead of a conductive ground, the counterpoise is connected to the lower terminal of the antenna circuit by a wire leading through an insulated bushing in the screen. The dimensions of the counterpoise should be such as to give a potential node near the operator's position, which node may be varied if desired by providing a series coil and condenser similar to 12, 13; above described. In both cases, the screen is preferably grounded as at 14.

Variably coupled to the self-inductance 12 is a coil 15 having one terminal connected by wire 16 to the plate 17 of an audion or other suitable relay device 18. The variable coupling of these coils may be obtained by pivoting one coil relatively to the other so that their axes can be varied in relative relation.

By audion is meant any evacuated vessel having one hot and one or more cold electrodes and acting as a relay, whereby a relatively small alternating current and voltage supplied between one cold electrode and the hot electrode produces a relatively large alternating current and voltage in a circuit or circuits connected between the other cold electrode or electrodes and the hot electrode. As commonly used, the audion has a rectifying action in addition to this relay or amplifying action, but for the purposes of this invention, a separate rectifier or detector may be employed if desired.

The other terminal of coil 15 is connected by wire 19 to self-inductance 20, which is variable as shown for tuning this circuit. The other terminal of coil 20 is connected by wire 21 to the positive terminal of plate battery 23. The negative side of the battery is connected through an ammeter or other suitable current indicator 24 and the telephone receivers 25 to the screen. A capacity coupling is also provided between the antenna circuit 11 and the plate circuit by wire 26 through adjustable capacity 27 to the antenna circuit between coil 12 and capacity 13. 28 is a capacity connected between wires 16 and 21 around coil 20, to be used in case the inherent capacity of the audion and connected apparatus is insufficient to make the local circuit resonant. The shielding inductance coil 5 is interposed between the coil 20 and the plate battery 23 and within the screen, while the shielding condensers 3 and 6 are connected in shunt to the screen on opposite sides of inductance 5. The circuit of grid 30 is connected by wire 31 to variable inductance 32 which is variably coupled to inductance coil 20, so as to constitute a variable grid coupling, then by wire 33 passing through the screen to adjustable grid battery 34, then by wire 35 to grid potentiometer 36, and by wire 37 to filament 39 through adjustable filament resistance 40 and wire 41. By varying battery 34, the strength of oscillation is varied, and the potentiometer 36 gives fine control of the grid potential, coarse control being obtained by varying the number of cells in battery 34. 42 is the heating battery connected on one side to the screen and on the other to filament 39 through resistance 40 and wire 41.

The sending system comprises microphone transmitter 46 and primary 47 of an induction coil inserted between wire 37 and the screen, the primary 47 and the secondary 49 being inductively related by the core 48. Secondary 49 is connected between wire 33 and the grid battery 34. The grid coil 32 is shielded by means of condensers 51, 52 connected around secondary 49 to the screen through wire 53, it being found that the secondary 49 serves sufficiently well to be used instead of a radio frequency coil such as 5. In so using an audio frequency coil having relatively high self-inductance and inherent capacity, it is necessary to insure that the inherent capacity is not too high because if so it would then afford too good a path for the radio-frequency current and permit it to leave the inside of the screen. For radio telegraph sending by the compensating wave method, a condenser 55 is connected by wire 56 to key 57, which is connected to the screen by wire 58.

The shielding condensers 3, 6, and inductance 5 serve to separate the radio frequency current in the plate circuit of the audion from the audio-frequency and direct currents, the audio frequency current taking the path from the filament of the audion to the screen, thence to the shielding condensers 3, 6, thence to the radio frequency coils 20, 15, thence to the plate of the audion and back to the filament, without having left the inside of the screen. The audio-frequency and direct currents take the path from the filament to the screen, thence outside the screen to the telephone receivers 25, thence to the ammeter 24 of the plate battery 23 to the inside of the screen to coil 5 and finally through the coils 20, 15 and the plate 17 to the filament 39. It is desirable to place the telephone induction coil of the transmitter inside the screen in the grid circuit, because of better shielding, which is permitted by making the secondary 49 of proper proportions and associating it with shielding condensers 51, 52.

In order to permit audions at separated stations to operate in synchronism, and to stay so, it is desirable that the receiving audion oscillating in synchronism with the incoming signal oscillation, be able to readily change its frequency so as to accommodate itself to changes in the incoming frequency. The general type of audion receiving circuit herein described accomplishes this result, and also permits sending and receiving by the same audion without changes in adjustments. If the audions are not in synchronism, a beat note will be produced, or if the beat note be outside the audible range, the voice is unintelligible. To enable the extremely small energy transmitted from one station to the other to hold the audions in synchronism notwithstanding variation in the strength of the oscillation due to the voice vibrations, conditions such as the electrostatic capacities in the oscillating current circuit must be very constant. The shielding and antenna circuit arrangements herein described prevent such variations in capacities by isolating the radio frequency currents from the low frequency apparatus and preferably within the screen and by preventing variation of the antenna frequency as are caused for example by body movements.

The general type of audion circuit in which the audions tend to remain in synchronism is one wherein a local oscillating circuit, such as the plate circuit above described, is coupled to the antenna circuit in such manner that the coefficient of coupling is equal to the power factor of the antenna circuit. With mutually inductive coupling, this relation is expressed by the equation:

$$k_{12}=p_2, \text{ or } \frac{M_{12}}{\sqrt{L_1L_2}}=r_2\sqrt{\frac{C_2}{L_2}}$$

where M_{12} is the mutual inductance between the antenna and local circuits, whose inductances are L_2, L_1, respectively; and where r_2 is the resistance and C_2 the capacity, of the antenna circuit and where p_2 is the power factor of the antenna circuit. With other forms of coupling, such as common capacity, the coefficient of coupling (k_{12}) is expressed by other formulas, but it should still be made equal to the power factor, or substantially so. This coupling I call transition coupling, because it is the loosest coupling at which the oscillations maintained by the audion can have either of two frequencies. If the coupling is closer than this transition value, the frequency of oscillation will suddenly change by a finite amount when the natural frequency of one of these circuits is gradually changed and passed through the value for the other circuit. If the coupling is looser than this transition value, the frequency of oscillation will change gradually when the natural frequency of one of these circuits is changed.

To determine experimentally when the coupling has the desired transition value, the natural frequency of one of the coupled circuits is continually varied through the turning point (*i. e.*, the point at which the two circuits have the same natural frequency); and the coupling is slowly decreased. As long as the coupling exceeds the transition value, at the instant when the tuning point is passed a momentary "beat note" or click will be heard in the telephone receivers 25 connected in the plate circuit and at the same time ammeter 24 connected in the plate circuit will show a sudden jump. When the coupling is loosened so that the click or beat note and the jump in the ammeter reading just disappear, transition coupling has been attained. This procedure is the same no matter what form of coupling or what audion connection is employed, so long as the connections are of the type described above.

By plotting the voltage in the antenna circuit required to maintain synchronous operation against the relative natural frequency for which the receiving system is adjusted, I have found that with the natural frequency out of adjustment by $\frac{1}{20}$ of 1% (when $k_{12}=0.005$ or 0.02), fifteen times the antenna voltage for $k_{12}=0.005$, and seventeen times the antenna voltage for $k_{12}=0.02$, is required to maintain synchronous operation of two audions at distant stations, as for telephone receiving and sending with a single audion, as is required to maintain synchronous operation where the transition coupling has the value of $k_{12}=0.01$. Synchronous operation with transition coupling thus not only enables the same audion to be used for receiving and sending, but decreases the required transmitting power, and in conjunction with the shielding system herein described provides an advantageous system for either simultaneous telephony, or telegraphic receiving by damped waves, or by sustained waves according to the heterodyne or beats method.

Preferably, a receiving set will have means for tuning both the antenna and local circuits in a single operation by a positive mechanical connection as by having the movable elements of the tuning condensers insulated from each other on the same shaft, which adjusts both together, because with transition coupling, the circuits do not have to be so accurately tuned to an incoming signal, as with other values of coupling, or with separate adjustments for each, since with transition coupling, the receiving system is least affected by being slightly out of tune as a whole with the incoming signal oscillation. This relieves the operator of the necessity of highly accurate tuning to incoming signals, as would be the case without transition coupling.

What is claimed, is:

1. An antenna having dimensions proportioned according to the wave length and including a series coil and condenser, whereby to produce a potential node at a point near the operators' position, means for producing oscillations coupled to the antenna circuit between said nodal point and the ground, and an electrostatic screen inclosing said series coil and condenser, and said oscillation producing means.

2. Means for confining a high frequency current to a desired circuit and at the same time permitting low frequency and direct current to flow in a portion of said high frequency circuit, comprising a high frequency impedance in the lead between the high frequency and low frequency circuits, and capacities in the remaining portion of the high frequency circuit connected to said lead on opposite sides of said impedance.

3. Means for preventing variation of electrostatic capacity in an antenna circuit by movements of adjacent bodies comprising a grounded conducting screen inclosing the lower portion of said antenna circuit, a series coil leading outside the screen to low frequency apparatus, and a capacity in said circuit within said screen connected between the high frequency side of said coil and the screen.

4. Means for isolating a high frequency current on one side of a screen from low frequency or direct current apparatus on the other side having connections leading past the screen to the high frequency circuit, comprising an impedance coil in series between the high frequency and low frequency circuits, and a capacity connected from each side of said coil to the screen.

5. Means for separating high from low frequency or direct current comprising an inclosing screen containing a high frequency conductor, a low frequency or direct current conductor passing through the screen, an impedance coil in series between the conductors, and a capacity connected from each side of the coil to the screen.

6. A radio apparatus having an antenna, means for producing a potential node in the antenna circuit at the point near the operator's position, radio responsive apparatus coupled to said antenna circuit between said nodal point and the ground, an electrostatic screen inclosing the lower portion of said antenna circuit and said radio responsive apparatus, connections between said screen and

said apparatus for confining radio frequency current within said screen, and communication controlling means outside said screen connected to said radio responsive apparatus.

7. A radio apparatus having an antenna, means for producing a potential node in the antenna circuit at the point near the operator's position, radio responsive apparatus coupled to said antenna circuit between said nodal point and the ground, an electrostatic screen inclosing the lower portion of said antenna circuit and said radio responsive apparatus, connections between said screen and said apparatus for confining radio-frequency current within said screen, and a telephone outside said screen connected to said radio responsive apparatus.

8. A radio apparatus comprising means for generating radio-frequency oscillations, an electrostatic screen inclosing said means, an external radio-frequency conductor having transition coupling within the screen to the circuit of said oscillation generator, connections between said oscillation generator and the screen confining the radio frequency current in the circuit of said generator within the screen, and communication controlling means outside the screen connected to said oscillation generator.

9. A radio apparatus comprising means for generating radio-frequency oscillations, an electrostatic screen inclosing said means, an external radio conductor tuned to the same frequency and coupled within the screen to the circuit of said oscillation generator, means between said oscillation generator and the screen confining the radio-frequency current in the circuit of said generator within the screen, and audio-frequency apparatus outside the screen connected to said oscillation generator beyond said means.

10. A tuned antenna having means for producing a potential node at the point near the operator's position, in combination with a circuit tuned to the same frequency as the antenna circuit and coupled to the antenna circuit between said nodal point and the ground, means in said coupled circuit for generating high frequency oscillations, an electrostatic screen inclosing said coupled circuit and the antenna coupling and connected to said circuit by means passing only high frequency current, and audio responsive apparatus outside of said screen and having series impedance connection to the circuit of said oscillation generator beyond said latter means.

11. A radio apparatus comprising a grounded inclosing screen, radio responsive means within said screen directly connected thereto on one side and on the other side connected thereto by means passing only radio-frequency current, and an external low-frequency or direct current circuit connected on one side to said screen and by series impedance on the other side to the circuit of said radio responsive means beyond said latter means.

12. Means for separating a radio current from an audio-frequency or direct current having paths partly in common, comprising a radio frequency conductor, a low-frequency or direct current conductor, an intervening series impedance, a conducting screen through which said low-frequency conductor passes, and means within the screen connected between the high frequency end of said impedance and said screen passing only radio-frequency current from the radio conductor to the screen without preventing passage of low-frequency current through said impedance and a portion of the radio frequency circuit.

13. Means for separating a radio-frequency current from a low-frequency or direct current having paths partly in common, comprising a radio-frequency conductor, a low-frequency or direct current conductor including a series impedance, a conducting screen through which said low-frequency conductor passes, and connections within the screen between the ends of said impedance and said screen for rendering the impedance between the conductors to radio-frequency current greater than the impedance to radio-frequency current between said radio-frequency conductor and the screen, and increasing the impedance between said low-frequency conductor and the screen for low frequency current relatively to the impedance between said conductors for low-frequency current.

14. A radio apparatus comprising an inclosing conducting screen, an audion within said screen having its heated electrode connected thereto, and a radio-frequency coil connected to one cold electrode of the audion and to said screen through a connection passing only radio-frequency current.

15. A radio apparatus comprising an inclosing conducting screen, an audion within said screen having its heated electrode connected thereto, a radio-frequency coil connected to the cold electrode of the audion and to said screen through means passing only radio-frequency current, and a low-frequency circuit externally connected with said screen at one end and connected at the other end within said screen by series impedance to said radio circuit to pass only low-frequency current.

16. Means for radio communication employing at a station a single electric oscillator both generating and amplifying oscillations, and contained within an electrostatic screen, and sending and receiving means outside the screen connected within the screen to the oscillator.

17. Means for radio commuication em-

ploying at a station a single electric oscillator both generating and amplifying oscillations, and said oscillator being contained within an electrostatic screen, sending and receiving means outside the screen and connected within the screen through impedance to the oscillator, and a condenser on each side of said impedance connected to said screen.

18. An antenna, a lead wire between said antenna and the ground, means for producing and amplifying oscillations coupled to the antenna circuit, an inclosed non-magnetic conducting screen surrounding said lead wire, said coupling and said oscillation producing means, and connections confining radio frequency current within the screen.

19. Apparatus for two way radio communication comprising a receiving circuit containing an electric oscillator tuned in synchronism with an incoming signal, an electrostatic screen inclosing said oscillator, a receiver outside said screen connected to said oscillator, and sending means outside said screen connected to said oscillator.

20. Apparatus for radio-telephone voice receiving comprising a receiving circuit oscillating at a substantially constant frequency in synchronism with the incoming signal, an electrostatic screen inclosing said oscillating circuit, a telephone receiver outside said screen and connected within the screen to said oscillating receiving circuit, and connections confining radio frequency current within the screen.

21. Apparatus for radio-telephone voice receiving comprising a receiving circuit oscillating at a substantially constant frequency in synchronism with the incoming signal, an electrostatic screen inclosing said oscillating circuit, and a telephone receiver outside said screen and connected within the screen through impedance to said oscillating receiving circuit, and capacity connections from each end of said impedance to the screen.

22. Apparatus for radio-telephone voice receiving comprising an antenna circuit receiving incoming signals, an electrostatic screen, a receiving circuit coupled to said antenna circuit within said screen in such manner that the coefficient of coupling is substantially equal to the power factor of the antenna circuit and oscillating at a substantially constant frequency in synchronism with the incoming signal, and a telephone receiver outside said screen and connected within said screen to said oscillating receiving circuit.

Signed at Hoboken, in the county of Hudson and State of New Jersey this twenty-seventh day of October, A. D. 1917.

LOUIS ALAN HAZELTINE.

Witnesses:

MARIUS A. CHARAVAY,
L. A. BELDING.