United States Patent

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[72] Inventor Theodore Hafner
1501 Broadway, New York, N.Y. 10036

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[54] **TEMPERATURE CONTROLLED SURFACE WAVE FEEDER LINES**
7 Claims, 7 Drawing Figs.

[52] **U.S. Cl.** .... **333/95 S,** 333/97, 174/15 C
[51] **Int. Cl.** **H01p 3/08,** H01p 1/30, H01b 7/34
[50] **Field of Search** .... 333/95 S, 95; 343/785, 704, 704.5; 174/15 C, 47, 83; 138/155

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Primary Examiner—Herman Karl Saalbach
Assistant Examiner—Wm. H. Punter
Attorney—Theodore Hafner

ABSTRACT: The invention consists of a surface wave antenna feeder in the form of a conductive tubing coated with a dielectric to produce on the outside of the coated conductor a field carrying substantially the entire electromagnetic wave energy from the transmitter to the antenna, and providing inside the tubing a circulating fluid so controlled as to maintain the line at a constant temperature substantially to exclude longitudinal expansion, regardless of the power level of the surface wave and the temperatures surrounding the line.

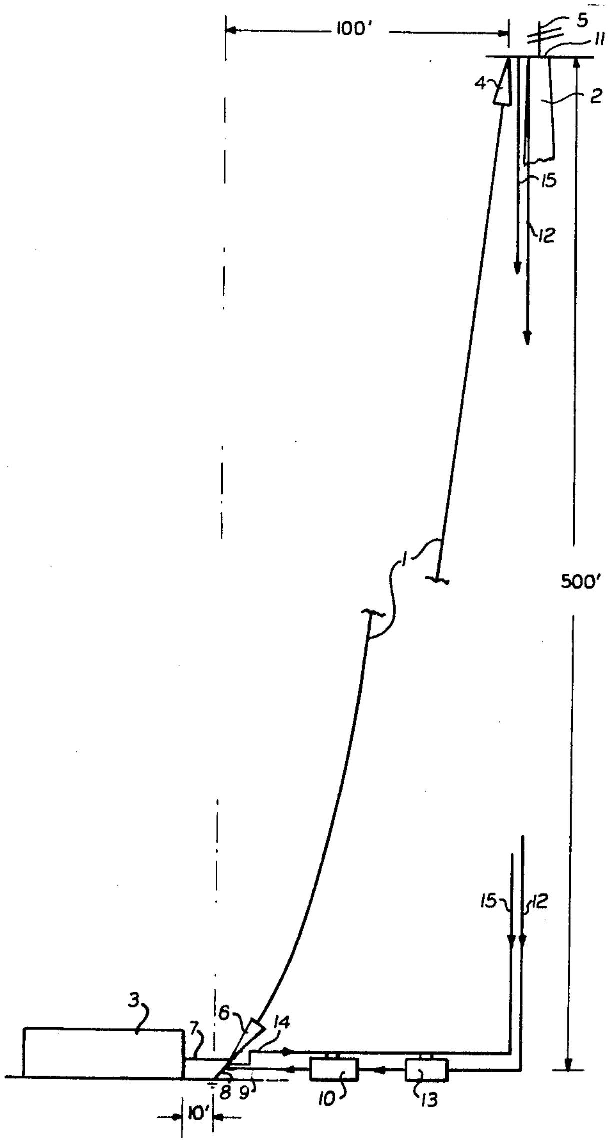

FIG. 1.

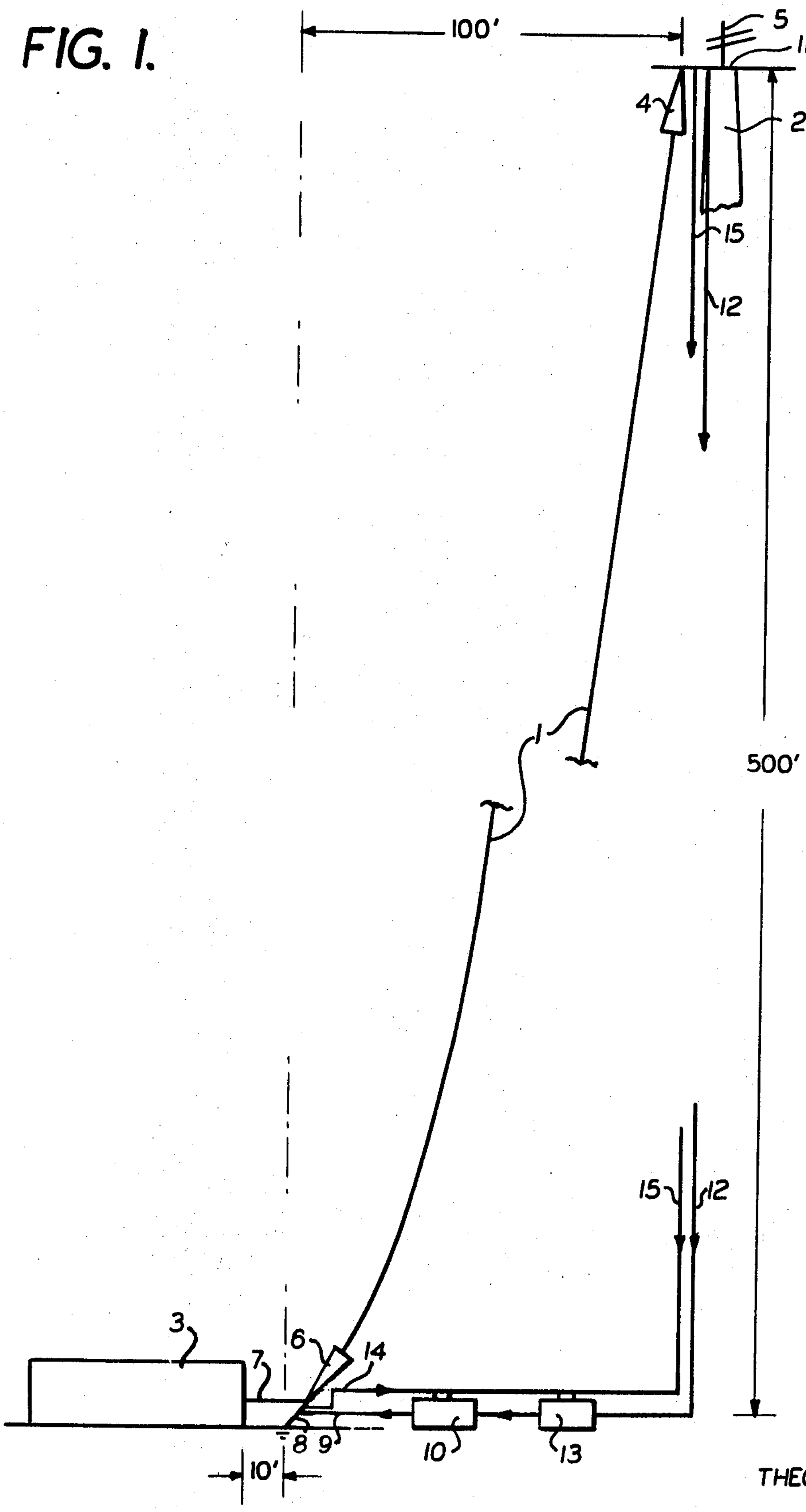

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FIG. 2.

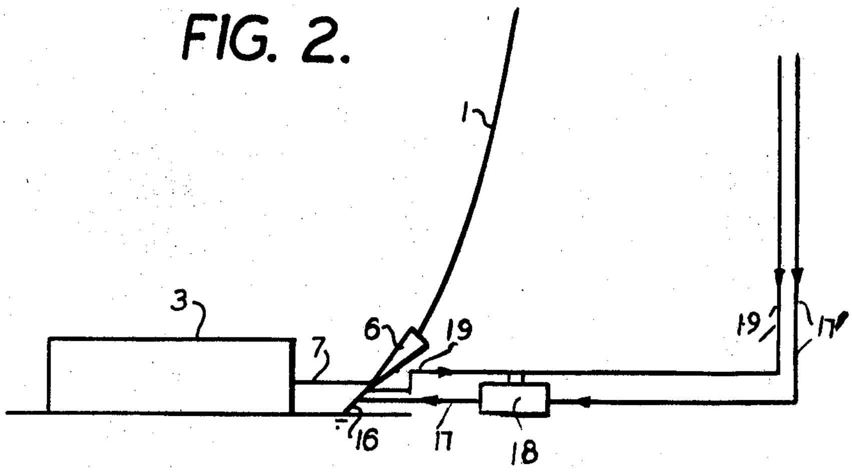


FIG. 6.

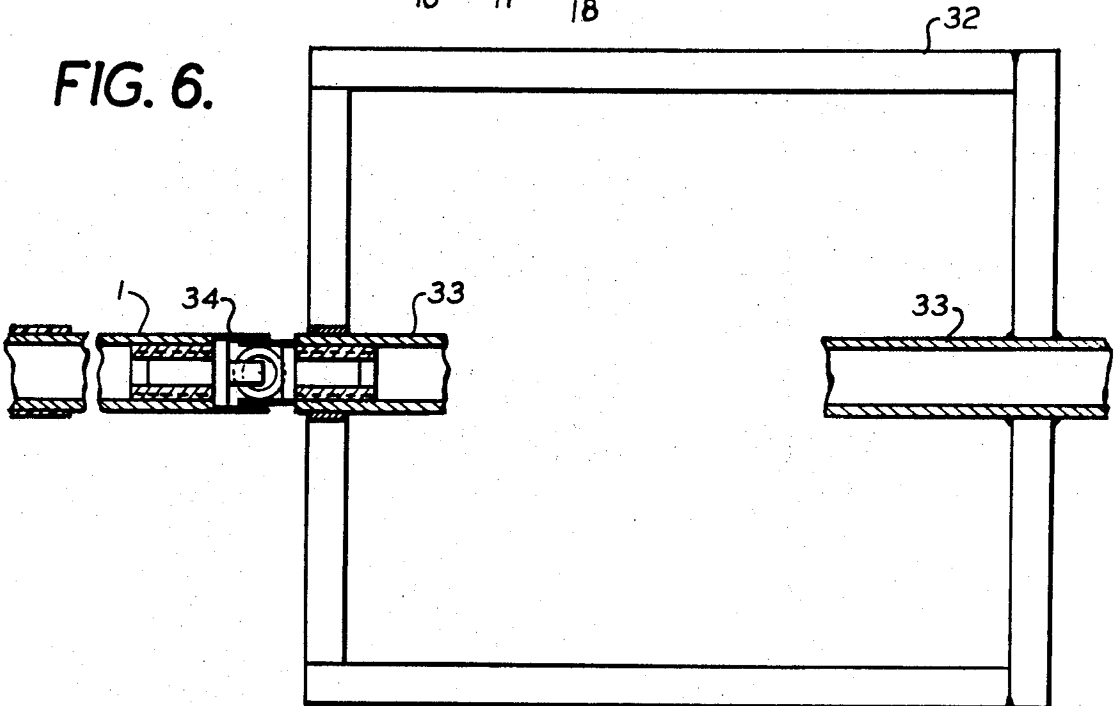
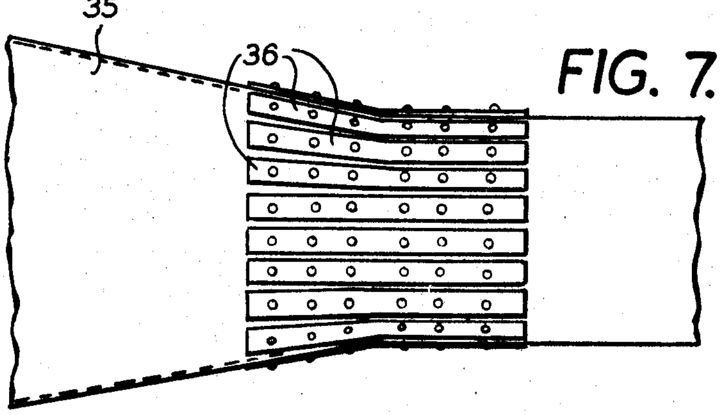


FIG. 7.



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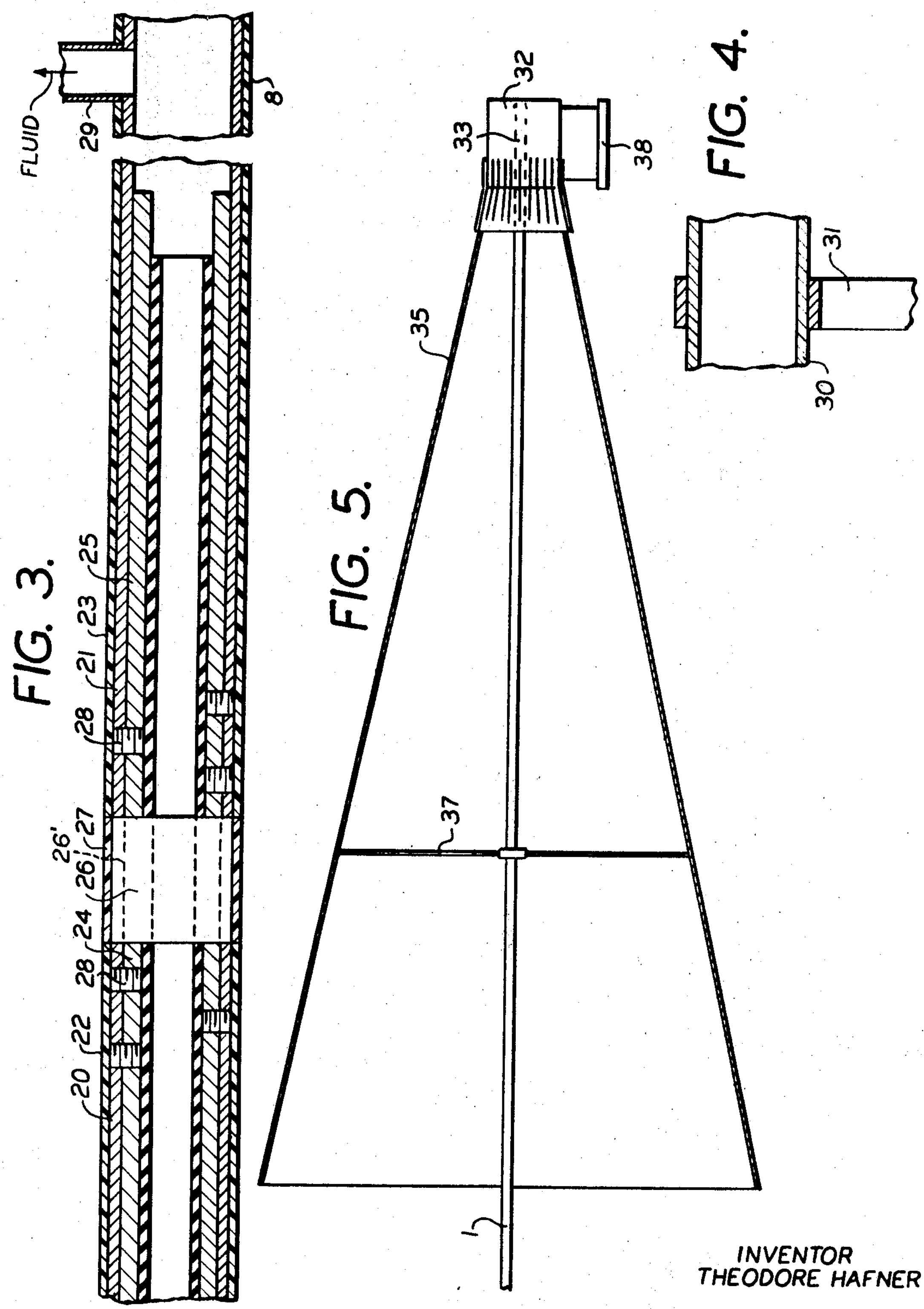
THEODORE HAFNER



INVENTOR
THEODORE HAFNER

TEMPERATURE CONTROLLED SURFACE WAVE FEEDER LINES

The invention consists of an antenna feeder line in the form of a conductive tubing coated with a dielectric and forming a surface wave transmission line, with means being applied to the tubing either in the form of a coolant fluid or in the form of electric current so as to control the temperature of the line to make it substantially independent from atmospheric conditions while carrying high R.F. power, especially in the VHF and UHF frequency ranges.

One of the objects of the invention is to dispense with large coaxial cables and waveguides as antenna feeder lines to carry the high power required for present day VHF and UHF television transmitters. Such cables and waveguides are not only expensive in manufacture but they also involve very high cost of installation and maintenance. At the same time of course, power must be carried over the feeder line with a very low loss and an equally low VSWR; for example, at 50 kw. and 800 MHz., a 500 ft. feeder line is expected to have a total loss of the order 0.7 db. and VSWR over a bandwidth of 10 MHz. of only 1.05.

In accordance with one aspect of the invention, an antenna feeder line in the form of a conductive tubing consisting for example of copper or copperplate stainless steel, and coated with a dielectric of low loss for example a loss figure of 0.0005 at UHF and forming a surface wave transmission line, and capable of being arranged at a slant depending from the antenna tower, is provided with a coolant system in which a fluid is passed through the tubing maintaining its temperature constant and thereby reducing atmospheric influences to a minimum. At the same time while providing loss and VSWR values equivalent to those of coaxial cable, for example of the rigid 6⅛-inch type, or of corresponding waveguides, cost of manufacture and especially cost of installation of the feeder line are reduced to a fraction of those prevailing in the past.

In a modification of the invention, instead of a fluid, electrical heating is applied to the tubing, to prevent icing, under control of temperature difference prevailing between the temperature due to the power carried by the line, or the absence of such power, and the temperature caused by the weather.

These and other features of the invention will be more fully apparent from the drawings annexed herein to which:

FIG. 1 illustrates schematically an antenna feeder line in accordance with the invention supported on an antenna tower; FIG. 2 a modification thereof.

FIG. 3 shows an example of a tubular feeder line, in part only and in a cross-sectional side view; FIG. 4 a modification thereof.

FIG. 5 shows an example of the launcher arrangement for the feeder line, embodying certain principles of the invention, and

FIGS. 6 and 7 show parts of FIG. 5, for a UHF transmitter, in greater detail, also embodying certain aspects of the invention.

As apparent from FIG. 1, a tubular surface wave transmission line as will be described in greater detail further below, and schematically indicated by line **1**, is shown suspended from a tower part of which is indicated at **2**, and which is 500 ft. high. Line **1** extends at a slant to a transmitter station **3** disposed about 100 ft. away from the foot of tower **2**. Preferably the slant is so disposed as to permit line **1** depending from tower **2** with minimum tension, say of the order of 2000 lbs. for a 50 kw. 800 MHz. TV transmitter feeder line. Such a slant does not only reduce strain on the tower to a minimum but it also permits to reduce to a minimum any interference between the structure of tower **2** and the field radius of surface wave transmission line **1**, which is generally of the order of about 1 wavelength of the operative frequency range of the system.

Tubular line **1** is connected in a manner, at least in principle known per se, and as will be explained more specifically further below, to its terminal equipment, at one end over a receiver horn **4** to an antenna schematically shown at **5**; at its other end, line **1** is rigidly connected over a similar launcher horn **6** and a coaxial cable **7** to the transmitter station **3**. Tubular transmission line **1** after having passed through the launcher **6**, is anchored to ground and also electrically grounded as indicated at **8**, as need not to be explained in detail, and as may be considered well known per se for example, from U.S. Pat. Specification No. 3,440,576.

At ground platform **8**, another tube **9** is connected which leads a coolant fluid derived from a pump system schematically indicated at **10** but otherwise well known per se, into, and up to the tubular transmission line **1**, on the top of which it is passed in a manner similar to that described above, through receiver horn **4** a tube portion **11** to a pipe **12** attached to tower **2** for recirculation, and if necessary after recooling or reheating as the case may be, in accordance with the temperature requirements of the system, or any other conditions of control.

In the specific embodiment of the invention shown in FIG. 1, recirculation pipe **12**, is connected to another pump system schematically indicated at **13** and which is adapted to act as a heating system while pump system **10** is adapted to act as a cooling system. Each of systems **10** and **13** is controlled by the average temperature along tubular line **1** as indicated in FIG. 1 by control lines **14**, **15** connected respectively to thermoelements (not shown) attached to the end portions **8**, **11** of line **1**, respectively which represent ground and top platform planes, respectively. Under control of these temperatures, or an average thereof, the corresponding signal voltages, after amplification if necessary, well known in the art of telecontrol and telemetering, may be used to operate, depending on the temperatures involved, either pump system **10** which cools the fluid passing therethrough, or pump system which heats the fluid passing therethrough. In this way, tubular line **1** may be maintained, regardless of its mode of operation or atmospheric or weather conditions, on a substantially constant temperature, which may be relatively low or so determined as to produce optimum transmission conditions and a minimum of mechanical stress such as extensions of length due to varying temperature arising out of changes in the transmitted power, atmospheric variations or other varying conditions.

Since fluid coolant or heating systems are well known per se, there is no need to describe such systems in greater detail; any type of such system may be applied therefore, without departing from the scope of this disclosure.

In this particular application, the intention has the advantage that it will not be necessary in the mechanical support of tubular line **1**, to provide means to compensate or tolerate longitudinal changes of line **1**. All that will be necessary, is to provide the angular or rotary movement of the line under wind pressure, as will be explained further below in connection with the attachment or guidance of the tubular line through the launching horn.

In the modification shown in FIG. 2, tubular line **1**—which is otherwise suspended in a manner similar to that shown in FIG. 1 except certain changes as conditioned by this modification—at an outer lower portion **16** is electrically connected over line **17** to an AC or DC power source schematically indicated at **18**, and over line **17'** to an upper cable portion (not shown). Temperature sensor lines schematically indicated in FIG. 2 at **19**, **19'**, after comparing temperatures prevailing on line **1**, or averaged from its ends, with atmospheric temperatures, control power source **18** which applies low frequency or DC current to tubular line **1**, thereby increasing its temperature to an amount preventing the formation of ice or providing other conditions maintaining maximum efficiency.

Since such heating systems and their control under varying temperatures, are well known per se, they will not be described in detail, and they may be applied in any form or manner whatsoever without limiting the scope of this invention.

FIG. 3 shows a portion of the tubular line, and more specifically a joint where a number of tubes forming such a line, are attached to each other.

In accordance with this invention, it has been found practical to provide a line consisting of a cascade of tubes which can be connected during the installation of the line, but otherwise may be constructed of tubes of such length that can be easily handled during transportation, coating and further assembly.

In a particular realization, a 500 ft. tubular line has been constructed of 25 tubes of 20 ft. length each, consisting of hard drawn copper which after having been coated with an appropriate dielectric such as polyethylene or Teflon (reg. TM), the latter having a loss figure of 0.0002; are attached to each other in the field and prior to the mounting on the antenna tower. While polyethylene is used as coating, generally, where relatively low operating temperatures are permissible, as for example provided for in the fluid system application illustrated in FIG. 1, the application of an electric heating system such as provided in FIG. 2 would require relatively high temperature resistant material as a coating such as Teflon.

It has further been found practical, to apply the dielectric coating not by extrusion but by means of heat shrinking of tubular material on the tubes. The tubular material may then consist either of homogenous plastic material such as polyethylene or Teflon of appropriate dielectric constant and low-loss properties as required for surface wave maintenance.

Alternatively, the heat shrinkable tubing may have a sandwich type of structure, and especially in the case of polyethylene, consist of a bottom layer of relatively low-loss but weather-sensitive plastic material, and a top layer of relatively high-loss but weather insensitive plastic material, whereby the top layer is relatively thin compared to the bottom layer so as to reduce losses to a minimum while maintaining a high degree of weather resistivity.

The invention, however, is not limited to any particular dielectric material or coating structure, nor to a particular way of its production or application.

Nor is the invention limited to any particular way controlling or affecting the temperature of the tubular line or its dielectrical coating. In effect, if necessary such systems can be combined, as for example the fluid system such as exemplified in FIG. 2, with an electrical heating system such as indicated in FIG. 1, without departing from the scope of this disclosure.

Furthermore, since the fluid systems shown in FIG. 1, make the line virtually independent from the power transmitted therethrough, or the heat produced by such power—which is the case of the above-mentioned example of a 500 ft. 50 kw., 800 MHz. tubular surface wave transmission line, may amount to 5 kw.—the same line could be used to transmit much higher powers as for example in the above-mentioned case, a power of the order of 100 kw.—thereby reducing cost of the design for different power lines to a minimum.

In FIG. 3 a portion of tubular transmission line is shown in cross-sectional view, and more particularly a portion showing a joint between two adjacent tubes forming sections of the line and attached to each other during the installation of the line.

In FIG. 3 the end portions of two line sections consisting for example of copper tubes of 20 ft. length, are schematically indicated at 20, 21, respectively, each coated with a dielectric layer in the manner as previously indicated, and schematically shown at 22, 23, respectively. Each of copper tubes 20, 21 at each of its ends, is provided with an insert 24, 25 which may also be of copper or of stainless steel or any other suitable material. Inserts 24, 25 are provided with outer threads to permit attachment of tubes 20, 21 to each other with the aid of intermediate piece 26 which through an inner thread schematically indicated at 26′, assures electrical and surface contact between tubes 20, 21 and, being also coated with a dielectric coating of the type shown at 22, 23, and indicated for piece 26 at 27, will assure the required continuity for maintaining a surface wave along the tubular line.

Inserts 24, 25, are attached to the ends of tubes 20, 21 by means of a number of setscrews schematically indicated in FIG. 3 at 28 which may also serve, if necessary, to fix the threads of intermediate pieces 26 in their position.

However, inserts 24, 25 may be attached to tubes 20, 21 in any desired manner for example by brazing or welding. Alternatively, also without departing from the scope of this disclosure, the inserts of the type shown at 24, 25 may be omitted and threads or other attachment elements directly be provided inside and outside, respectively of the adjacent ends of tubes 20, 21 in the forms of threads or the like so as to permit assembly in the field to the desired length of transmission line.

If required, further, more intermediate pieces of the type shown at 26 may also be omitted and the ends of tubes 20, 21 directly attached to each other by welding or screwing or in any other way, also without departing from the scope of this disclosure.

FIG. 3 also shows the attachment of the tubular line, or at least a predetermined portion thereof, to a fluid line to control the maintaining of temperature along the line, in accordance with one of the aspects of the invention, as schematically at 29.

In the modification shown in FIG. 4, designated for applying electrical heating current to an end portion of tubular line 1, such an end portion as indicated in FIG. 4 at 30 is shown connected over a conductor 31 to a temperature controlled source of electric power, not shown but otherwise well known in the art. In this case, of course, the recirculation pipe shown in FIG. 1 at 12 may be omitted and replaced by a return cable for the electric heating current, or the tower 2 itself used as an electric return medium.

FIG. 5 illustrates a surface wave launcher especially designed to cooperate with a tubular line in accordance with the invention. The launcher consists of a transducer schematically indicated at 32 including a coaxial line the inner conductor of which is also of tubular shape and dimensions similar to those of tubular line 1, as schematically indicated at 33, and also in FIG. 6 in greater detail.

In accordance with one embodiment of the invention, especially where by the maintaining of constant temperature of operation, which excludes longitudinal variations of the line, the connection between conductor 33 and line 1 is made so as to permit angular deviations, without impairing electrical contact, fluid transmission and wave propagation. This is achieved by replacing at the exit of transducer 32, the tubular structure of relative rigid configuration by a flexible phosphore bronze sleeve schematically indicated in FIG. 6 at 34 and attached to inner conductor 33 and line 1, respectively, by screws, rivets or welds. Sleeve 34 can be made flexible by being shaped in the form of a bellow, in the form of phosphore bronze fingers similar to the flexible fingers 36 shown in the flexible attachment between transducer 32 and horn 35 described further below.

Transducer 32 is connected to a horn which serves in otherwise well-known manner, to transform the coaxial wave emerging from transducer 32 into a surface wave, as indicated in FIG. 5 at 35. Horn 35 is also attached flexibly to transducer 32 by means of a number of phosphore bronze fingers 36, arranged peripherally around the ends of horn 35, as shown in greater detail in FIG. 7, where the figures 36 are shown attached to the ends of horn 35 and transducer 32, respectively, in such a way as to permit the horn 35 to be supported on the tubular line 1 only—or its extension inside horn 35—supported thereon if necessary by a dielectric cover disc schematically indicated in FIG. 5 at 37. In this way, horn 35 is permitted to follow the deviations of tubular line 1 without transferring any strain to transducer 32, and any equipment connected thereto such as the heavy rigid and mechanically sensitive coaxial cable connected to the output flange 37 of transducer 32.

I claim:

1. In a long-distance high-power antenna feeder system, a continuous tubing which at least at its outer surface is conducting, a dielectric coating surrounding said conducting surface and adapted to maintain a surface wave of predetermined radius in the space surrounding said coating, and means including a circulating fluid connected to the inside of said tubing, and temperature control means adapted to maintain said fluid at such a constant temperature as to substantially ex-

clude longitudinal expansions, in a manner substantially independent of the power level of the surface wave and the temperature surrounding said tubing.

2. System according to claim **1**, comprising a tower, an antenna attached to its top and a transmitter arranged near its base; wherein said tubing at least partially connects said transmitter and said antenna, and comprises a series of tubes attached to each other at their ends through an intermediate tubing adapted to connect adjacent tubes by means of threads permitting assembly of the line at the antenna site; each of said tubes having a conducting insert extending from said tube and having a thread permitting connection to the thread of said intermediate tubing.

3. System according to claim **2**, wherein said tubes consist of copper plated stainless steel.

4. System according to claim **1**, wherein said dielectric coating consists of polyethylene having a dielectric loss figure of the order of 0.0005 in the UHF range.

5. System according to claim **1**, wherein said dielectric coating consists of Teflon (trademarked by Dupont) having a dielectric loss figure of the order of 0.0002 in the UHF range.

6. System according to claim **1**, wherein said dielectric coating consists of heat-shrunk material.

7. System according to claim **1**, comprising surface wave launcher means including a transducer and a horn flexibly connected to said transducer and supported at least on part of said tubing, and a transmitter rigidly connected to said transducer; said transducer including a coaxial line having an inner conductor extending therefrom and flexibly connected to said tubing so as to permit lateral movements of said tubing only, while maintaining said tubing a substantially constant length.