Aug. 27, 1963

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SPIRAL WOUND ANTENNA WITH CONTROLLED SPACING FOR IMPEDANCE MATCHING

3,102,268

Filed April 11, 1960

2 Sheets-Sheet 1

Fig. 1.

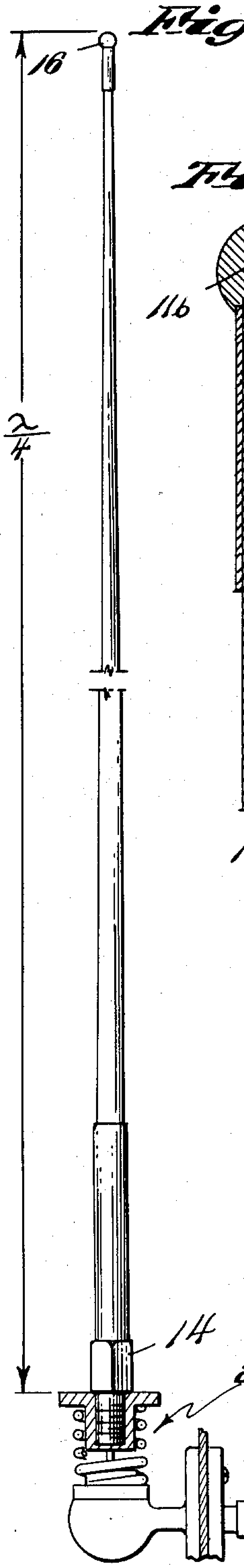



Fig. 3.

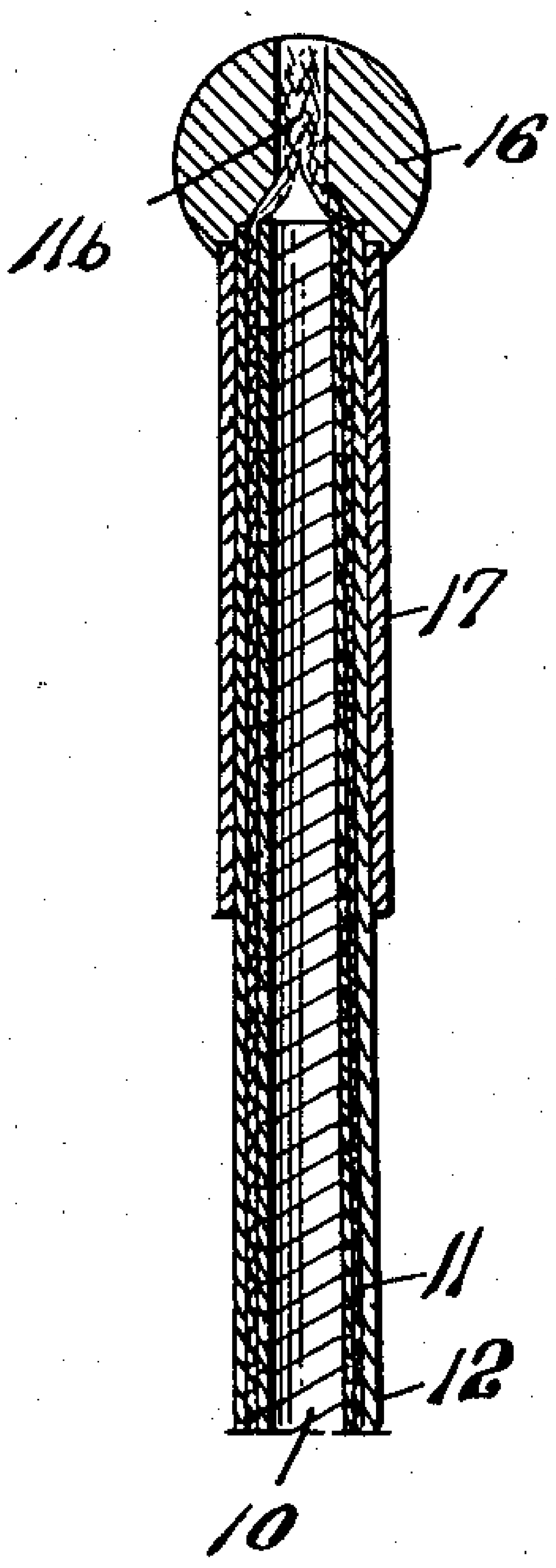



Fig. 2.

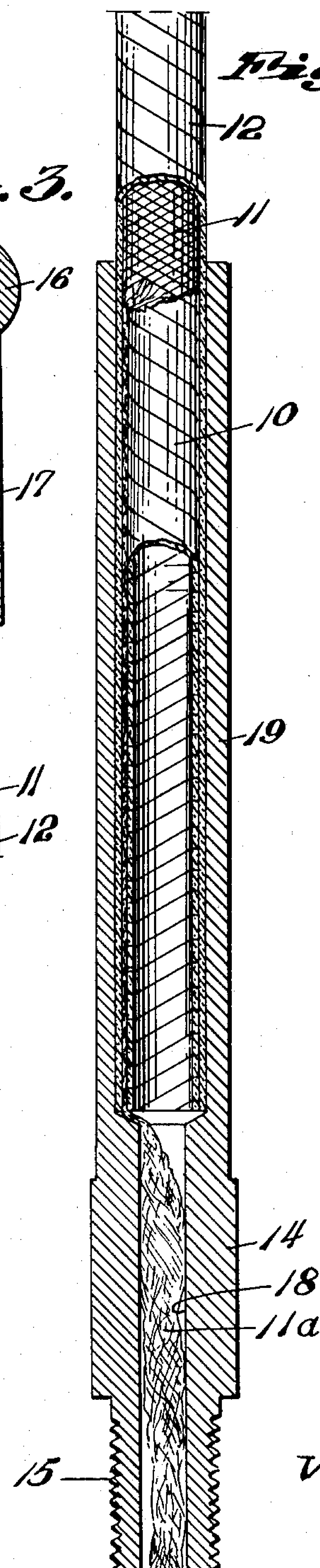
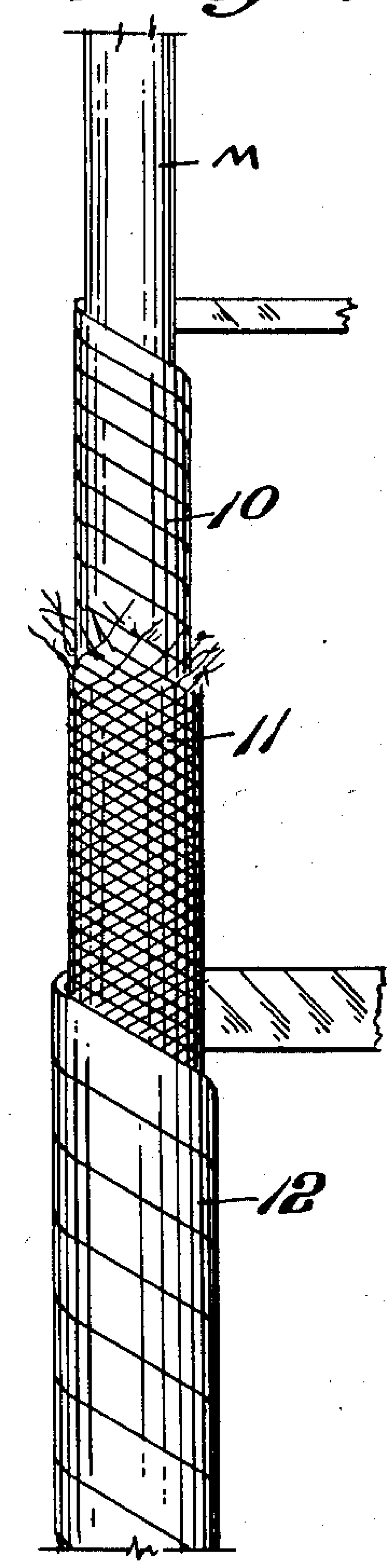



Fig. 4.



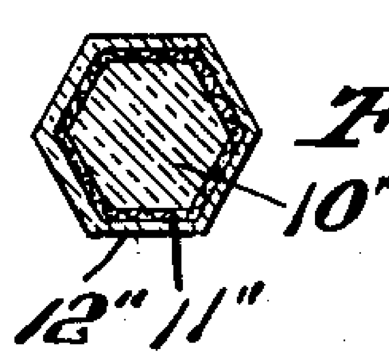




Fig. 6.

Fig. 5.

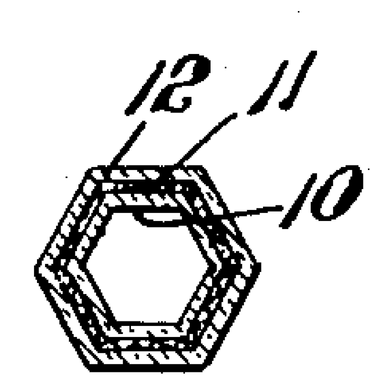



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Fig. 7.

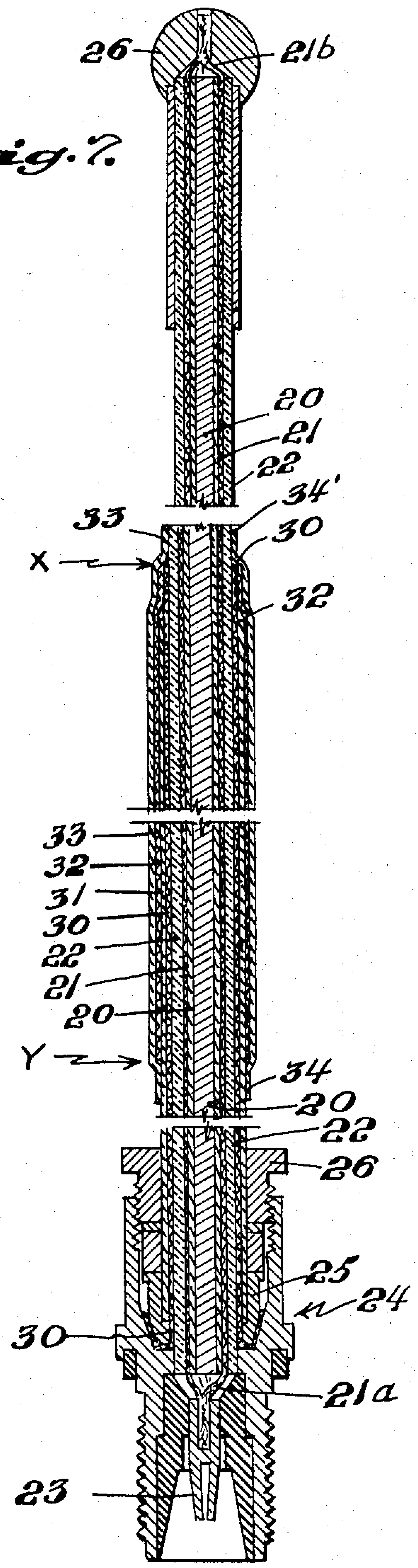
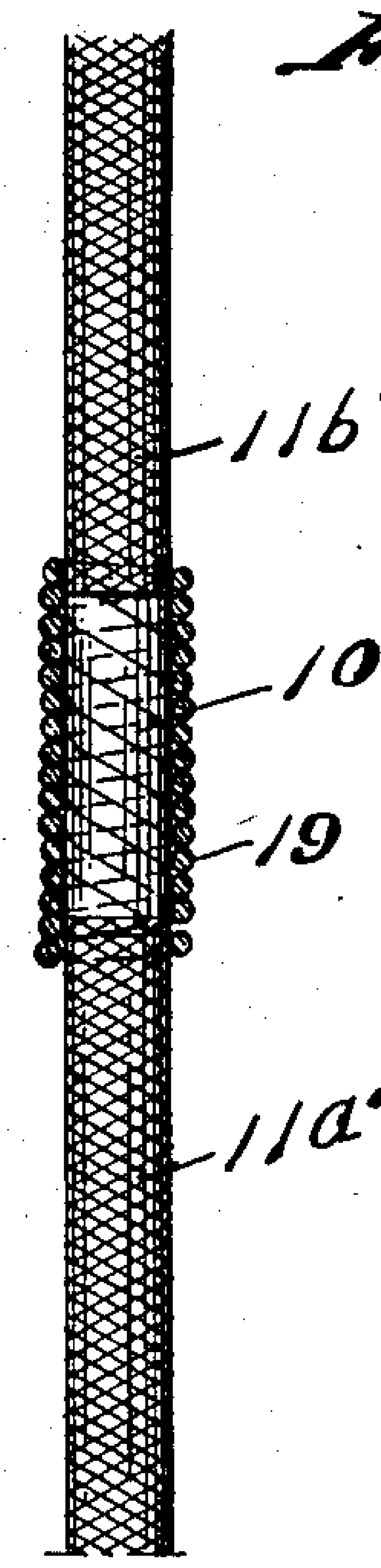



Fig. 8.



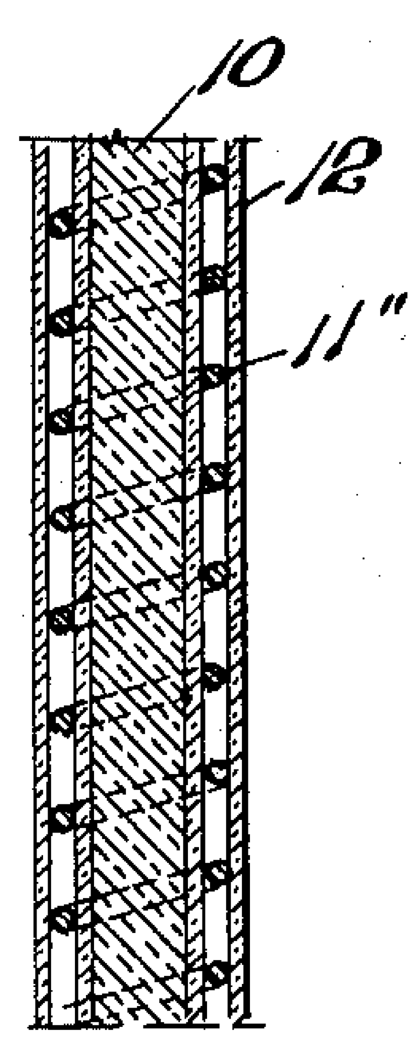




Fig. 9.

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# SPIRAL WOUND ANTENNA WITH CONTROLLED SPACING FOR IMPEDANCE MATCHING

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2 Claims. (Cl. 343—895)

This invention relates to a radiation system and more particularly to an antenna and is a continuation-in-part of my application Serial No. 580,116, filed April 23, 1956, now abandoned.

Modern developments of communication make it necessary to have a means of transmitting wide bands of frequencies. In some instances the antennas which have been utilized for this purpose have taken the form of a cylindrical tube which may or may not be telescoping and which is generally made out of a range of materials including steel, copper, tin, and aluminum. It is well known that radio frequency energy is conducted on the skin or surface of the conductor. Because of this physical phenomenon some difficulty has been experienced with certain materials which have oxidized or otherwise been affected in corrosive atmospheres. Coatings of various types have, of course, been used and suggested to inhibit the oxidation effects, but in themselves they only offer a solution to a portion of the antenna problem.

In communications, precipitation static is a serious problem. Precipitation static technically is a corona discharge which is an electrostatic impulse that occurs more or less regularly with time and frequently is heard in a receiver as semi-musical or screaming in character. These discharges effectively block radio communications for the duration thereof. It has been found that this electrical phenomenon is not associated alone with thunderstorms but occurs with all types of precipitation including snow, rain, and dust and is not limited to moving antennas. Bare antennas, therefore, may very well be one of the first elements to start discharging because of the small radius of curvature compared to the other portions of the system. It is, of course, well known that the potential gradient required to produce corona on a conductor depends upon the radius thereof, the surface electric field being inversely proportional to the radius. For practical reasons, however, a limit soon intervenes before the conductor may be unduly enlarged to reduce the effect. This problem suggests that if corona current in an antenna can be completely suppressed by covering the antenna with an insulating layer, the antenna would be satisfactory. Tests have indicated that certain synthetic materials meet the physical and electrical qualifications for insulating against this phenomenon, which characteristics resolve themselves into a very high electric resistance, high di-electric strength, a low radio frequency loss, a minimum deterioration due to ultra-violet radiation and an ability to withstand the normal operating temperatures encountered.

It is also highly desirable in an antenna to have a rather effective impedance match between the antenna and the input circuit. One of the commonly used input impedances is 52 ohms. To achieve this impedance, there are certain physical factors involved in antenna design which can be related, such as the length-diameter ratio and the electrical length, which will effect this proper impedance match. These various design considerations are summarized by Brown and Woodward in the "Proceedings of the IRE," April 1945, pages 257–262, and indicate that in order to obtain a pure resistive impedance termination of 52 ohms, the length-diameter ratio is a critical one. In certain frequency ranges this length-



diameter ratio may produce an antenna of rather large diameter proportions which introduces a weight and size problem that cannot readily be solved with existing structures.

The antenna construction of the instant invention takes into account the aforementioned problems and produces an antenna whose length-diameter ratio may be readily varied without unduly increasing the weight thereof and whose impedance for a chosen length may be varied. The resulting antenna is therefore one which renders consistent radiation results and maintains a constant impedance termination in a variety of operating environments. Some attempts at producing insulated antennas are known, one of the prior art structures being exemplified in the Closson Patent No. 2,373,660 which embodies a wire embedded in a synthetic material. This antenna, while satisfactory for the reception of radio waves in a high density field strength, is not satisfactory for two-way communications where high efficiency is necessary as the impedance characteristics are particularly poor as will be exemplified by the cited Brown and Woodward article.

One of the main objects, therefore, of this invention is to produce an antenna structure which will be light in weight.

A principal object of the invention is to produce an antenna structure which can be readily manufactured to provide a pure resistive termination to a co-axial feed line.

Another object of the invention is to produce a structure which is susceptible of having its termination impedance varied once its length-diameter ratio has been determined to obtain an efficient impedance match.

A further object of this invention is to produce an antenna which will be more efficient throughout the life thereof than existing structures.

A still further object of the invention is to produce an antenna which is completely insulated and self-supporting.

In the drawings:

FIGURE 1 is a detached elevational view of one form of my antenna;

FIGURE 2 is an elevational view of the bottom portion of one form of my antenna with parts broken away in section;

FIGURE 3 is a sectional view of the top portion of one form of my antenna;

FIGURE 4 is an elevational view of a portion of my antenna showing one manner of construction;

FIGURE 5 is a cross sectional view of a modified form;

FIGURE 6 is a cross sectional view of still another modified form;

FIGURE 7 is a detached sectional view of my antenna in coaxial form;

FIGURE 8 is a partial elevational view of a portion of my antenna without the outer sheath and having a loading coil which is illustrated in section;

FIGURE 9 is a longitudinal sectional view of a further modified form of the antenna.

In proceeding with this invention and by way of example of one method of manufacturing the antenna, I take insulating material which may be impregnated with a suitable insulating resin and form this material into a suitable cross sectional shape. The resulting structure is then placed in a braiding machine or winder and an electrical conductor may be either braided or helically wound thereon with suitable pigtails left at either end for later fabrication. Upon the conductor another layer of insulating material is formed, this material being also suitably impregnated with a synthetic resin, and the entire structure is then placed in an oven for curing of the resin in accordance with techniques developed for the resin in use so as to establish a homogeneous structure.

Referring to the drawings, the antenna shown therein consists of a core **10**, which is preferably composed of a material impregnated with a suitable resinous insulating material such as a phenolic. The material utilized may, of course, take many forms illustrative of which would be a resinous sheet with reinforcing fibers, a woven material, laminates, etc. The core **10** may assume any shape, such as elliptical, cylindrical, or polygonical, as shown in FIGURES 5 and 6, and may be hollow or solid. The core may be formed of a strip or sheet of material wound upon a removable mandrel M or solid insulation of any polygonical cross section such as shown in FIGURE 6 coated with an insulating resin. This core has formed thereon a conductor **11** shown as composed of braided single strands of wire which are bare. The conductor **11** may, however, be varied by winding bare wire strands over the core in successive opposing helices if desired, which will yield a structure that from outward appearance will be very similar to a braid. It will be apparent, therefore, that at each of the crossings of the wires a rather good electrical contact is maintained, the braiding or winding in effect forming a conductor of appropriate diameter in accordance with the criteria discussed above. The outer sheath **12** consists of a material similar to the core and is likewise impregnated with a suitable resin. The sheath may be formed over the conductor so as to completely cover the same (see FIGURE 4), or a preformed covering may be utilized. Although in the drawings, by way of example, I have shown the sheath **12** as wound or laid in the same direction as core **10**, it will be understood that under certain conditions, in order to impart additional strength to a structure that is formed as illustrated, the core and sheath may be wound or laid in opposing helices. The conductor may be further varied by using a single helical winding **11″** (see FIGURE 9).

Tapering of the antenna structure to the general outline of FIGURE 1 may be readily effected by utilizing known techniques such as used in the fishing rod industry. It will be apparent that I may change the spacing of the individual group of wires of the helices or braids, and in experiments that have been conducted, I have found that the impedance of the antenna may be nicely varied over a rather narrow range by varying this spacing without changing the diameter of the core **10**. After the structure is completed, it is placed in an oven of appropriate temperature, for the resin in use, to cure the resin. The curing makes the antenna a homogeneous mass. As a result thereof, a perfect bond is maintained between the inner core and the outer sheath, which effectively embeds the conductor **11** within the resin and prevents the access of air to the braided or wound conductor. Also by utilizing this construction, the antenna may be readily flexed into slightly more than a 90 degree bend without undue distortion of the cross sectional shape thereof.

A suitable mounting ferrule **14** may be placed over one end of the antenna, which is made in accordance with the procedure suggested above. This ferrule is provided with means for attachment of the conductor **11** thereto, such as a bore **18**, which is adapted to receive a pigtail **11*a*** that may be soldered therein. The lower end of the ferrule has an end **15** suitably threaded for attachment to various antenna mounts represented at **20** which have a coaxial feed line **21**, while the upper end of the ferrule has a supporting sleeve **19**. The other or tip end of the antenna may be left plain or finished with a ball **16** and sleeve **17** secured thereto. The method of securing may vary; for instance, if the parts are metal, the pigtail **11*b*** may be soldered to the ball **16**.

The above procedure results in an antenna of the vertical whip type that if made in conjunction with certain techniques will be immediately ready for use. The techniques involve first determining the length of a quarter wavelength at the operating frequency, or at least nearly so taking into account end-effects and the like, and then calculating the proper length-diameter ratio to achieve a characteristic impedance which will match the feed-line to the antenna. Co-axial feed lines are generally employed for this type of radiator and for whip antennas will have a characteristic impedance somewhat in the vicinity of 52 ohms. It is, of course, well known that the impedance of a whip antenna can be controlled to a degree by the length-diameter ratio as pointed out above. Still such a design consideration will lead one to an approximate impedance termination but does not give one exact impedance. To provide this exact impedance, as suggested above, the spacing between the individual wires can be varied until by experiment a perfect termination has been secured widening the spacing lowering the impedance and vice versa. Such gives the antenna feed line practically zero standing waves and yields an antenna of utmost efficiency in operation. Accordingly, in the physical structure actually produced, an improved result is obtained by varying the size of the spacing between the individual strands to provide the proper impedance, a result that cannot be successfully accomplished by trimming the length for the current loop must be kept in optimum position of the antenna.



I have also shown in FIGURE 7 of the drawings an antenna which is particularly adapted for broad band operation and which consists of a second conductor element located in spaced relation to the first element at one end of the antenna. This produces a coaxial antenna, or a hypodermic antenna or sleeve type antenna, as it is sometimes called, and which lends itself to a broad band effect of operation. This antenna comprises a core **20** upon which there is superimposed a conductor **21** which terminates at either end thereof in pigtails **21*a***, **21*b***. Pigtail **21*b*** is secured to a tip **26**, while pigtail **21*a*** is secured to the center coaxial contact pin **23** of connector **24**. Surrounding the conductor **21** is an insulating covering **22** which extends the full length of the antenna. Braided or otherwise formed over this covering **22** is another conductor **30** which in effect forms the outer sheath of what might be termed a coaxial cable that extends from the connector **24** to point X. Spaced slightly from point X and extending into the connector **24**, the conductor **30** is covered with insulation **31**. Over this insulation **31** a third conductor **32** is braided from point X toward the connector **24** a distance in the order of one-quarter wave length for the mean frequency of operation, it being understood that the antenna above point X is usually but not necessarily the same order of length of the antenna below point X. It will be noted that by the arrangement of the insulation **31**, the conductors **30** and **32** join at point X, which juncture may be enhanced by soldering or any other bonding technique. Covering the conductor **32** is a layer of insulation **33** which is bonded to insulation **22** as at **34**, **34′**. Any suitable connector **24** may be utilized, the illustrated form being shown merely by way of example to include suitable conductor shield gripping means **25** in the form of a wedge actuated by nut **26**. It should further be understood that the dimensions of the antenna structure are not to scale, for, as is well known in the art, the diameter of conductors **30** and **32** must be chosen to provide an impedance in the vicinity of 70 ohms and also that the insulating coverings are bonded together as described in connection with the first embodiment.

In FIGURE 8 I have shown a further adaptation of my antenna construction in which a loading coil may be inserted at any appropriate point therealong, preferably near the center thereof, to raise the current lobe in the lower section. Commercial loading coils are generally bulky and add greatly to the weight and moment of the antenna, which results in a tendency to swing violently, a result eliminated with my construction. Briefly, the core **10′** has formed thereover a conductor that is in two sections **11*a*′** and **11*b*′**, the sections being joined together by a coil **19** wound over the core **10′**. As in the previous embodiments, the entire structure is then covered with an insulating material suitably impregnated and then cured to yield a homogeneous antenna with loading features and extremely small diameter.

It will thus be apparent that I have produced an antenna construction which is readily adaptable for manufacturing variations and in which the RF losses are considerably less than the skin losses exhibited with other conductors. The factor of less loss comes about through the phenomenon of providing a plurality of small conductors, which in effect produce a larger surface area for the conduction of radio frequency energy. Thus, for any given diameter of a braided structure vs. a tubular structure there will be present more surface area for the energy to be conducted therealong. In addition to providing a large conductive area, the conductive part of the antenna may be nicely varied to provide an impedance match to a co-axial feed line which is accomplished by varying the spacing between the wires and the antenna structure after using the primary design technique of determining the optimum length-diameter ratio.

I claim:

1. A radio frequency antenna which is adapted to be connected to a radio frequency transmission line having a predetermined characteristic impedance, said antenna comprising: a core of dielectric material having first and second bare wire strands encircling said core in helical fashion to form an antenna having a length-diameter ratio which is chosen to achieve said predetermined characteristic impedance approximately, said first and second strands being wound about said core in opposite directions to cross each other and make contact at the crossing points to form finite spaces between said strands, said antenna being improved by selecting for each of the wound strands a particular pitch angle within a range of pitch angles that effect the resistance component of the impedance of said antenna, said resistance component changing from a larger value for the smallest pitch angle in said range to a smaller value for the largest pitch angle in said range, whereby said predetermined characteristic impedance is achieved precisely by the selection of said particular pitch angle.



2. In combination a transmission line, an antenna having a length of approximately one quarter wave length at the mean frequency to be radiated therefrom and of a predetermined characteristic impedance, and a transmission line connector means for connecting said antenna to said transmission line, said antenna comprising a supporting core coated with resinous material and a plurality of individual spaced bare wire strands encircling said core in helical fashion, each strand crossing a plurality of other individual spaced bare wire strands that encircle said core in opposite helical fashion, each of said strands being in contact with each other at the crossings thereof and leaving finite spaces between adjacent strands, the length-diameter ratio of said strands being arranged to produce said predetermined characteristic impedance approximately, said finite spaces having a particular width that is selected from a band of widths that affect the resistance component of the impedance of said antenna, said resistance component changing from a larger value for the smallest width in said band to a smaller value for the widest width in said band, whereby said predetermined characteristic impedance is achieved precisely by the selection of said particular width.

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