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J. COLLARD
HIGH-FREQUENCY ELECTRIC TRANSMISSION
LINES OR WAVEGUIDES
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2,557,261

Fig. 1.

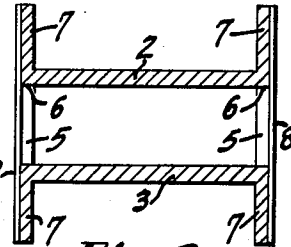
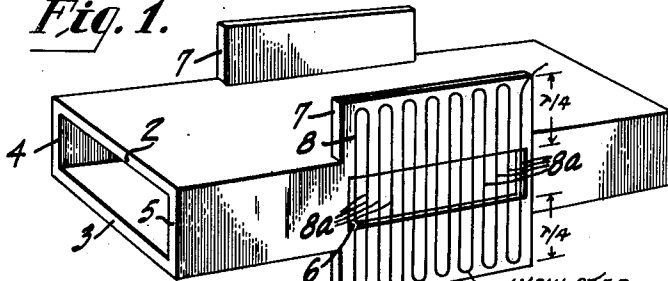


Fig. 2.

INCISIONS IN
CONDUCTIVE
COATING
MATERIAL

INSULATING
MATERIAL

INSULATED
WIRE

Fig. 3.

CONDUCTIVE
COATING
MATERIAL

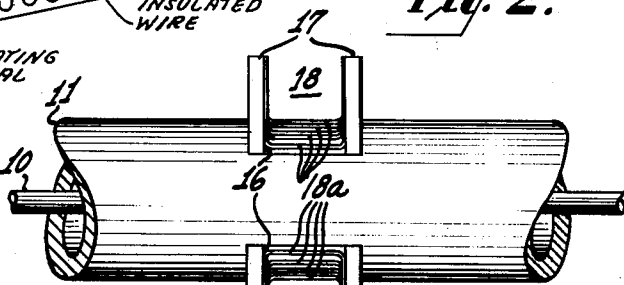
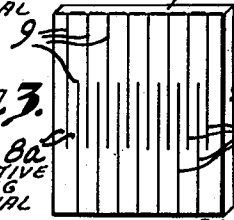


Fig. 4.

FLEXIBLE
INSULATING
MATERIAL

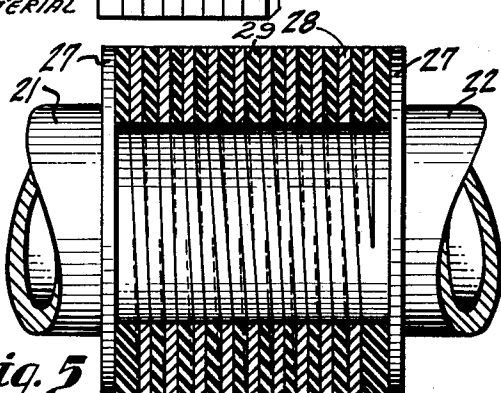


Fig. 5.

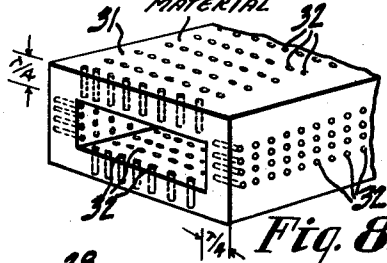


Fig. 8.

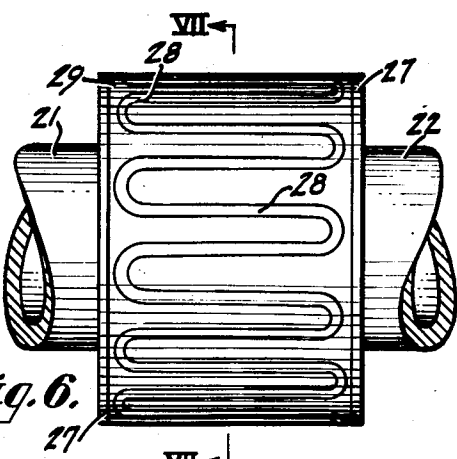


Fig. 6.

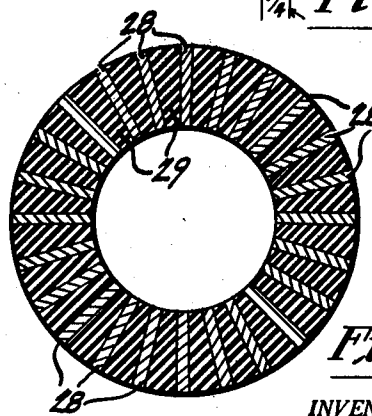


Fig. 7.

INVENTOR.
JOHN COLLARD
BY
H. S. Grover
ATTORNEY

UNITED STATES PATENT OFFICE

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HIGH-FREQUENCY ELECTRIC TRANSMISSION LINES OR WAVE GUIDES

John Collard, Hammersmith, London, England,
 assignor to Electric & Musical Industries Limited,
 Hayes, England, a company of Great Britain

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6 Claims. (Cl. 171—95)

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The present invention relates to high-frequency transmission lines or waveguides.

The main object of the present invention is to provide high-frequency transmission lines or waveguides which afford a number of advantages.

The invention also provides apparatus for measuring the power in a transmission line or waveguide.

According to one feature of the present invention there is provided a high-frequency transmission line or waveguide wherein at least a part of the surface of the line or guide which serves to confine energy travelling through said line or guide is composed effectively of a plurality of conductors insulated from one another and closely spaced so as to prevent substantial escape of energy, said conductors being of such dimensions and are so arranged with respect to portions of said line or guide or with respect to one another as to provide transmission line sections which, in respect of energy transmitted along said line or guide, appear to be short-circuited at said surface, whereby said conductors simulate in respect of said energy a substantially continuous conducting surface.

According to another feature of the invention there is provided a high-frequency transmission line or waveguide having an opening therein which is covered by a grid which serves to prevent a substantial escape of energy, said grid being insulated from the line or guide and having conducting elements which co-operate with portions of said line or guide to form transmission line sections which, in respect of energy transmitted along said line or guide, appear to be short-circuited at said opening whereby said grid causes said opening to appear in respect of said energy to be a substantially continuous conducting surface.

In certain forms of the invention the transmission line or waveguide has an opening in its surface having extensions projecting from opposite sides of said opening, said conductors extending across said opening and having end sections which co-operate with said expansions to afford said transmission line sections. Said conductors may be effectively afforded by a continuous length of conductor extending back and forth across said opening and extensions or may be afforded by a conducting coating on an insulating base.

In other forms of the invention the transmission line or waveguide may comprise a pair of tubular conductors having spaced flanged ends, the space between said ends being surrounded effectively by said plurality of conductors which

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co-operate with said flanged ends to afford said transmission line sections. In this case the said conductors may be effectively afforded by a length of conducting tape which may be helically wound between said flanges or wound back and forth between said flanges, the thin side of the tape being presented towards the longitudinal axis of said transmission line or waveguide.

According to another feature of the invention there is provided a flexible waveguide comprising a flexible insulating member having a plurality of conductors extending through the wall thereof, the length of said conductors being such that adjacent conductors co-operate to form transmission line sections which, in respect of energy transmitted along said guide, appear to be short-circuited at their inner ends, whereby said conductors simulate a substantially continuous conducting surface.

A section of waveguide or transmission line formed in accordance with the invention may be arranged to pass only those frequencies in respect of which the aforesaid transmission line sections appears to be short-circuited at their inner ends.

Thus, a section of waveguide in accordance with the invention may be employed as a filter for eliminating unwanted frequencies including D. C. Moreover, in apparatus according to the invention the aforesaid conductor or grid will be directly heated by the currents excited by the wave travelling through the apparatus and their temperature will afford an indication of the power in the line or guide. For power measurement purposes the elements are preferably formed of material having a suitable coefficient of variation of resistance with temperature and the elements may be included in a suitable bridge circuit for measuring their resistance to afford an indication of the temperature of the conductors or grid and consequently of the power in the line or guide.

In order that the said invention may be clearly understood and readily carried into effect, it will now be described with reference by way of example to the accompanying drawings, in which:

Figure 1 is a diagrammatic perspective view in section of a waveguide according to the invention,

Figure 2 is a diagrammatic sectional view of the section of waveguide of Figure 1 at the mid-plane perpendicular to the axis of the guide,

Figure 3 is a detail view showing an alternative form of the plurality of conductors employed in Figures 1 and 2,

Figure 4 is a diagrammatic view in side elevation of a transmission line embodying the invention,

Figure 5 is a side elevational view partly in

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section of another waveguide embodying the invention.

Figure 6 is a side elevational view of a waveguide similar to that shown in Figure 5, but having the conductors formed in a different manner.

Figure 7 is a sectional view in the plane VII-VII of Figure 6, and

Figure 8 is a fragmentary perspective view of a flexible waveguide constructed in accordance with the invention.

Referring to Figures 1 and 2 of the drawing, a waveguide is shown of rectangular cross-section having wide sides 2 and 3 shown horizontally and narrow sides 4 and 5 shown vertically. The guide is intended for transmitting waves in the H_{10} mode, the waves being transmitted within the space enclosed by the inner surface of the guide in well-understood manner. Each narrow side 4 and 5 is provided with a rectangular opening 6 having its longer sides horizontal, the two openings 6 being in registry, as will be seen from Figure 2. Above and below the openings 6 the walls 4 and 5 are formed with extensions 7. The openings 6 are covered effectively by a plurality of conductors. The conductors in the example shown in Figures 1 and 2 are arranged to form grids 8, each grid being formed of a continuous length of insulated wire bent back on itself for a number of times, the lengths of conductors 8a between successive bends extending vertically from the top of the upper extension 7 to the bottom of the lower extension 7. The electrical lengths of the conductors 8a between their upper or lower ends and the upper or lower edge of the opening 6 are made equal to a quarter of a wavelength at the operating frequency of the guide, due allowance being made for the presence of the insulation. Each opening 6 is thus covered with a grid formed of a series of parallel conductors 8a which have end sections extending for a quarter wavelength above and below each opening.

If the waves are propagated through the guide in the H_{10} mode, the currents flowing in the two narrow sides of the guide will flow at right angles to the axis of the guide. Thus, each end section of the conductors 8a co-operates with the adjacent portion of the wall 4 or 5 and the appropriate extension 7 to provide a two-conductor electrical circuit which is a quarter of a wavelength long at the operating frequency and is open-circuited at the far end. Thus, as seen from within the waveguide, the conductors 8a appear to be short-circuited to the wall 4 or 5 at the edges of the opening 6, and in respect of high-frequency currents, each grid 8 acts as though it were made up of a grid of conductors having separate elements crossing the opening 7, each element being bonded to the wall of the guide at the edges of the opening 6. Thus, in respect of high frequencies, if the conductors 8a are sufficiently close together so that no radiation takes place through their interstices, each grid 8 replaces the piece of guide cut away to form the opening 6 and the guide thus behaves to high-frequency currents practically as though no apertures were there.

When power flows through a section of waveguide the loss in the section of guide causes the temperature of the guide to rise and the increase in the temperature of the guide over the ambient temperature is a measure of the power passing through the guide. It has already been proposed to make use of that fact by wrapping an insulated winding of suitable wire round a section of the guide so that when power passes through the

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guide the increase in temperature which follows causes the wire to become heated by conduction so as to cause the resistance of the wire to change. The change of resistance can then be measured by including the wire in a suitable electric bridge circuit in well-known manner so as to afford an indication of the power passing through the guide. In this case, as the insulated wire is heated by conduction of heat from the guide to the wire through the insulation, the transfer of heat is slow. However, the form of guide shown in Figures 1 and 2 may be employed for power measurement purposes by inserting the grids 8 in bridge circuits without this disadvantage arising, as in this case each grid 8 will be traversed by currents excited by the waves and will consequently be heated directly. The measurement can thus be effected more rapidly than with the known arrangements.

Moreover, as the wire forming each grid is quite long, its D. C. or low-frequency resistance can readily be made quite high, so that if the wire has a large coefficient of change of resistance with temperature, the arrangement will have a good sensitivity. At the same time, the grids 8 will have a low resistance to the high-frequency waves travelling in the guide and will not greatly disturb the operation of the guide. The power measuring apparatus can thus be employed to afford a continuous indication when the guide is in use.

A convenient method of constructing the grid 8 is illustrated in Figure 3, which is a detail view of a single grid. In this case the grid is formed on a support of insulating material such as mica of a size such that the support can be applied to one side of the waveguide to extend from the top of the upper extension 7 to the bottom of the lower extension 7 and to cover the opening 6 in the wall of the guide. The insulating support is coated or plated with a film of conducting material such as platinum having a good coefficient of variation of resistance with temperature, and the coated or plated support is provided with incisions 9 extending from the top and bottom edges alternately as indicated at 9 in Figure 3, the incisions being of such length that when the sheet is assembled the incisions extend from edge to edge of the opening 6 over which the grid is applied. The conductors 8a of the grid are then constituted by the strips of conducting film lying between the overlapping portions of the incisions 9, the grids so formed having a high D. C. resistance and a good coefficient of variation of resistance with temperature. Preferably, the conducting film on the portions of insulating support lying above and below the upper and lower edges respectively of the opening 6 is made thicker than on the portions of the sheet extending over the opening 6 so that the resistance of the conducting film in those parts which co-operate with the extensions 7 on the guide to provide quarter wave line sections is decreased.

The grids 8 of the form shown in Figure 3 are applied to the waveguide with the support outwards, and to insulate the conducting coating from the side of the guide the extensions 7 may have a coating of insulating material. The nature of this material will affect the dimensions of the parts of the grids required to co-operate with the extension 7 on the guide to provide line sections having the required electrical length.

With a grid of the kind shown in Figure 3, no difficulties will be occasioned due to radiation through the gaps between the conductors, as

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these gaps can be made sufficiently narrow to prevent radiation.

To compensate for changes in ambient temperature, the resistance bridge employed for indicating the temperature of the two grids 8 may include another pair of grids similar to the grids 8, each further grid being included in an opposite arm of the bridge to that in which one of the grids 8 is included, the further grids being arranged so as to be subjected to changes in ambient temperature, but not to be affected by waves passing through the guide or by temperature changes confined to the guide.

In the case of a rectangular guide used for the transmission of waves in the H_{01} mode, the openings such as 6 should be provided in the wide sides 4 and 5 and not in the narrow sides, these openings being covered with grids such as 8 co-operating with extensions of the wide sides similar to the extensions 7 of Figures 1 and 2.

Figure 4 illustrates the invention in application to a section of transmission line of the co-axial conductor type having cylindrical inner and outer conductors 10 and 11 respectively. The outer conductor 11 is provided with two diametrically opposed openings 16 corresponding to the openings 6 of Figures 1 and 2 and provided with flanges 17 on the edges at right angles to the axis of the line. Between the flanges 17 are mounted insulated grids 18 corresponding to the grids 8 of Figures 1 and 2, each conductor 18a of the grids comprising a portion extending across the associated opening 16 parallel to the axis of the system and having end sections extending radially across each of the flanges 17 associated with each opening. The flanges 17 and the co-operating portions of the elements 18a extend radially over a quarter of a wavelength at the operating frequency of the guide.

In the case of a co-axial line, currents travel in the outer conductor 11 in a direction parallel to the axis of the line instead of at right angles to the axis as they do in the narrow sides 4 and 5 of the rectangular guide of Figures 1 and 2, and hence in the arrangement shown in Figure 4 the grids 18 have their conductors 18a extending across the apertures 16 in a direction parallel to the axis of the line. In the arrangement of Figure 4 the grids 18 act in a manner similar to that in which grids 8 of Figures 1 and 2 act and the grids 18 may be regarded as effectively replacing the pieces of conductor 11 removed to form the opening 16. However, as the grids are insulated from the conductor 11 and are traversed by currents excited by the wave flowing through the guide they are available for power measurement like the grids 8 of Figures 1 and 2.

In a modification of the arrangement of Figure 4 the outer conductor 11 may be replaced by a pair of hollow conductors having flanged ends presented to each other, and the two grids 18 may be replaced by a grid forming a cylindrical cage-like structure and affording, in effect, a continuation of the surfaces of the hollow conductors.

Figure 5 shows the application of the invention to a waveguide formed of hollow cylindrical conductors 21 and 22. In the case of guides of this form the current flow is generally too complex, except for the H_{01} mode, to permit the use of a simple wire grid. The conductors 21 and 22 are therefore provided with radial end flanges 27 and these flanges co-operate with a plurality of effective conductors. These conductors are effectively provided by a length of conducting tape 28 wound to form a helix, as shown, having

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an inner diameter the same as that of the outer diameter of the hollow conductors 21 and 22, the flanges 27 and the conductor 28 having a width such as to afford an electrical length of a quarter of the wavelength at the operating frequency. The tape is wound with its thin side directed towards the longitudinal axis of the guide. With the arrangement of Figure 5 it will be appreciated that at any point on the inner edges of the flanges 27 of conductors 21 and 22 the appropriate flanges 27 and the surface of the adjacent turn of the conductor 28 constitute a two-conductor circuit open-circuited at the end remote from the point and extending radially outwards from the point. Thus, in respect of waves transmitted through the guide, any point on the inner edge of flange 27 may be considered as being short-circuited to the nearest point on the inner edge of the adjacent turn of conductor 28 so that the flange 27 and the turn of conductor 28 adjacent the flange may be considered as directly connected in respect of wave transmission. Similarly, any point on the inner edge of each turn of the conductor 28 may be regarded as directly connected to the nearest points on the inner edge of the neighboring turns in respect of wave transmission, and as a result the two conductors 21 and 22 and the conductor 28 appears as a continuous tubular conductor in respect of wave transmission. If the turns of conductor 28 are sufficiently closely spaced there will be no appreciable radiation through the spaces between the turns.

To insulate the conductor 28 insulating material 29 may be formed about the conductor or one or each side of the conductor may have an insulating strip or layer applied to it. It will be appreciated that the width of the conductor 28 and the flanges 27 will be such as to give an electrical quarter wavelength with the particular insulating material 29 which is employed. In the arrangement of Figure 5 a wave travelling through the guide constituted by the conductors 21, 22 and 22 will excite currents in the conductor 28 which will become directly heated. Thus, the conductor 28 may be included in a resistance bridge and employed for power measurement as in the case of the grids 8 and 18 of Figures 1 to 4. Moreover, it is to be observed that in the arrangement of Figure 5, while the conductor 28 provides a connection between conductors 21 and 22 in respect of wave transmission, no such connection is provided in respect of D.-C. Thus the invention provides an arrangement forming a waveguide having sections insulated one from the other in respect of the transmission of D.-C. Moreover, the turns of the conductor 28 will only appear short-circuited from their inner edges in respect of a particular frequency and certain harmonics of that frequency so that the conductor will not operate to transfer waves of all frequencies, but will act as a filter.

In the embodiment of the invention shown in Figures 6 and 7 the conductor 28, instead of being wound on a helix, is wound in lengths which are arranged to extend back and forth between flanges 27 of conductors 21 and 22 parallel to the axes of the guide, the conductor 28 being bent back on itself at the end of each length. In this case also the inner edges of the successive lengths of tape may be regarded as effectively directly connected together and to the inner edges of flanges 27 in respect of wave transmissions along the guide.

Figure 8 is a diagrammatical representation

of a flexible waveguide made in accordance with the invention. This guide consists of a tube 31 of flexible insulating material, such as rubber, the inside surfaces of the tube constituting the operative surfaces of the guide and the thickness of the wall of the tube being made such as to afford an electrical length of a quarter wavelength at the operating frequency of the guide between the inner and outer face of each wall. The tube 31 may be rectangular as shown or of other cross section. A large number of conductors, such as wires 32, are inserted normally in the walls of the guide 31, each wire having a length equal to the thickness of the walls of the guide so that the wire extends from one surface to the other of the wall in which it is inserted. With this arrangement each pair of adjacent wires, together with the rubber or other dielectric surrounding it, as seen from the inner surface of the guide, presents a section of transmission line extending outwardly from said surface and having an electrical length of a quarter wavelength and open-circuited at its remote end so that the inner ends of the wires appear to be directly connected together in respect of wave transmission along the guide and simulate a continuous electrically-conductive surface. Thus, the guide will operate substantially as though it were constructed entirely of conducting material.

The wires 32 may be inserted in the guide 31 of Figure 8 by means of a hollow steel needle which is used to pierce the wall and through which the wire is fed into the rubber so as to be gripped therein when the needle is removed.

It will be appreciated that while in the foregoing description the extensions 7 and 8a of Figures 1, 2 and 3, and the flanges 17 and elements 18a of Figure 4, the flanges 27 and the conductor 28 of Figures 5 and 7, and the wires 32 of Figure 8 have been arranged to form quarter wavelength transmission lines, they might be formed to provide lines having lengths which are odd multiples of a quarter of a wavelength. Also the conductors referred to might be arranged to provide lines which are short-circuited at their outer ends and have lengths equal to a whole number of half wavelengths.

Moreover, while in the foregoing examples the invention has been shown as applied to hollow transmission lines or guides, it will be understood that the interior of these members might be filled with dielectric material and in the case of the arrangement of Figure 8, the member 31 might be replaced by a rigid insulating material.

Having now particularly described and ascertained the nature of my said invention and in what manner the same is to be performed, I declare that what I claim is:

1. A high-frequency transmission waveguide, a portion of the energy confining surface thereof

having an aperture therein, extensions of said surface arranged in the proximity of said aperture and a continuous conductor insulated from and arranged upon said extensions and extending back and forth across said aperture, coincident portions of said extensions and said conductor being a quarter wavelength long at the frequency of the energy transmitted whereby the portion of said energy confining surface constituted by said conductor appears to be short-circuited at said surface with respect to the energy transmitted along said waveguide and the temperature variations of said conductor when energy is transmitted through said guide serves an indication of the power transmitted there-through.

2. The combination claimed in claim 1, said continuous conductor comprising a single wire.

3. The combination claimed in claim 1, said continuous conductor comprising a film of conducting material having incisions.

4. The combination claimed in claim 1, said waveguide being a rectangular hollow pipe waveguide having a pair of parallel broad walls and a second pair of parallel walls narrower than and normal to said broad walls, the inner surface of said walls being said energy confining surface, said aperture being in said narrow walls.

5. The combination claimed in claim 1, said waveguide having a circularly cylindrical pipe the inner cylindrical surface of which is said energy confining surface.

6. The arrangement claimed in claim 1, said continuous conductor having a known coefficient of change of resistance with respect to temperature, whereby a resistance measurement of said conductor is a measure of said power.

JOHN COLLARD.

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