Aug. 16, 1960 T. HAFNER 2,949,589

MICROWAVE COMMUNICATION LINES

Filed May 20, 1955

Fig. 1

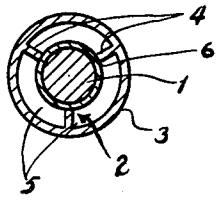


Fig. 2

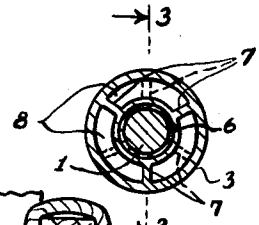


Fig. 3

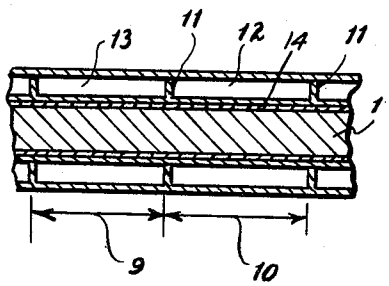


Fig. 4

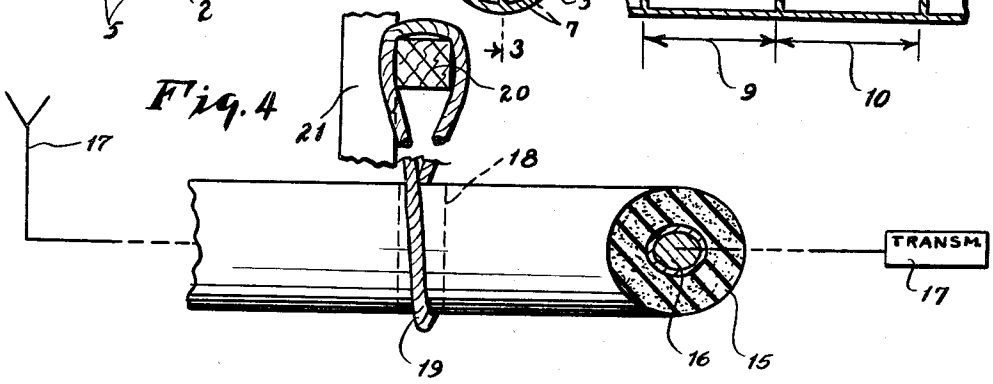


Fig. 5

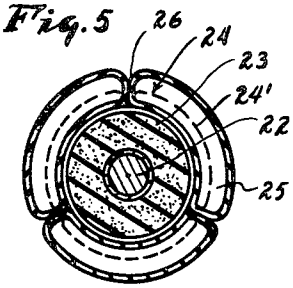


Fig. 6

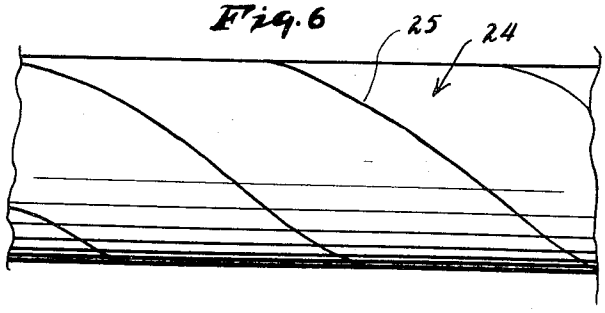


Fig. 7

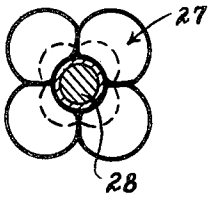


Fig. 8

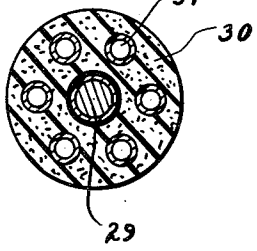


Fig. 9

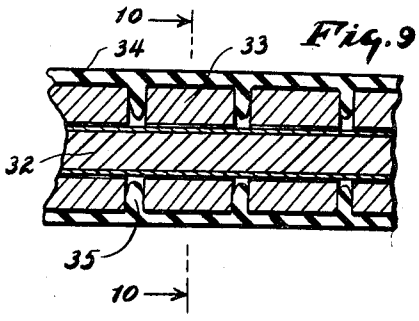
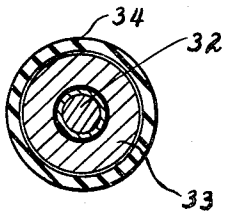


Fig. 10



INVENTOR.
THEODORE HAFNER

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2,949,589

MICROWAVE COMMUNICATION LINES

Theodore Hafner, New York, N.Y., assignor to Surface Conduction Inc.

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12 Claims. (Cl. 333—95)

This invention relates to microwave communication lines and more particularly to relatively short lines such as connecting a microwave transmitter to the station equipment.

One of the objects of the invention is to provide a communication line for extremely high frequencies of the order of 5,000 megacycles and more which is substantially independent from atmospheric influences such as humidity, ice and snow, and at the same time simple in construction and efficient in operation.

A more specific object of the invention is a communication system including a surface wave transmission line connecting appropriate receiving and transmitting elements and having a dielectric coating of a general or overall thickness extending substantially beyond the region of maximum intensity of the surface wave field but of a general or overall dielectric consant which is of the order of the surrounding atmosphere or at least not substantially higher.

Another object of the invention is a surface wave conductor having a dielectric coating of a substantially discontinuous type of structure, consisting of an outer shell arranged at a distance beyond the region of maximum intensity of the surface wave field and surrounding a number of hollow spaces arranged regularly or irregularly between the outer shell and the conductor surface thereby reducing the overall dielectric constant of the dielectric coating to a minimum.

Still another object of the invention is to provide a cellular type of dielectric coating on the surface wave conductor.

A further object of the invention is to combine a dielectric coating having an outer shell extending beyond the region of the maximum intensity of the surface wave field, with an inner coating arranged directly on the surface of the surface wave conductor but of a thickness which is small against the diameter of the region of maximum intensity of the surface waves to be transmitted.

These and other objects of the invention will be more fully understood from the drawings annexed herewith, in which

Fig. 1 shows in cross section a surface wave conductor embodying certain features of the invention.

Figs. 2 and 3, in front and side cross sectional views respectively, show modifications of Fig. 1.

Fig. 4 illustrates diagrammatically a complete surface wave transmission system in accordance with the invention.

Figs. 5 and 6 in cross section side view respectively, represent another type of surface wave conductor in accordance with this invention, and especially suited for relatively short distance microwave communications, for example, antenna lines.

Figs. 7 and 8 represent cross sections of modifications of the structures shown in Figs. 5 and 6.

Figs. 9 and 10 in cross section and side view respectively, represent another embodiment of the invention, especially applicable to long distance communication lines, and relatively low microwave frequencies.

In Fig. 1, 1 is a copper wire of No. 16 gauge adapted for example to transmit a microwave frequency of say 10,000 megacycles.

In the past it has been found that at such high frequencies a surface wave conductor requires very little if any insulation or surface deformation to produce the relatively small diameter wave field extending substantially parallel to the conductor and enclosed substantially in a cylindrical region of wave length dimension surrounding the conducting surface.

General theory and practice of such surface wave conductors and appropriate systems therefore are disclosed in U.S. patent specification No. 2,685,068, filed by G. J. E. Goubau.

However, at very high frequencies, especially of the order as contemplated in this disclosure, water drops or layers, ice layers or any other atmospheric deposits on the conductor surface are apt to disturb the surface wave field especially if they are of the order of wave field dimension in view of the relative smallness of the surface wave field.

As a result the surface wave field becomes unduly attenuated, standing waves result and undesired radiation will occur.

In accordance with the invention, surface wave conductor 1 is provided with a discontinuous type of polyethylene coating 2 which is of a radial dimension substantially greater than the wave length or lengths concerned, or which extends at least beyond the region of maximum intensity of the surface wave field surrounding the conductor surface.

At the same time by providing of low dielectric discontinuities in the polyethylene coating, the overall dielectric constant of coating 2 is held sufficiently low, not higher or not substantially higher than the dielectric constant of the atmosphere surrounding the surface wave conductor.

In this way, losses in the dielectric coating due to undesired wave field concentration, especially in the region of maximum intensity immediately surrounding or adjacent to the surface of conductor 1 are reduced to a minimum. Simultaneously, the accumulation of water, ice, and any other field distorting or obstructing atmospheric elements are placed substantially beyond the region of maximum field intensity.

In the realization of the invention of Fig. 1, the dielectric coating is shown to consist of an outer shell or wall 3 of a diameter extending substantially beyond the region of maximum surface wave field intensity, or at least beyond a region of wave length dimension of the surface wave field. Outer shell 3 is maintained in this position by a number of radial walls schematically indicated at 4 between which hollow spaces or cavities 5 are formed.

This arrangement of elements 3, 4 and 5, results in a dielectric structure of an overall dielectric constant which, if anything, is only slightly higher than that of atmosphere surrounding outer shell 3.

Radial walls 4 are supported directly on the outer surface of conductor 1 or, alternatively, as also shown in Fig. 1 on a thin enamel layer 6 of a dimension which is small against the operating wave length range and therefore does not substantially conrtibute to field attenuation while at the same time serving to protect and define the outer surface of the conductor in a predeterminedly controllable manner.

In Fig. 1, cavities or cellular spaces 5 are shown to be filled with substantially the same gas, in this case air

such as would exist in the atmosphere surrounding the outer wall 3, which need not be perfectly continuous but only sufficient to keep the disturbing atmospheric or other elements at the proper distance out of the maximum field strength region.

However, the invention is not limited to this specific arrangement.

Alternatively, complete enclosure of the cavities 2 may be provided as apparent from the modification of the invention shown in the different cross sectional views of Figs. 2 and 3.

In this case, in addition to the outer shell 3 there is provided an inner shell 6 of a dimension which is rather small against wave length dimension and therefore substantially not contributive to field attenuation with radial ribs being provided as before at 7 forming cavities 8 reducing the overall dielectric constant in accordance with the invention to a value which is not higher or not substantially higher than that of the surrounding atmosphere or air.

In accordance with a further feature of the invention, cavities 8 may be so arranged that they do not extend continually and in the same direction throughout the entire length of the conductor surface but only over predetermined short lengths 9, 10, as apparent from Fig. 3 which are separated from each other by walls 11 extending perpendicular to the axis of the surface wave conductor and which are angularly displaced with respect to each other so as to present a better distribution or homogenization of the dielectric constant over the entire length of the surface wave conductor of say several thousand foot length. This especially applies to antenna lines in which the invention is believed to be of particular advantage.

Thus a number of completely enclosed cavities 12, 13 are realized extending radially around as well as longitudinally along conductor 1.

In accordance with another feature of the invention it is now feasible to further reduce the dielectric constant and to bring it as close as possible to that of the surrounding air by enclosing in these spaces a gas at lower dielectric constant than that prevailing in the surrounding atmosphere.

Such gases of lower dielectric constant are well known in the art, for example, hydrogen or helium; and to enclose such gases into dielectric cavities made of rubber, polyethylene or any other thermosetting plastic or extrusion material is well known and need not be explained in detail.

One of the simplest ways of achieving such gas enclosures of predetermined dimensions and gas content is to form or extrude the plastic in such a gas atmosphere or at least to add to the extrusion liquid or solution the desired gas content in a form in which during the extrusion process it will either be formed or exist at the moment of extrusion at the desired portions of the extrusion structure.

While Figs. 2 and 3 show a direct application of the low dielectric constant coating on a surface wave conductor it has been found useful to provide in addition to such coating a continuous density type of rather usual and relatively high dielectric constant but of a thickness which is small against the wave length contemplated or at least small as compared to the diameter of the region of maximum intensity of the surface wave field.

In Fig. 2, intermediate coating 14 is an enamel coating and serves not only to concentrate the wave field to the required dimensions but at the same time to protect the outer surface of the surface wave conductor itself against atmospheric or mechanical attack or any other influences affecting the surface wave field.

In Figs. 2 or 3, the inner shell 6 may replace the immediate dielectric layer or alternatively may be added to enhance protection and definition of the outer conductor surface.

Instead of providing cavities such as shown in Figs. 1, 2 or 3 in more or less regular or symmetrical array around and along a surface wave conductor of appropriate dimensions, such cavities may be arranged in an irregular or asymmetrical manner with more or less equivalent effect on the overall dielectric constant of the dielectric coating.

As apparent from Fig. 4 dielectric coating 15 surrounding an enameled coated surface wave conductor 16 is of a dimension substantially exceeding wave length dimension or at least the region of maximum intensity of the surface wave field and including a number of irregularly arranged cavities or pores thereby reducing the relatively high dielectric intensity of the coating material itself to the relatively low value approximating the dielectric constant of air, in accordance with the invention.

It has been found in practice that foam rubber or foam polyethylene or any other foam type dielectric can be used in accordance with the invention.

Here too, in accordance with a further feature of the invention, the pores can be arranged to be filled with air or any other relatively low type dielectric constant gas in otherwise well-known manner.

As apparent from the cross section of Fig. 4, the discontinuous type of foam rubber structure does not extend uniformly across the entire length of the surface wave conductor extending from antenna 17 to transmitter station 17' but is interrupted periodically through relatively short but relatively densely or continuously structurized dielectric portion 18, which in this particular case may consist of relatively less porous, or unporous polyethylene, polystyrene or any other thermostatic plastic.

These relatively hard or rigid portions of the dielectric coating surrounding the surface wave conductor may serve as supporting points or portions for the entire surface wave conductor line, to hold for example nylon strings 19 depends from cross arms 20 of poles 21.

In this way, wear and tear on dielectric coating of the surface wave conductor is reduced to a minimum without impairing excessively its attenuation characteristics.

In order to reduce this impairment of attenuation to a minimum the transition from the relatively porous to the relatively unporous structure of the dielectric coating is made gradual, all this without exceeding from the scope of the invention.

The embodiment of the invention illustrated in Figs. 5 and 6 represent means for preventing or breaking up the formation of ice on surface wave transmission lines of the kilomegacycle range and of relatively short lengths, such as are used as antenna lines.

In Figs. 5 and 6 a surface wave conductor 22, enamelled or otherwise protected in otherwise well known manner, or also unprotected as the case may be, is provided with a foam or sponge type polyethylene coating 23, removing the influence of rain or ice as far as possible from the high intensity region of the surface wave field surrounding conductor 22.

In addition, there is provided around the circumference of coating 23 a cylindrical balloon-like structure made of flexible and preferably elastic dielectric material such as rubber schematically indicated at 24.

Structure 24 can be inflated by pumping a gas, such as air, therethrough.

In deflated condition structure 24 is indicated by dotted line 24'.

Inflation of structure 24' to shape 24 will produce a mechanical movement removing the ice partially or completely or at any rate removing the ice to a distance which is far out of the region of high intensity of the surface wave field created by conductor 22.

As apparent from Figs. 5 and 6 structure 24 is formed into three—or more—compartments 25 having side walls 26 which assure proper centrifugation around dielectric coat 23.

In the realization of a balloon-like structure shown in

Fig. 6, the various compartments **25** are shown to extend spirally around dielectric coating **23** and as a result deformation of the balloon-like structure **24** will not only occur in a direction radial with respect to the surface wave conductor, but also in a direction longitudinal to that conductor, and as a result the balloon-like structure will be subjected to twisting movements which will enhance de-icing.

In the embodiment of Fig. 7 the balloon-like structure is applied directly at **27** around a surface wave conductor **28**.

In the modification of Fig. 8 a surface wave conductor **29** is provided with a foam polyethylene coating **30** which is provided with a number of longitudinally or spirally extending channels **31**.

Such channels may serve to carry hot air or an anti-freeze liquid reducing icing to a minimum.

At the same time under appropriate pressures or pressure changes of the gas or liquid passing through channels **31**, the entire dielectric crating **30**, and especially its surface, will be subjected to movements causing de-icing, or at least preventing or reducing the formation of ice to a minimum.

Additional heating can be applied in all of the embodiment of Figs. 1 through 10 to prevent or reduce interior icing or at least reduce internal condensation to a minimum.

However, in accordance with the invention, the electric heat required in the case of Figs. 1 to 8 is relatively small and may be held substantially below the temperature affecting the structure or efficiency of the insulating coating of the surface wave conductor, such as polyethylene, since the principal de-icing operation is taken over by the balloon-like structure or inflatory movements.

In Figs. 9 and 10, de-icing is shown to be caused by electric heating applied to a surface wave conductor in a manner especially adapted for long distance communication and relatively low microwave ranges such as of the order of several hundred megacycles. In this case, a surface wave conductor schematically indicated at **32** is provided with a number of relatively high heat conducting but still well insulating rings, cylinders, discs or the like, in a pearl string-like fashion as schematically indicated at **33**, and consisting for example of steatite.

In this way it is possible to heat the structure to a much higher temperature than that possible with polyethylene or a similar type of thermosetting plastic, and yet at the same time to obtain a good conduction of the heat to the outside.

In order to assure dielectric continuity on the pearl-like structure **33** an outer polyethylene cover tubing **34** is provided which by proper means such as a plastic filler **35**, can be extended into the interstices between rings **33**.

Rings **33** can also be made of ferrites to increase the electric efficiency of the line.

While the invention is particularly applicable to high microwave frequencies or to frequencies in which water, snow and ice and other deposits on the surface wave conductors are of wave length or field affecting dimensions, the invention is not limited to any particular frequency in this frequency range, nor is it limited to the particular form, structure or type of dielectric, cells or cavities but may be applied in any form or manner whatsoever without departing from the framework of this disclosure.

I claim:

1. In a microwave communication system, means for launching surface waves at a predetermined wave length range, means for receiving said surface waves, and a surface wave transmission line connecting said launching and receiving means including a longitudinal conductor including a dielectric layer exposed to the atmosphere and having an outer surface spaced from the conductor surface at a distance of the order of one wave length of said wave length range whereby said dielectric surface lies beyond the region of maximum intensity of the surface wave field; and a number of gas filled cavities in said dielectric layer between said outer surface and said conductor surface so distributed as to produce a dielectric constant of an overall value not substantially different from that of the atmosphere surrounding said layer; both said layer and cavities extending substantially over the entire length of said line as exposed to said atmosphere.

2. System according to claim 1 wherein said conductor surface is formed of a dielectric layer of relatively high dielectric constant and of a thickness which is small relative to wave length.

3. System according to claim 1, wherein said cavities are substantially closed from the outer atmosphere and filled with a gas of lower dielectric constant than the outer atmosphere.

4. System according to claim 1 wherein said cavities have an outer wall bordering the atmosphere and an inner wall bordering the conductor which is small relative to wave length dimension.

5. System according to claim 1, wherein said dielectric layer is interrupted by short portions of continuous type of dielectric layer.

6. System according to claim 1, wherein said dielectric layer is elastic and comprises inflatable portions.

7. System according to claim 1, wherein at least part of said dielectric layer includes a cavity permitting passage of a fluid under greater than atmospheric pressure.

8. System according to claim 1, wherein said dielectric layer is divided into cavities forming channels parallel to the conductor axis.

9. System according to claim 1, wherein said dielectric layer is divided into cavities forming channels helicoidal to the conductor axis.

10. System according to claim 1, wherein the dielectric layer consists of a number of cylinders arranged over said conductor in pearl-string fashion.

11. System according to claim 10 comprising means including a thermosetting plastic for filling at least a portion of the interstices between said cylinders.

12. System according to claim 10, wherein said cylinders consist of ferrites.

References Cited in the file of this patent

UNITED STATES PATENTS

2,129,711	Southworth	Sept. 13, 1938
2,588,610	Boothroyd et al.	Mar. 11, 1952
2,688,732	Kock	Sept. 7, 1954
2,770,783	Clavier et al.	Nov. 13, 1956

FOREIGN PATENTS

694,622	Great Britain	July 22, 1953
899,685	Germany	Dec. 14, 1953
1,075,609	France	Apr. 14, 1954
1,075,899	France	Apr. 14, 1954