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ANTENNA SYSTEM FOR SLEET MELTING AND CONDUCTOR THEREFOR

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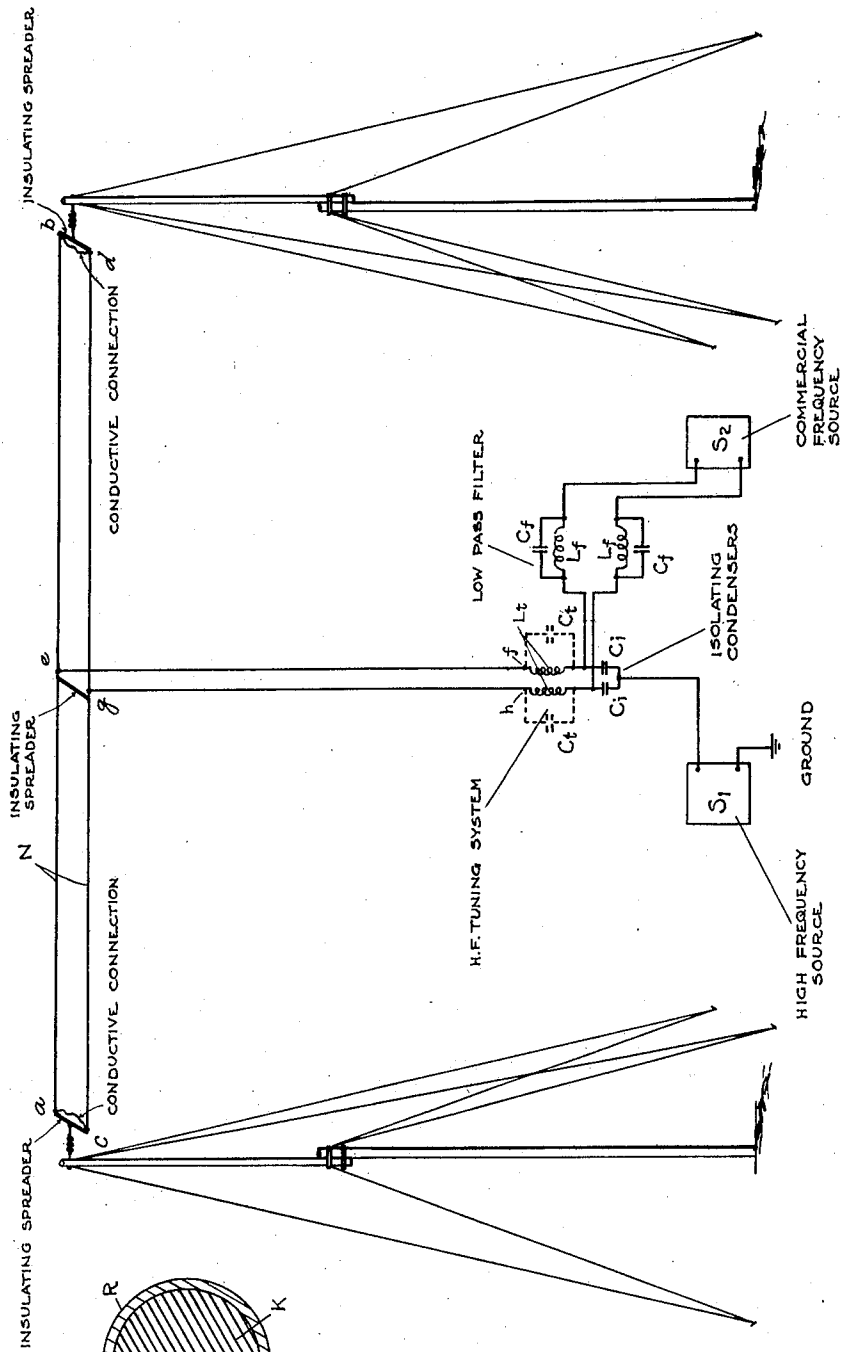


FIG. 1.

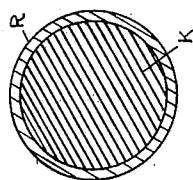


FIG. 2.

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ANTENNA SYSTEM FOR SLEET MELTING AND CONDUCTOR THEREFOR

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My invention relates to methods and means for employing in any system of conductors whose normal function is to carry high-frequency currents, the heating effect caused by the passage of low-frequency or direct currents through the system, with freedom from interference between the sources of the several currents and with economy and maximum effectiveness in the performance of the two functions.

More specifically, my invention is directly applicable to the heating by electrical current of systems of elevated conductors, such as radio antennas, for the purpose of eliminating the effect of high humidity or the hazard of failure due to sleet formation.

Particularly in northern latitudes, antennas are likely to acquire heavy loadings of ice or sleet. It is highly desirable to reduce to a minimum such ice and sleet loadings, not only because of the risk of breaking the antenna conductor and causing the antenna to fall, but also because a heavy ice or sleet loading is likely to detune the antenna, first because the antenna conductors may sag badly and thus change their effective height from ground and their effective capacity to ground, and secondly because ice has a dielectric constant of about three and the presence of a considerable layer of such a medium immediately surrounding a conductor will change its capacity to ground.

My invention will be understood from the following specification and accompanying drawing. For purposes of explanation I have described a specific embodiment but it will be understood that my invention is not limited thereto, but may be applied in many other and different embodiments, without departing from the spirit and principles of my invention.

In the drawing, Figure 1 shows an antenna system embodying the principles of my invention, and Figure 2 shows a cross-section of the composite or non-uniform conductor which I employ.

As an example of the application of my invention, in Figure 1 there is shown a conventional type of radio antenna which is in general use for broadcasting and other pur-

poses. It will be noted that in this T type antenna the horizontal portion, or "flat top", *abcd* is connected through the two "down leads", *ef*, and *gh*, to the source of high-frequency current S_1 , and to the source of low-frequency or direct current S_2 . Included in the circuits of the down leads are, of course, the conventional adjustable tuning inductances L_1 , which brought their adjustability allow for the precise tuning out of the otherwise present reactance of the antenna circuit to the end that the antenna circuit may be made resonant to the frequency of the high-frequency supply, S_1 . Where the frequency of the high-frequency supply is less than the natural frequency of the antenna system, the use of the simple series inductance here shown will serve for the tuning of the antenna system while, if the frequency of the high-frequency supply is greater than the natural frequency of the antenna a negative or capacitive reactance must be supplied in series with the antenna to bring about resonance. This can be provided either by means of a properly chosen tuning condenser in series with the antenna and adjustable tuning inductance, or in shunt with the tuning inductance, as shown in dotted lines at C_1 , the condenser-inductance combination being jointly in series with the antenna. In either event, however, the ease and economy of provision for adjustability in an inductance element and the lack of these desirable characteristics in commercially feasible condensers requires the use of inductance elements, even where the reactance required by the antenna system is negative and hence capacitive.

Throughout my specification, it will be understood that in using the expression "low-frequency current" I intend in each case to include direct current as current of zero frequency.

It will be noted that provision must be made in this system for the effective isolation of the two power sources, S_1 and S_2 , from the influence of one another, lest, on the one hand, any appreciable portion of the extremely costly high-frequency power output of source S_1 be lost in the low-frequency

source S_2 , and on the other hand, lest the potentially destructive effects of the large currents of the low-frequency or direct current source S_2 be allowed to operate on the structural elements of the high-frequency source S_1 . To this end the isolating condenser, C_i , are provided in series with the down leads, ef and gh , while in series with the connections to the low-frequency source are connected the choke coils L_r , which constitute a net work in the connections to S_2 to exclude the high-frequency power from S_2 by virtue of the coil impedance, or preferably, in combination with condensers C_r , and tuned to the frequency of the high-frequency supply, through the extremely high terminal impedance of this condenser-coil combination at this frequency.

In Figure 1, it will be noted that the antenna conductors and the terminal cross connections are so arranged that there are continuous paths for the low-frequency current which constitute substantially the entire antenna conductor.

It will be noted that the isolating condensers C_i , may be made to serve the dual function of isolating the high-frequency source from the low-frequency current and to supply a negative reactance for tuning the antenna system when the remainder of the antenna system is positive in its reactance. Where, however, the antenna proper is, itself, negative in reactance, the isolating condensers, C_i , must be chosen of sufficiently high capacity (low reactance) to supply negligible reactance to the antenna system. In either event, however, it will be found that the low-frequency reactance of these isolating condensers will be of such a high order of magnitude that substantially complete isolation of the high-frequency source from the effects of the low-frequency current will be provided.

Similarly, the inductance of the filter chokes, L_r , may be employed for assisting in the tuning of the antenna circuit although practical considerations dictate the wisdom of avoiding the interdependence of these several reactive elements through the tuning of the chokes by condensers C_r , as shown, in order that the filter systems may present a purely resistance impedance to the high-frequency currents and thus make the tuning of the antenna system substantially independent of the constants of the filter system and the adjustment of its elements, and, simultaneously, reduce the high-frequency power loss in the low-frequency source to a completely negligible magnitude.

Since in any of the commonly employed forms of antennas except the so-called loop or coil antennas the path of the high-frequency current in the circuit of the antenna is closed through the capacity of the antenna and is thus effectively open circuited to low-

frequency currents such as would be economically useful for heating the antenna, special arrangements of the conductors of the antenna system must be made to provide a closed circuit for the heating currents. In the T type of antenna shown in Figure 1, this is accomplished by constructing both the down lead and the flat top portions of the antenna of at least two conductors and interconnecting them so that the low-frequency current will flow through substantially all parts of the antenna conductors and thus provide heating power throughout the antenna circuit. The use of two conductors properly insulated to low-frequency current placed closely adjacent will, in general, not serve because of the high thermal insulation inherent in materials of acceptable electrical insulating properties and the consequent need for relatively high temperatures in the conducting portion of such a conductor and because also, of the necessarily great high-frequency dielectric loss that is inherent in such conveniently available insulating materials as would give acceptable low-frequency insulation.

It is desirable to provide generous spacing between the conductors of the antenna for purposes of low-frequency insulation between the several portions which are adjacent but at considerable difference in low-frequency potential and to provide spreaders, " ca " and " db " and " eg " of insulating material to minimize the possibility of contact between the conductors of the antenna as a result of their swinging in the wind.

The low-frequency heating current then flows through the following path: from the low-frequency source, S_2 , through the low pass filter inductance coil, L_r , to the terminal h of the down lead gh , to the junction point of the flat-top conductor cd where it divides between the two low-frequency paths provided by the flat-top flowing from g to c to a to e and from g to d to b to e thus in effect, putting the two portions, of the flat-top, $gcac$ and $gdbe$ effectively in parallel to the low-frequency current. The two heating currents join at e and pass down the down lead ef to the low pass filter and thence to the low-frequency source, S_2 .

The path of the high-frequency currents is quite different from that of the low-frequency currents. Thus, the two down leads, hg and fe , as well as the two sets of tuning elements, C_r and L_r , are effectively in parallel by their attachment to the high-frequency source through the isolating condensers C_i , and, as a result the high-frequency currents divide between the two down-leads in flowing into the flat-top portion of the antenna. At the junction points e and g of the flat-top and down lead the high-frequency current further divides between the four portions of the flat top, the current in

hg dividing between *gc* and *gd* while the current in *fe* divides between *ea* and *eb*, thus placing *gc* and *gd* in parallel and similarly placing *ea* and *eb* in parallel to the high-frequency currents from the down leads.

The return paths for these high-frequency currents are by displacement current through the capacity of the antenna conductors to ground and back to the high-frequency source.

Because of the symmetry of the conducting circuit of the antenna structure the points *c* and *a* and likewise the points *b* and *d* are at the same high-frequency potential so that no high-frequency current flows through the cross connections *ca* and *db* and these cross connections serve only for carrying the low-frequency current.

Where, however, structural symmetry of the antenna as here described is not present and where the consequent asymmetry of high-frequency potential distribution must not be disturbed by the required continuity to the low-frequency current, such cross connections as are required by this latter condition may be supplied in the form of low-pass filters, such as are shown in C_r and L_r .

In such an antenna system as is here shown it is vitally important that, in the interest of radiation efficiency, the ohmic resistance at high frequency of the conductors constituting the antenna be of acceptably small value as compared with the radiation resistance and that the cross-section of the conductors be of correspondingly large value.

For a solid homogeneous non-magnetic conductor, the resistance at 60 cycles varies inversely with the square of the radius, whereas, at a radio-frequency the resistance varies inversely with the first power of the radius at least to a first approximation. With solid copper conductors the wire required to get a proper value of radio-frequency resistance is so large that its resistance and heat dissipation at 60 cycles are quite small.

For example, if the antenna is to be employed at the frequencies used for broadcasting—of the order of one megacycle, 300 meters—the length of the entire flat top of the antenna would be chosen to be about three hundred feet, while the length of the down lead would be about two hundred feet. In such an antenna using solid copper conductors the effective radiation resistance would be of the order of fifty ohms, and the choice of the diameter of the conductors constituting the antenna must therefore be made to provide an effective radio-frequency conductor resistance, as measured at the base, of not more than a few per cent of the radiation resistance, in order to provide suitably high radiation efficiency. Such a choice of conductor sizes will, in practice, result in the use of No. 10 B. and S. gauge copper wire in the

flat top and in the use of No. 7 or No. 8 B. and S. gauge copper wire in the down lead, and in a total effective conductor resistance somewhat less than one ohm. It will be realized, however, that any definite statements as to electrical properties of antennas must be limited to narrow temperature ranges, and that in practice, particularly in northern latitudes, the variations of temperature to which an antenna is exposed are far greater than exist in most electrical structures. For these reasons, the specific data which I give are to be considered simply as illustrative examples, and in actual practice the principles of my invention are applicable in accordance with familiar and well-known engineering practices.

However, as a result of this choice of conductors for acceptable efficiency of radiation which is made necessary by the extremely high cost of radio-frequency power, the resistance of the antenna circuit to such low-frequency current as may be employed for heating the antenna is necessarily extremely low and, in the case here considered, is of the order of one-third of an ohm, for a solid copper conductor, thus making it necessary to supply the antenna system with exceedingly large currents for the generation of sufficient heat. Experience indicates that for the prevention of the formation of sleet on such an antenna as this, it is desirable that about ten watts of heating power per foot of antenna conductor be provided, and thus that in this antenna a total of ten kilowatts of heating power be supplied. Where provision is to be made for the melting of any considerable amount of sleet that may have been allowed to form on the antenna conductors, even greater powers per foot must be provided up to, and including, thirty watts per foot of conductor, depending, of course, on the sleet melting capacity desired and on the size of the conductors employed. In order, however, that only the smaller heating power may be supplied, it is, therefore, necessary that the antenna be supplied with heating current of about 175 amperes at a voltage of about sixty volts.

The requirement of such high currents as these at such relatively low voltages results in several practical difficulties that make its employment both costly and unreliable. In the first place, the unusually low voltage at which this power is required makes it impossible to suit the needs of such a system as this to the voltages commonly available in power supply systems, while the extremely high currents required bring with them the need for the construction of the tuning inductances, L_t and L_r , and all interconnecting conductors, of very large sizes and costs of copper, and within the limitations of coil size and cost involve an excessive temperature rise and power waste. In addition, and

of more serious import, the extremely large currents make it extremely difficult to provide movable contacts on these inductance elements and other separable connectors of sufficiently low contact resistance to avoid the slow deterioration or complete destruction of these connections and others throughout the system due to the contact heating effects of the large currents.

I have discovered, however, that the employment of certain especially prepared types of conductors in the antenna system eliminate these difficulties through providing a higher resistance in the antenna circuit to the low-frequency heating current while leaving the resistance of the antenna circuit to the high-frequency current substantially unchanged.

The high-frequency current and low-frequency current will flow simultaneously through the antenna conductor, with substantially no mutual interference, and sleet can be melted from an antenna which is simultaneously radiating.

Typical of this type of especial conductor is one made up of a core of steel, or high-resistance, and preferably non-magnetic, alloy completely enclosed in a cylindrical covering of substantially pure copper. Such a conductor may be prepared by welding or soldering to a cylindrical billet of steel or other high resistance alloy an outer shell of copper of annular section and then drawing down the composite billet so made to the desired size of wire.

Figure 2 shows a cross-sectional view of such a composite conductor, wherein K is a core and R is a surrounding shell.

Such specially prepared conductors may be employed in all parts of the antenna structure, or only in particular parts, such as in the horizontal elements of the type of antenna shown in Fig. 1, retaining a homogeneous conductor, as solid copper, for the down leads, according to the conditions existing in a particular installation. Thus the down leads may be of considerable length, and parts of them may be near the ground, for which conditions solid copper may be most suitable. The atmospheric conditions may be much less favorable to the formation of ice near the ground than at the top of an antenna. Greater mechanical strength to avoid breaking may be required in the flat top, and hence it may be more important to use the specially prepared conductor in the top of an antenna than in the down leads, to get both greater tensile strength and increased resistivity. Or, in particular instances, as over swamps, the atmospheric conditions may most favor the formation of ice on conductors near the ground, in which cases it may be more important to use the specially prepared conductors in the down leads than in the top of the antenna, especially since the stress dia-

gram will show that a foot of sleet-loaded conductor adds more stress on the supports when on the down leads than when on the horizontal top conductors.

Since, in any conductor, when operated at such high frequencies as are here discussed, the effective penetration of the current is not greater than a few thousandths of an inch, it is possible to provide a composite conductor of the type here described in which sufficient thickness of copper surfacing is provided to carry the high-frequency currents with substantially the same losses as in a homogeneous solid copper conductor of the same diameter, while, at the same time, the low-frequency currents which distribute themselves substantially uniformly over the cross-section meet with many times the resistance of that of a homogeneous solid copper conductor of the same cross-section. More specifically, a copper-steel conductor of this type can be prepared very economically to provide a threefold increase of the low-frequency resistance while giving completely negligible increase in the high-frequency resistance. Further, if the core is made of a suitable high-resistance alloy the low-frequency resistance of the conductor may be made as high as twenty or more times as great as that of the pure copper conductor without material change in the high-frequency resistance.

It is also possible to employ a conductor whose cross-sectional resistivity distribution is radially non-uniform with distribution other than the particular structure which I have here shown in detail, and it will be understood that conductors embodying such other non-uniform radial resistivity distributions are comprehended within the spirit of my invention.

The conductor which I have described in detail has a resistivity characteristic which is discontinuous where the core and shell meet. Conductors may be constructed having a cross-sectional resistivity characteristic which is non-uniform but is not discontinuous. The different materials will ordinarily be interpenetrated. One way of preparing such a conductor is to immerse a somewhat porous core in a molten copper bath, preferably in an atmosphere of hydrogen, nitrogen, or other reducing or inert gas. Another way is to make a wire from an alloy which contains metals which do not readily oxidize, such as any of the higher resistance alloys that are used for heating and furnace work, and in preparing the alloy for the wire, adding a generous amount of a material such as the oxide or sulphide of copper or silver; then, after drawing the wire, reducing the copper or silver on the surface by suitable reducing agents and further drawing and polishing to make the skin continuous and of low resistance. In these or

other ways, it is possible to obtain a conductor whose resistivity over the cross-section varies gradually and continuously.

5 The resistivity of B. B. steel wire may be taken as approximately seven times that of pure copper. For a non-magnetic core, an alloy which is suitable consists of 4 per cent aluminum, 12 per cent of iron-free manganese, and 84 per cent copper. Other alloys
10 which may be employed are "manganin", consisting of 4 per cent nickel, 12 per cent manganese, and 84 per cent copper, and "Constantan" alloy, consisting of 40 per cent nickel and 60 per cent copper. Some compositions
15 of Monel metal, which are iron-free and contain about two-thirds nickel and one-third copper will also serve. These alloys have resistivities of from twenty-six to thirty times that of copper, and are practically non-magnetic. That is, their permeabilities are well
20 less than 1.1. In the cases of some materials, such as Monel metal, it may be desirable to give particular heat treatment as quenching, to obtain low permeability. Other alloys of
25 high resistivity and which have substantially unity permeability may likewise be employed.

The selection of the materials and cross-sectional dimensions of the conductor in any given case require calculation and investigation to obtain the optimum combination, and is a compromise in view of the various factors which must receive consideration.

30 The range of high frequencies to be employed, and the diameter of antenna conductor required for mechanical reasons, are important considerations. In an iron-core conductor, surrounded by a copper shell not thinner than 0.01 centimeter, and for a conductor
35 not smaller than about No. 8 B. and S., for high-frequency currents of frequency not less than one megacycle, about 99 per cent of the high-frequency current will be carried in the copper. The copper must not be made too
40 thin or appreciable high-frequency current will be forced into the core, with resultant loss of the expensive high-frequency energy. With a non-magnetic core such as manganin it is desirable with the size of antenna conductor mentioned to employ a copper coating
45 not less than 0.03 centimeter in thickness which will cause over 98 per cent of the high-frequency current to flow in the copper. When iron is employed as a core, its high permeability tends to keep the high-frequency
50 out of the core, and it is possible to use a thinner copper shell. For the purposes of my invention, however, this advantage, of iron is overcome by the higher resistance of a
55 manganin core conductor to low-frequency current, and it is simply necessary to see that the copper is not so thin as to force more than, say 2 per cent of the high-frequency current into the core, nor so thick as to materially reduce the low-frequency resistance.

In general, therefore, the use of a suitable non-magnetic core is to be preferred.

If the copper is made too thin, the process of drawing the composite wire from the billet is likely to cause the core to be exposed in spots with resultant more rapid weathering, and this is a limiting condition on the thickness of the copper. One of the most important considerations is to get a large conductor resistance at low frequency without materially affecting the high-frequency resistance. The mechanical requirement for the minimum thickness of the copper will usually provide sufficient thickness of copper even on a conductor with non-magnetic core, on the specification just mentioned, to avoid having any appreciable amount of high-frequency current flowing in the core.

Thus, when employing this type of conductor is such an antenna structure as has been here described, it becomes possible to greatly reduce the value of the low-frequency heating current to avoid the difficulties of heating of the tuning elements and the deterioration of the contacts in the circuit as well as to conserve the heating power for use only in the elevated portions of the antenna structure.

More specifically, the employment of the simple copper-steel conductor referred to above allows the reduction of the heating current to one hundred amperes and the increase of the supply voltage to about one hundred volts, and hence allowing for the direct connection of the antenna system to the commonly available power supply systems and the reduction of the power losses in the tuning and filter inductances to one-third the values which are met when employing solid copper antenna conductors. Further, the employment of a composite conductor having a non-magnetic alloy core will even more markedly improve the conditions of operation of this system, making the low-frequency power losses in all parts of the antenna system other than the elevated conductors completely negligible and usually making it possible to employ the higher voltages of conventional power distribution systems without transformers or other costly and power consuming devices.

While I have described specific embodiments of my invention, it will be understood that the principle of my invention is of broad scope and applicable to embodiments other than those which I have described specifically, and I do not intend to impose any limitation upon the scope of my invention except as set forth in the appended claims.

Having now particularly described my invention and in what manner it is to be employed, I claim:

1. In an antenna system, an antenna conductor consisting of an inner core of comparatively high electrical resistivity and an outer contiguous shell of comparatively low

electrical resistivity, and means for delivering a low-frequency current to two separated points of said antenna conductor, said two points being so located that low-frequency current delivered to said antenna conductor traverses paths constituting substantially the entire length of said antenna conductor in passing between said points.

2. In an antenna system, an antenna conductor consisting of an inner core of comparatively high electrical resistivity and an outer contiguous shell of comparatively low electrical resistivity, said antenna conductor comprising a plurality of conductor elements connected to form a continuous electrical path, means for delivering high-frequency energy to said antenna conductor, and means for delivering low-frequency current to two separated points of said antenna conductor which are electrically distant from each other for low-frequency currents.

3. In an antenna system, a plurality of conductor elements, means for interconnecting terminal points of said conductor elements for forming a continuous low-frequency path therethrough, means for delivering high-frequency energy to said conductor elements, means for delivering low-frequency energy to two separated points of said conductor elements which are electrically distant from each other for low-frequency currents, said interconnecting means being connected between points of substantially the same high-frequency potential, said conductor elements having a cross-sectional resistivity distribution which is radially non-uniform and decreases from the center outwardly.

4. In an antenna system, an antenna conductor whose cross-sectional resistivity distribution is radially non-uniform, and means for delivering a low-frequency current to two separated points of said antenna conductor, said two points being so located that low-frequency current delivered to said antenna conductor traverses substantially the entire length of said antenna conductor in passing between said points.

5. In an antenna system, an antenna conductor whose cross-sectional resistivity distribution is radially non-uniform, said antenna conductor comprising a plurality of conductor elements connected to form a continuous electrical path, means for delivering high-frequency energy to said antenna conductor, and means for delivering a low-frequency current to two separated points of said antenna conductor which are electrically distant from each other for low-frequency currents.

6. In an antenna system, an antenna conductor consisting of an inner non-magnetic core of comparatively high electrical resistivity, and an outer contiguous non-magnetic shell of comparatively low electrical resistivity, and means for delivering a low-frequency current to two separated points of said antenna conductor, said two points being so located that low-frequency current delivered to said antenna conductor traverses paths constituting substantially the entire length of said antenna conductor in passing between said points.

7. In an antenna system, an antenna conductor consisting of an inner core of comparatively high magnetic permeability and comparatively high electrical resistivity, and an outer contiguous non-magnetic shell of comparatively low electrical resistivity, and means for delivering a low-frequency current to two separated points of said antenna conductor, said two points being so located that low-frequency current delivered to said antenna conductor traverses paths constituting substantially the entire length of said antenna conductor in passing between said points.

8. In an antenna system, an antenna conductor consisting of an inner non-magnetic core of comparatively high electrical resistivity, and an outer contiguous shell of comparatively low electrical resistivity, said antenna conductor comprising a plurality of conductor elements connected to form a continuous electrical path, means for delivering high-frequency energy to said antenna conductor, and means for delivering a low-frequency current to two separated points of said antenna conductor which are electrically distant from each other for low-frequency currents.

9. In an antenna system, an antenna conductor consisting of an inner core of comparatively high magnetic permeability and comparatively high resistivity, and an outer contiguous shell of comparatively low electrical resistivity, said antenna conductor comprising a plurality of conductor elements connected to form a continuous electrical path, means for delivering high-frequency energy to said antenna conductor, and means for delivering a low-frequency current to two separated points of said antenna conductor which are electrically distant from each other for low-frequency currents.

10. In an antenna system, an antenna conductor consisting of an inner core of comparatively high electrical resistivity and an outer contiguous shell of comparatively low electrical resistivity, said antenna conductor comprising a plurality of conductor elements connected to form a continuous electrical path, means for delivering high-frequency energy to said antenna conductor, means for delivering low-frequency current to two separated points of said antenna conductor which are electrically distant from each other for low-frequency currents, and means for electrically isolating said means for delivering high-frequency energy from said means for

delivering a low-frequency current to two separated points of said antenna conductor, said two points being so located that low-frequency current delivered to said antenna conductor traverses paths constituting substantially the entire length of said antenna conductor in passing between said points.

delivering low-frequency current, whereby high-frequency current and low-frequency current can circulate simultaneously in said antenna conductor without mutual interaction of said means.

11. In an antenna system, an antenna conductor consisting of an inner core of comparatively high electrical resistivity and an outer contiguous shell of comparatively low electrical resistivity, said antenna conductor comprising a plurality of conductor elements connected to form a continuous electrical path, means for delivering high-frequency energy to said antenna conductor, and means for delivering direct current to two separated points of said antenna conductor which are electrically distant from each other for low-frequency currents.

12. In an antenna system, an antenna conductor comprising a pair of substantially parallel wires, conductive cross connections at the ends of said wires, a pair of leads attached to said wires substantially at the midpoints thereof, a source of high-frequency current, means for excluding low-frequency current and passing high-frequency current connected between said leads and said source of high-frequency current, a source of low-frequency current, means for excluding high-frequency current and passing low-frequency current connected between said source of low-frequency current and said leads, said antenna conductor consisting of an inner core of comparatively high electrical resistivity and an outer contiguous shell of comparatively low electrical resistivity, whereby high-frequency current and low-frequency current circulate simultaneously in said antenna conductor and leads without interaction of said sources.

13. In an antenna system, a pair of similar sets of conductor elements symmetrically arranged with reference to a plane, said conductor elements being cross connected at terminal points thereof symmetrically disposed with relation to said plane, in such manner as to constitute substantially the entire length of said pair of sets of conductor elements a continuous low-frequency current path, means for delivering high-frequency energy to said conductor elements, and means for delivering low-frequency energy to two separated points of said conductor elements which are electrically distant from each other for low-frequency currents, said conductor ele-

ments having a cross-sectional resistivity distribution which is radially non-uniform.

14. In an antenna system, an antenna conductor composed of two different materials, one of said materials being of comparatively low electrical resistivity and being principally disposed in an outer shell, the other of said materials being of comparatively high electrical resistivity and being principally disposed in an inner core, said materials being interpenetrated over a substantial part of the cross-section of said conductor, means for delivering high-frequency energy to said antenna conductor, and means for delivering low-frequency energy to two separated points of said antenna conductor which are electrically distant from each other for low-frequency currents.

15. In an antenna system, an antenna conductor whose cross-sectional resistivity distribution is radially non-uniform and continuous, said antenna conductor comprising a plurality of conductor elements connected to form a continuous electrical path, means for delivering high-frequency energy to said antenna conductor, and means for delivering a low-frequency current to two separated points of said antenna conductor which are electrically distant from each other for low-frequency currents.

16. In an antenna system, an antenna conductor comprising a pair of substantially parallel wires, conductive across connections at the ends of said wires, a pair of leads attached to said wires substantially at the midpoints thereof, a source of high-frequency current, means for excluding low-frequency current and passing high-frequency current connected between said leads and said source of high-frequency current, a source of low-frequency current, means for excluding high-frequency current and passing low-frequency current connected between said source of low-frequency current and said leads, said antenna conductor and said leads consisting of an inner core of comparatively high electrical resistivity and an outer contiguous shell of comparatively low electrical resistivity, whereby high-frequency current and low-frequency current circulate simultaneously in said antenna conductor and leads without interaction of said sources.

In testimony whereof, I affix my signature.

LAWRENCE C. F. HORLE.

Certificate of Correction

Patent No. 1,917,205.

July 4, 1933.

LAWRENCE C. F. HORLE

It is hereby certified that error appears in the printed specification of the above-numbered patent requiring correction as follows: Page 1, line 59, for "brought" read *through*; page 2, line 6, for "condenser" read *condensers*; and line 26, for " C_1 " read C_i ; page 4, line 126, for "sliver" read *silver*; page 5, line 85, for "is" read *in*; and page 7, line 98, claim 16, for "across" read *cross*; 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 17th day of October, A. D. 1933.

[SEAL.]

F. M. HOPKINS,
Acting Commissioner of Patents.