No. 706,739. Patented Aug. 12, 1902.

R. A. FESSENDEN.

CONDUCTOR FOR WIRELESS TELEGRAPHY.

(Application filed May 29, 1901.)

(No Model.)

FIG. 1.

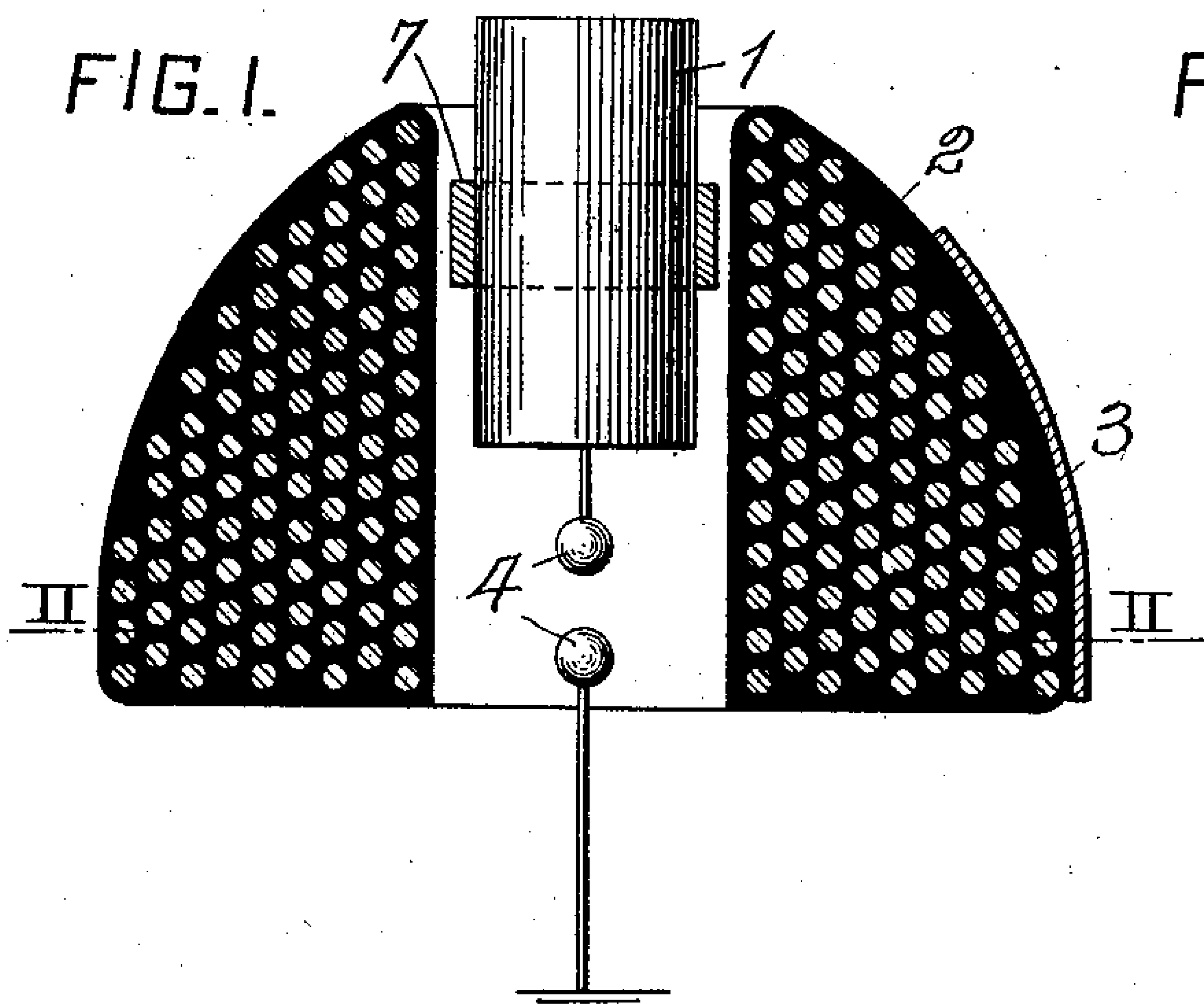


FIG. 2.

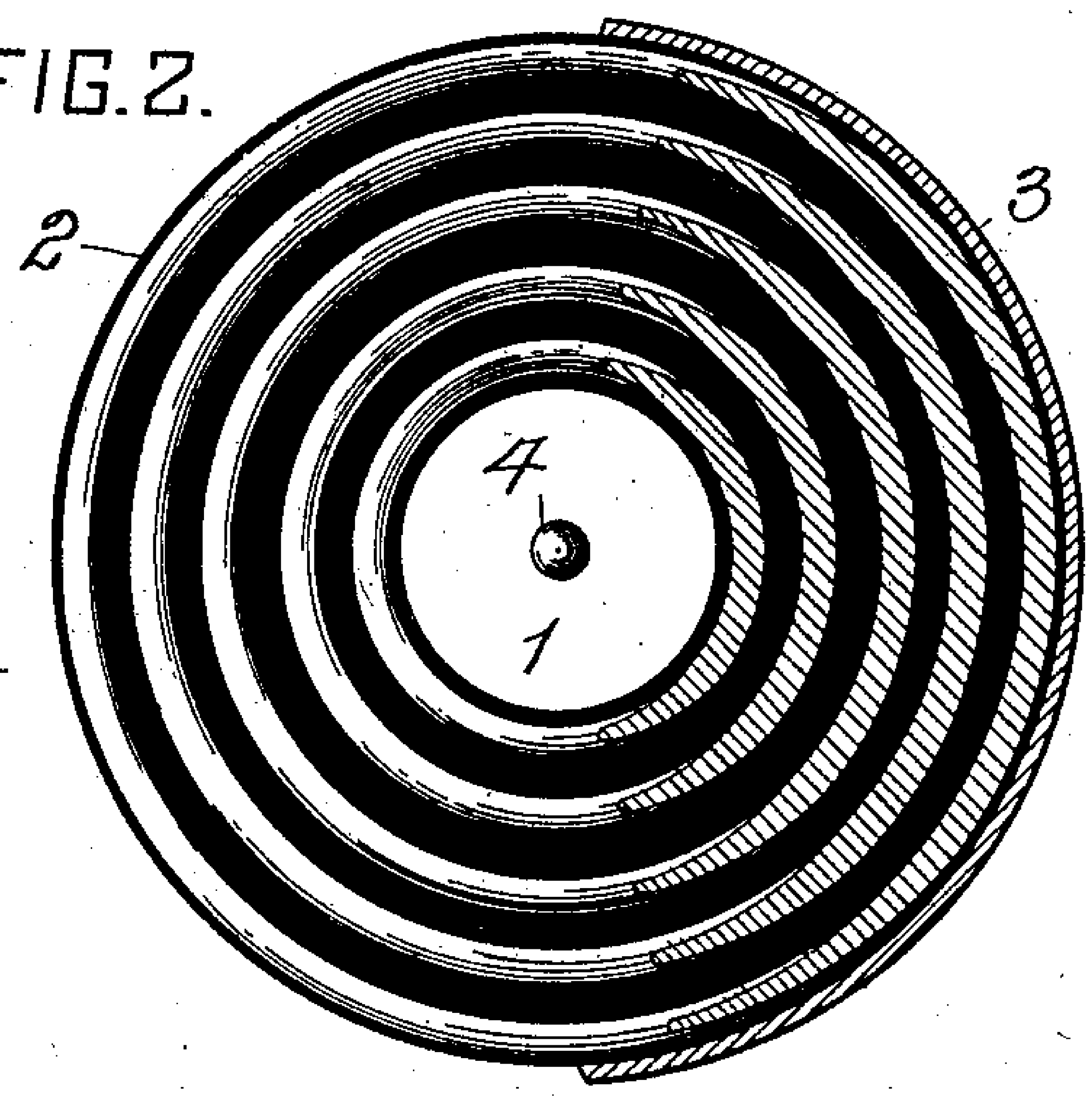


FIG. 3.

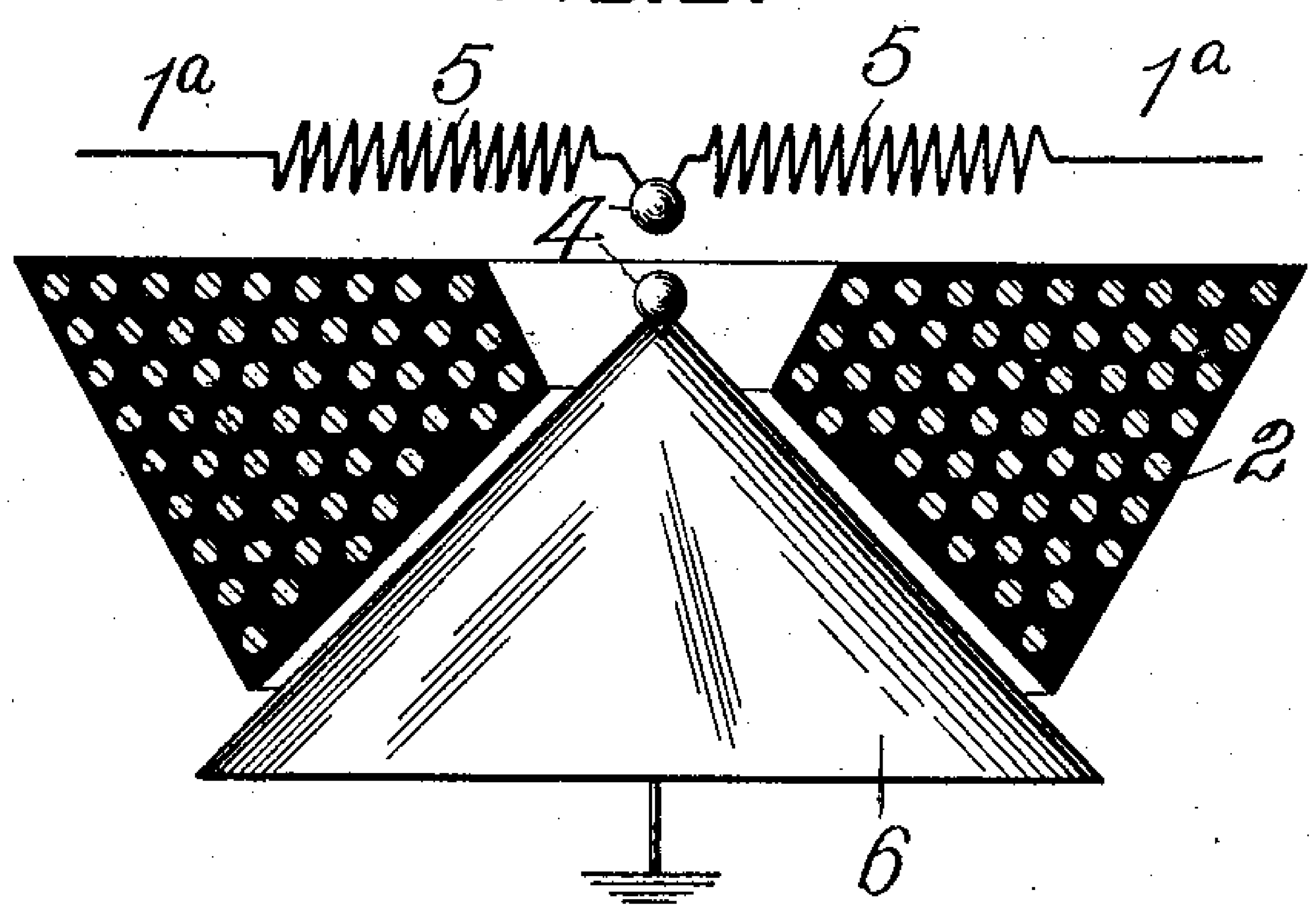


FIG. 4.

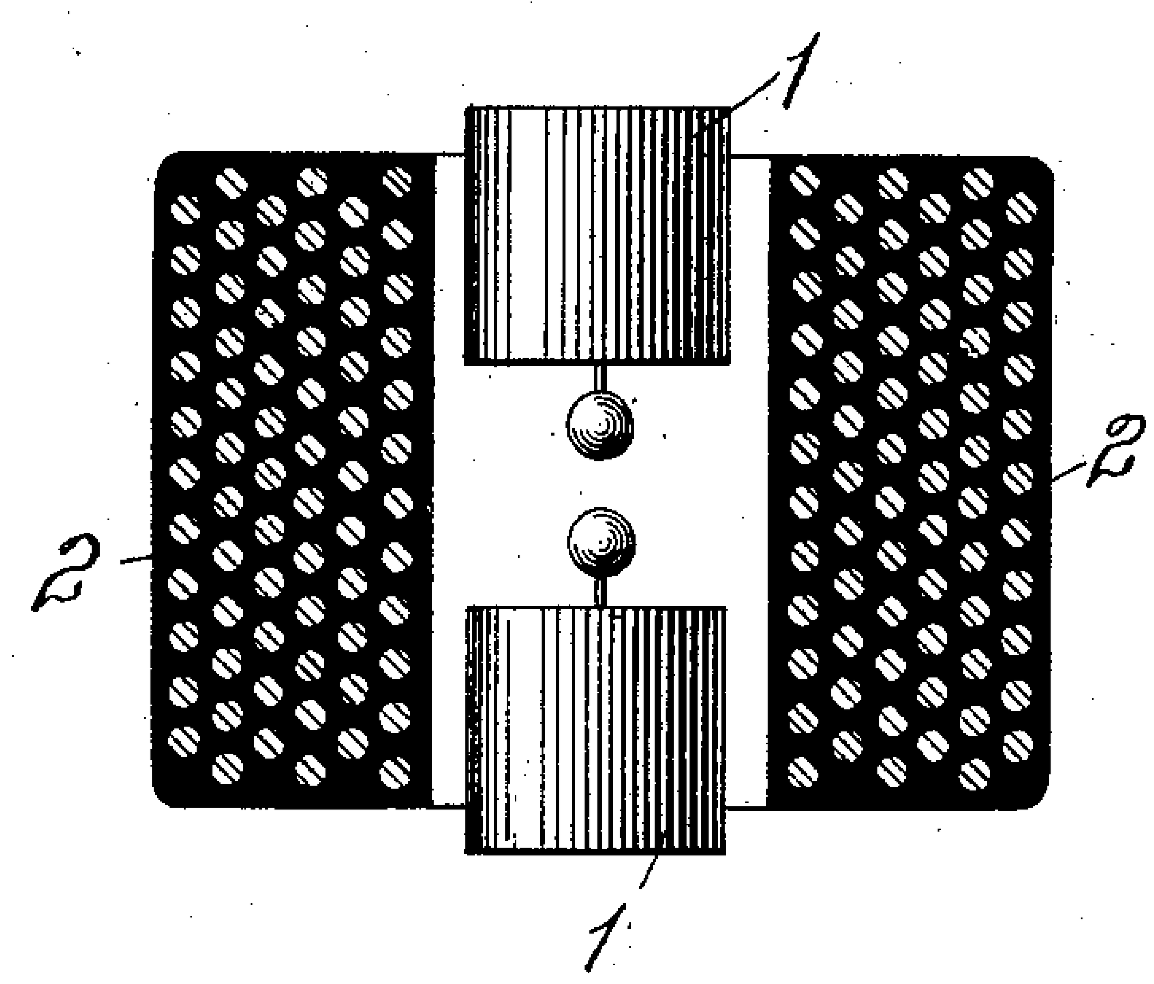


FIG. 5.

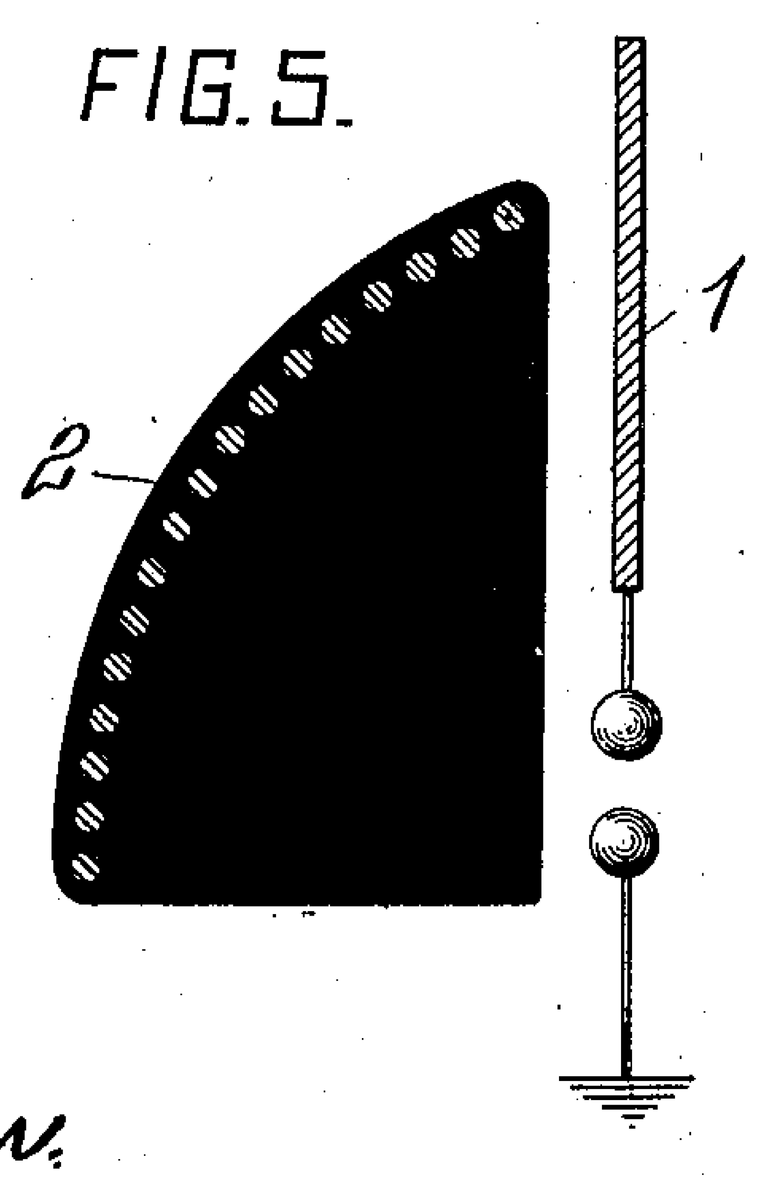
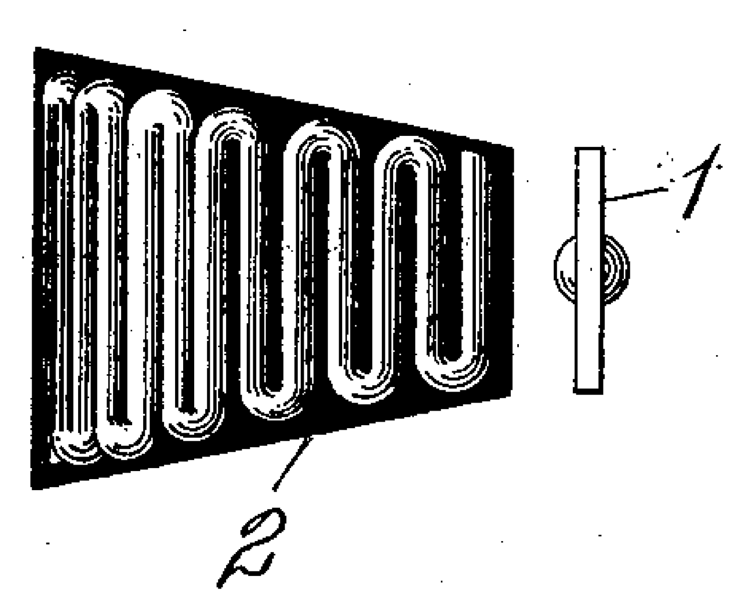


FIG. 6.



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UNITED STATES PATENT OFFICE.

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CONDUCTOR FOR WIRELESS TELEGRAPHY.

SPECIFICATION forming part of Letters Patent No. 706,739, dated August 12, 1902.

Application filed May 29, 1901. Serial No. 62,303. (No model.)

To all whom it may concern:

Be it known that I, REGINALD A. FESSENDEN, a citizen of the United States, residing at Allegheny, in the county of Allegheny and State of Pennsylvania, have invented or discovered certain new and useful Improvements in Conductors for Wireless Telegraphy, of which improvements the following is a specification.

It is generally believed that conductors of a considerable length are necessary for the efficient production of electromagnetic waves. By the term "electromagnetic waves" as used herein is meant waves of a wave length long in comparison with the wave length of what are commonly called "heat-waves" or "radiant heat." By "grounded conductor" is meant a conductor grounded either directly or through a capacity, an inductance, or a resistance, so that the current in the conductor flows from the conductor to ground, and vice versa, when electromagnetic waves are generated. The terms "tuned" and "resonant" are used herein as one including the other. Such impression is, however, erroneous, as I have discovered that by generating the waves in a medium whose permeability to electromagnetic waves or specific inductive capacity, or both, are greater than that of air short conductors may be used for the purpose of propagating and receiving electromagnetic waves. Where one of the constants only is increased, the same general effects are produced—as, for example, where the conductor is immersed in water so pure as to be non-conducting, in alcohol, or other substances having large specific inductive capacity the periodicity is decreased compared with that of the same conductor in air, and radiation is increased thereby, giving the effect of long conductor.

In the accompanying drawings, forming part of this specification, Figure 1 is a sectional elevation of my improved conductor for wireless telegraphy. Fig. 2 is a sectional view of the same. Figs. 3, 4, and 5 are sectional elevations illustrating modifications of the conductor, and Fig. 6 is a plan view of the form as shown in Fig. 5.

In the practice of my invention I preferably employ at the sending-station a conductor 1, having a large capacity and low self-induction. The capacity can be regulated by increasing the surface or area of the conductor and the self-induction by turns or coils in the wire connecting the conductor to the generator, which may be an induction apparatus or an alternating generator. A medium 2, consisting of wire or lamina formed of magnetic material, as iron or nickel, is arranged adjacent to the conductor on the side facing the direction of the receiving-station. The wires forming the medium are arranged in coils, turns, or folds, as shown. Good results have been obtained by the employment of No. 40 B. & S. insulated wires. It is preferred that the wire, especially when formed of nickel, should be wound and maintained under tension. The coils, turns, or folds, which may be arranged indiscriminately, as shown in Figs. 1 and 3, or may be arranged to form a single layer, as in Fig. 5, are spaced a distance apart less than the diameter of the wire and preferably a distance approximately equal to one-fourth ($\frac{1}{4}$) the diameter of the wire and are insulated from each other. The insulation of the coils, turns, or folds can be conveniently effected by filling the spaces or surrounding wire with an insulating material preferably of high specific inductive capacity, such as india-rubber, water, alcohol, paraffin, &c. The medium may entirely surround the conductor, as shown in Fig. 1, or be arranged only on the side facing the receiving-station, as shown in Figs. 5 and 6. If the conductor be surrounded by a medium having the coils, turns, or loops spaced a distance apart equal or approximately equal to one-fourth ($\frac{1}{4}$) the diameter of the wire and embedded in rubber of specific inductive capacity four, the virtual specific inductive capacity of the medium will be approximately sixteen times that of air, because the presence of the conducting-wire will reduce the distance through which the electrostatic lines have to pass to one-fourth the length and in that one-fourth the lines pass through a medium having four times the specific inductive capacity of air, and hence we will have sixteen times the number of lines that we would have if the medium were not there, while the permeability of the iron might be chosen so high that virtual permeability of the medium will be approximately nine hundred (900) times that of air. The time period T of natural oscillatory electromagnetic waves generated by a conductor depends upon the square root of the capacity and the square root of the inductance of the conductor—*i. e.*, $T = 2\pi\sqrt{CL}$. The capacity of a conductor depends, among other things, upon the specific inductive capacity of the medium surrounding it and varies directly as this specific inductive capacity. The inductance of a conductor depends, among other things, on the permeability of the medium surrounding it and varies directly as this permeability. Thus it follows that since the period T of the waves formed in the medium described will be $\sqrt{16 \times 900} = 120$ times as great as the period of waves formed by the same conductor in air. Now the velocity of electromagnetic waves in a medium is $V = \frac{1}{\sqrt{k\,\mu}}$, where k is the dielectric constant or specific inductive capacity and μ is the permeability of the medium; but as I have made k equal sixteen times that of air and μ equal nine hundred times that of air, it follows that the velocity of the travel of waves in this medium will be $V = \frac{1}{\sqrt{16 \times 900}} = \frac{1}{120}$ of that in air; but in any wave propagation the velocity equals $V = n\lambda$, where n equals the frequency and λ equals the wave length. Hence, as I have decreased the velocity to one one-hundred-and-twentieth of its value in air and have also decreased the frequency so that one one-hundred-and-twentieth of the value it would have if the medium I have described were not used—*i. e.*, $\frac{V}{120} = \frac{n}{120}\lambda$—it follows that the length of the waves in the medium will be the same as the length of wave generated by the same conductor when surrounded by air. Now it is a well-known principle in optics that if a wave emerges from a denser medium to one less dense the length of such wave is increased in proportion to the ratio of the speeds of the wave in the two media. So it is also in electroöptics. Hence as the waves pass from the medium in which its speed is one one-hundred-and-twentieth of its speed in air the wave length increases one hundred and twenty times. Hence a conductor one foot in length surrounded by and generating waves through such a medium will generate waves of the same length in air as the waves generated from a conductor one hundred and twenty feet long in air. By suitably proportioning the capacity of the conductor, which may be vertical or horizontal or of any desired form, in the manner stated or in any other suitable manner the amount of energy radiated may be increased as desired. If instead of rubber another insulating material or mixture of insulating material should be used having, for example, a specific inductive capacity sixty-four, the virtual specific inductive capacity with the same distance between the lines as before would be approximately four multiplied by sixty-four, and hence the waves in the medium would now be $\sqrt{256 \times 900} = 960$ times the length which the same conductor would produce in air. Similarly if the iron wire were of a poorer grade magnetically or were less permeable to magnetic forces of a high frequency its virtual permeability might be only one hundred, and if the same insulating material as in the last case were used the wave length would be $\sqrt{100 \times 256} = 160$ times the wave length produced by the same conductor in air. It will thus be seen that if a conductor in air having a certain self-inductance and capacity be surrounded by such a medium its self-inductance and capacity, or both, are increased. Since the wave length generated by the conductor depends upon the square root of the product of these two factors, it will be seen that the wave length from a given conductor can be increased by surrounding it by such a medium. Also since the energy when the conductor is charged varies for a given voltage directly with the capacity by increasing the capacity the energy available for radiation has been increased; and, further, with a given capacity the energy radiated depends upon the proportion which the wave length bears to the height of the conductor. Hence merely increasing the capacity of a conductor surrounded by air by increasing its surface without altering its height does not increase the radiation to the same extent as does increasing its capacity by increasing its height. In the present case, however, it is possible to increase the capacity of the conductor without altering its height and yet without altering the relation between the wave length and the medium and the height of the conductor—in other words, to obtain the same effect as is produced in air by raising the height of the conductor.

In the practice of my invention, except where it is desired for special purposes, to obtain as long wave lengths as possible it is preferred to use a medium having large specific inductive capacity and small permeability.

For some purposes—*e. g.*, where it is desired that the waves should have a high efficiency in one direction or on one side of the conductor—the medium may be arranged on the side of the conductor facing the point toward which the waves are to be principally effective, as shown in Figs. 5 and 6. An incremental effectiveness may be produced by the employment of a reflecting-plate 3, which is formed of metal arranged on the side of the conductor opposite that facing the direction in which the waves are to travel. The employment of a reflector for the purpose of concentrating and projecting the waves is practically possible only with short conductors. The dimensions, shape, and position of the reflector will be varied in accordance with the conditions under which it is used. In general it is desirable to arrange the reflector so as to form a portion of the outer wall of the medium.

When using an induction apparatus for charging and discharging the conductor, one end of the latter is connected to a knob 4, forming one side of the spark-gap, while the other knob is connected to ground. When using a dynamo or other source of alternating current, one terminal of the generator is connected to the conductor and the opposite terminal to ground.

It is preferred that the electromagnetic waves travel along or near the surface of the earth and that the generation of the waves should occur closely adjacent to the surface of the earth, thereby increasing their efficiency. To this end the conductor 1^a, which may be a wire, as shown, or may be in the form of a cylinder, as shown in Fig. 1, or a plate or sheet, as shown in Figs. 5 and 6, is arranged horizontally, or approximately so, as shown in Fig. 3; but this construction forms no part of the subject-matter herein. One of the sparking-knobs is connected to the conductor 1^a, preferably at a point midway of its length, as shown. Self-inductance coils 5 may be interposed between the conductor and knob to change the natural oscillation period of the system. The other sparking-knob is connected to a cone 6, formed of metal or other conducting material and arranged below the conductor. This cone may be arranged on a table or other support and connected to ground and may rest directly on the ground. In order to increase the efficiency of the conductor as regards the distance of travel of the waves, a medium 2—such, for example, as that heretofore described—is interposed between the conductor and cone. This medium may be made annular and extend entirely around the cone or may extend only partially around the cone on that side where the waves should be most efficient. The waves as they pass through the medium impinge on the surface of the cone and are deflected down onto and along the surface of the earth.

As shown in Fig. 4, a second conductor, instead of an "electrical image," as it might be termed, can be employed. In such case two similar conductors 1 are connected to opposite poles of the generating apparatus, and when an induction apparatus is used the spark-gap is formed between the conductors, the knobs 4 being connected to adjacent ends of the conductors. It is preferred that the conductors be surrounded either entirely or partially, as heretofore described, by a medium 2.

The employment of a medium in the manner described permits of the generation of electromagnetic waves of different periodicities from the same conductor as the periodicity of a wave is dependent upon the permeability and specific inductive capacity, or both, of the medium in which it is generated. As, for example, if the medium 2 be arranged in such relation to the conductor that the waves from a portion of the surface of the conductor pass through the medium, while the waves from other portions of the surface are generated and pass directly through the air, the two sets of waves will have different periodicities. In such cases the portion of the conductor outside of the medium is so constructed—*i. e.*, increased in height or capacity—that the waves generated therefrom will have the same, or approximately the same, effective travel as the waves passing through the medium.

The generation of waves of different periodicities from the same conductor may be effected by changing the capacity of the conductor at any desired point or points intermediate of its ends. This may be effected by enlarging the conductor at the desired portion or portions, as by a swell integral with the walls of the conductor or by a band or bands 7 of conducting material surrounding the conductor and in metallic contact therewith. This latter construction affords means for adjusting the capacity by adding or removing bands or changing the position thereof along the conductor. Such a conductor would generate two or more series of waves of different periodicities, the periodicity of one series of waves being dependent upon the length and configuration of the conductor and the periodicity or periodicities of the other series upon the bands or enlargements. This form of conductor thus enables me to obtain long waves from a short conductor, thereby avoiding the expense involved in the erection and maintenance of high masts. It has, however, another property, in that not only is the wave length the same as that from a long wire, but also the amount of energy radiated is the same for a given difference of potential as from a high wire. In other words, it is characteristic of this improvement that all the functions or desirable results incident to the employment of a long high conductor can be attained by a relatively short low conductor and with the additional and many advantages peculiar to this conductor—*e. g.*, it assists me in obtaining a construction which forms one of the objects of the invention embodied in application Serial No. 62,301, filed May 29, 1901.

The receiving-stations may have a conductor similar to that described, or plain conductors tuned to receive the several series of waves may be employed at the receiving-station.

It has been suggested in wireless-telegraphy work to employ apparatus in which the sparking terminals have been immersed in a liquid insulator of greater specific inductive capacity than air; but this was done for the purpose of obtaining a more abrupt spark, and not for the purpose of obtaining a greater length of wave from a given conductor. Moreover, as employed, while it would serve the purpose for which it was intended—*i. e.*, better insulation of the terminals and more abrupt spark—it would not when used as described produce the effect aimed at in the present application.

I claim herein as my invention—

1. A conductor for radiating electromagnetic waves, in combination with a medium having an electrical constant on which the wave length depends of a value greater than that of air arranged in suitable relation to the conductor.

2. A conductor for radiating electromagnetic waves having in combination therewith, a medium having an electrical constant on which the wave length depends of a value greater than that of air, arranged around the conductor, substantially as set forth.

3. A conductor for radiating electromagnetic waves in combination with a medium consisting of lamina of insulated magnetic material arranged in suitable operative relation to the conductor, substantially as set forth.

4. A conductor for radiating electromagnetic waves in combination with a medium consisting of lamina or wire of magnetic material and a material of higher specific inductive capacity than that of air, filling the spaces between the lamina of conducting material, substantially as set forth.

5. A conductor for radiating electromagnetic waves in combination with a medium having an electrical constant on which the wave length depends of a value greater than that of air and means for causing an incremental effectiveness in a given direction, substantially as set forth.

6. A conductor for radiating electromagnetic waves in combination with a medium having an electrical constant on which the wave length depends of a value greater than that of air and a reflector whereby the waves generated by the conductor may be concentrated and projected in a given direction, substantially as set forth.

7. A conductor for radiating electromagnetic waves in combination with means whereby a different periodicity is imparted to the waves generated from different portions of the conductor, and a medium having an electrical constant on which the wave length depends of a value greater than that of air arranged in suitable relation to the conductor, substantially as set forth.

8. A conductor for radiating electromagnetic waves in combination with a piece of conducting material arranged on the conductor, and a medium having an electrical constant on which the wave length depends of a value greater than that of air arranged in suitable relation to the conductor, substantially as set forth.

9. A conductor for wireless telegraphy in combination with a movable piece of conducting material arranged on the conductor, substantially as set forth.

10. A conductor for radiating electromagnetic waves, surrounded by a medium in which the wave length of electromagnetic radiation is less than the wave length of the same radiation in air, substantially as set forth.

11. A conductor for radiating electromagnetic waves, in combination with a movable piece of conducting material so arranged and proportioned that the system will simultaneously radiate waves of different periodicities of approximately the same energy, substantially as set forth.

12. A conductor for radiating electromagnetic waves, having a substantially uniform capacity over a large portion of its length and a piece of conducting material connected to such portion, whereby waves of different periodicities but of approximately the same energy may be radiated, substantially as set forth.

13. The combination of a vertically-arranged conductor for wireless telegraphy and a medium substantially as described arranged in operative relation to the conductor, substantially as set forth.

14. The combination of a conductor for radiating electromagnetic waves connected to ground and a medium having an electrical constant on which the wave length depends of a value greater than that of air arranged in operative relation to the conductor, substantially as set forth.

15. A grounded conductor for radiating electromagnetic waves in combination with a medium having an electrical constant on which the wave length depends, of a value greater than that of air, arranged in suitable relation to the conductor.

16. A grounded conductor for wireless telegraphy, having in combination therewith a medium having an electrical constant on which the wave length depends, of a value greater than that of air, arranged around the conductor, substantially as set forth.

17. A grounded conductor for wireless telegraphy, having in combination therewith a medium consisting of lamina of insulated magnetic material arranged in suitable operative relation to the conductor, substantially as set forth.

18. A grounded conductor for wireless telegraphy, in combination with means whereby a different periodicity is imparted to the waves generated from different portions of the conductor, and a medium having electrical constant on which the wave length depends,

of a value greater than that of air, arranged in suitable relation to the conductor, substantially as set forth.

19. A grounded conductor for wireless telegraphy, in combination with a movable piece of conducting material arranged on the conductor, substantially as set forth.

20. A combination of a vertically-arranged grounded conductor for radiating electromagnetic waves, and a medium substantially as described arranged in operative relation to the conductor, substantially as set forth.

In testimony whereof I have hereunto set my hand.

REGINALD A. FESSENDEN.

Witnesses:

W. B. FEARING,

S. C. GRAY.