

- [54] **COMBINED ELECTROMAGNETIC WAVEGUIDE AND MODE FILTER**
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- [51] **Int. Cl.**..... H01p 1/16, H01p 3/12
- [58] **Field of Search** 333/98 M, 98 R, 95 R

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[57] **ABSTRACT**
A substantially rigid, composite electromagnetic waveguide component comprises at least one waveguide of circular cross-section comprising a continuous, circumferential electrically conductive layer extending over a part of the length of the component and a mode filter extending over the remaining part of the component. Preferably the mode filter is constituted by a plurality of mutually spaced, circumferentially continuous, electrically conductive rings or at least one electrically conductive helix with closely spaced turns, the mode filter and waveguide overlying an inner tubular layer of insulating material. A reinforcing insulating body preferably surrounds the component and renders it substantially rigid. In a preferred embodiment a mode filter is positioned at one end of the component and the other end is shaped to form a socket.

12 Claims, 6 Drawing Figures

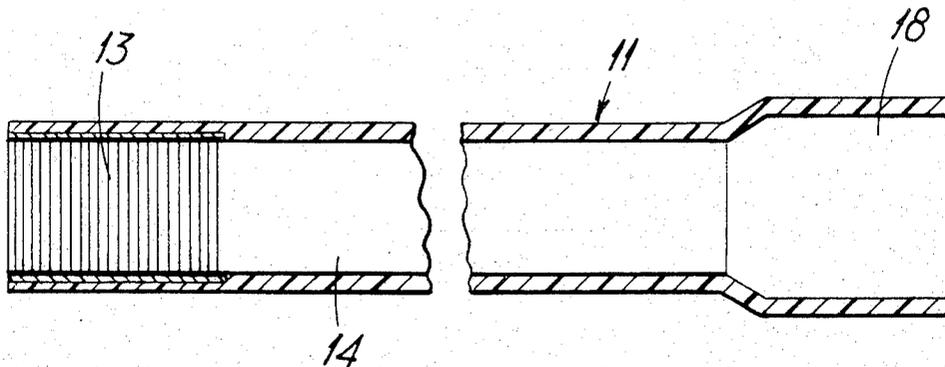


Fig. 1.

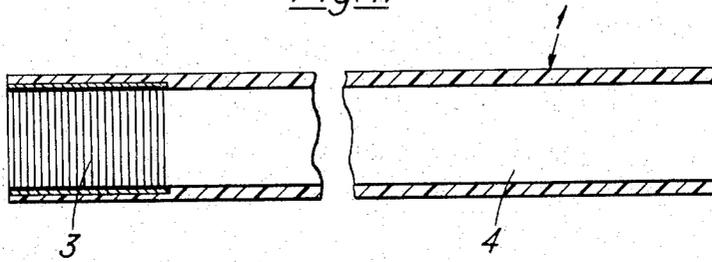


Fig. 2.

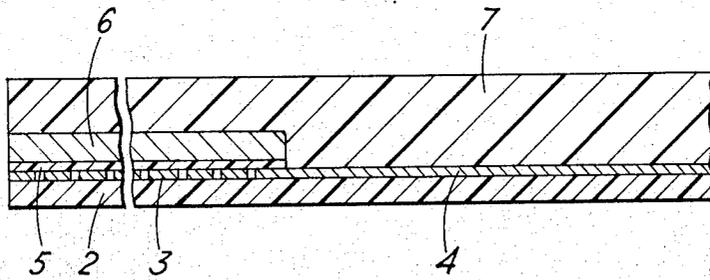
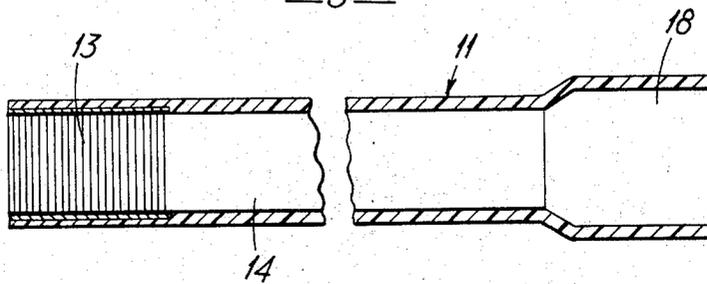
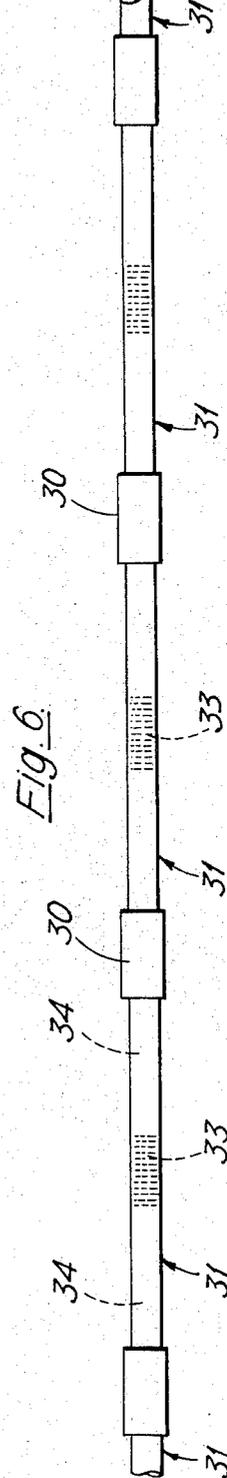
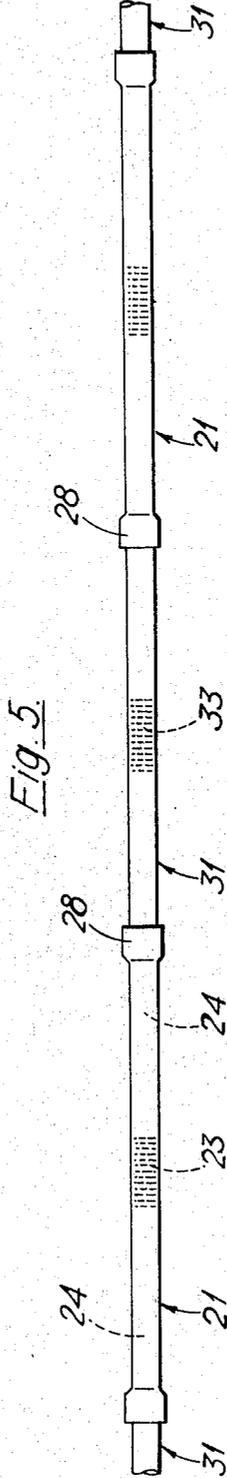
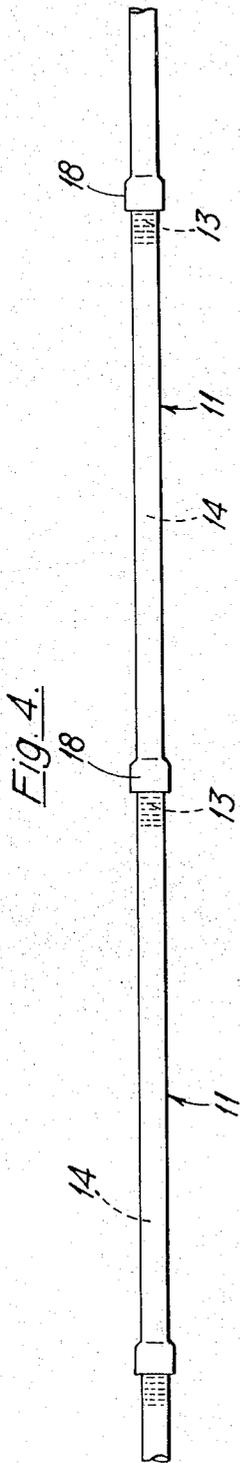


Fig. 3.





COMBINED ELECTROMAGNETIC WAVEGUIDE AND MODE FILTER

This invention relates to electromagnetic waveguides and is particularly concerned with electromagnetic waveguides of circular cross-section for use in effecting communication over a long distance by conveying microwave signals along the waveguides arranged continuously along an appropriate transmission path.

In the propagation of the lowest circular electric mode (TE_{01}) using electromagnetic waveguides of circular cross-section it is the general practice to incorporate in the transmission path at spaced locations along its length mode filters to suppress the propagation of unwanted modes introduced by irregularities in construction or curvature of the waveguide or waveguides. In transmission paths built up of electromagnetic waveguides of circular cross-section each comprising a continuous circumferential electrically conductive layer a common form of mode filter used for this purpose is a helix waveguide comprising an inner layer of closely wound turns of insulated copper wire covered with a lossy sheath.

It is an object of the present invention to provide a novel electromagnetic waveguide component for use in assembling a waveguide path of any required length, which component is cheap to manufacture but is of high dimensional accuracy.

According to the invention we provide a substantially rigid, composite electromagnetic waveguide component comprising at least one waveguide of circular cross-section comprising a continuous, circumferential electrically conductive layer extending over a part, preferably a major part, of the length of the component and a mode filter extending over the remaining part of the component. Preferably the component includes, at one or each of its ends, means for connecting the composite waveguide component to one end of a composite waveguide component of similar form or to one end of a substantially rigid electromagnetic waveguide of circular cross-section having a continuous circumferential electrically conductive layer extending throughout its length.

The composite electromagnetic waveguide component of the present invention has the important advantages that it combines in a single component the electrical performance of a waveguide of circular cross-section having a continuous, circumferential electrically conductive layer and the suppression effect of a mode filter and that a plurality of such waveguide components can be used in a simple manner to build up a transmission path which has mode filters distributed at frequent intervals along its length and which, by virtue of the substantial rigid construction of the waveguide component, has greater dimensional accuracy than transmission paths having separately formed mode filters incorporated at intervals.

The waveguide component preferably comprises an inner tubular layer of insulating material; at least one waveguide comprising a continuous circumferential electrically conductive coating extending over a part, preferably a major part, of the length of the outer surface of the tubular layer; and a mode filter constituted by a plurality of mutually spaced, circumferentially continuous, electrically conductive rings or at least one electrically conductive helix with closely spaced turns extending over the remaining part of the outer surface

of the tubular layer. Preferably the mode filter is located at or near an end of the component. The mode filter is preferably surrounded by a layer or layers of lossy material, for instance glass fibre tape containing graphite or other electrically conductive material, and to provide the component with the required rigidity the waveguide or waveguides and mode filter are preferably surrounded by a plurality of layers of resin bonded glass fibre or of other suitable reinforcing material. The component may have an outer conductive screen, for instance a thin steel jacket or a braided wire sleeve.

The means by which adjacent waveguide components are connected preferably takes the form of a spigot and socket connection. A spigot and socket connection between adjacent components may be effected by a separate unit making a spigot and socket connection with each component but preferably at one end of each component, the component is shaped to form a socket in which the opposite end of another waveguide component will fit. Where the component has a single mode filter located at or near one end the socket is preferably formed at the other end of the component.

Alternatively the waveguide component of the present invention may itself constitute a separate connector unit for making a spigot and socket connection between adjacent waveguide components, or between adjacent substantially rigid electromagnetic waveguides of circular cross-section each having a continuous circumferential electrically conductive layer extending throughout its length, and for this purpose the component preferably has a single mode filter located between its ends which are shaped to form sockets into which the ends of adjacent waveguides will fit.

The invention also includes transmission path built up of a plurality of waveguide components in accordance with the invention connected end to end.

The invention further includes transmission path built up of a plurality of substantially rigid electromagnetic waveguides of circular cross-section each having a continuous circumferential electrically conductive layer extending throughout its length, at least one pair of adjacent waveguides being connected end to end by a waveguide component in accordance with the invention.

In accordance with a further aspect of the invention we provide a method of forming a substantially rigid, composite electromagnetic waveguide component in accordance with the invention which includes the steps of applying a continuous circumferential layer of electrically conducting metal to a mandrel of circular cross-section and, before or after removing the mandrel from the electrically conductive layer so formed, forming over a portion of the length of the component a mode filter by removing a part of the layer over said portion to leave a plurality of mutually spaced, circumferentially continuous rings or at least one helix with closely spaced turns of electrically conducting metal.

The dimensions of the continuous rings or of the helix or helices so formed will be such that the mode filter of the component will suppress to at least a substantial extent the propagation of unwanted modes in a transmission path of which the component forms a part.

The inner tubular layer of insulating material on which the continuous electrically conductive layer and the mode filter are supported may be preformed or may be applied as a coating to the internal surface of the

component and in both cases preferably it is inserted into or applied to the component after the mandrel is removed but it may be initially applied over the mandrel and may itself constitute the outer part of the mandrel on which the electrically conductive layer or layers and mode filter are formed. In both cases a thin layer of material that will facilitate easy removal of the mandrel, for instance a coating of graphite, is preferably applied to the mandrel before forming the continuous layer or layers and mode filter.

The or each continuous circumferential electrically conductive layer may be formed by electro plating, spraying or vacuum deposition of a metal, e.g. copper, or by any other suitable method. The mode filter may be formed by initially applying to the mandrel a plurality of mutually spaced, circumferentially continuous rings or at least one helix with closely spaced turns of a resist from which the electrically conductive metal can be easily removed, e.g. by etching, or, in the case where a tubular layer of insulating material is not positioned within the component until the mandrel is removed, the continuous electrically conductive layer may be formed over the whole length of the component and, after the mandrel has been removed but before the insulating tubular layer is inserted, appropriate parts of the conductive layer removed by machining or by other means to form the mode filter.

A layer of electrically insulating material, for example resin bonded glass fibre, will normally be applied over the mode filter in accordance with normal practice and a layer or layers of lossy material, for instance carbon impregnated resin bonded glass fibre, applied over the insulating layer. The radial thickness of the lossy material will be such that in conjunction with the continuous rings or helix or helices the required impedance for the suppression of unwanted modes of propagation is provided. Layers of electrically insulating material, for instance resin bonded glass fibre, to provide the required rigidity will normally be applied throughout the length of the component, such layers being applied, and where necessary cured, before the mandrel is removed. An outer screen is preferably applied overall.

The mandrel, which is preferably of metal, may be of cylindrical cross-section throughout its length but, where one end of the component to be formed is to constitute a socket, the mandrel may be of appropriate increased cross-section at one end.

A substantially rigid mode filter of circular cross-section including a plurality of mutually spaced, circumferentially continuous rings of an electrically conductive coating, or at least one helix with closely spaced turns of an electrically conductive coating, overlying an inner tubular layer of insulating material and a method of forming said mode filter is the subject of our co-pending Patent Application No. 222,478 filed on the same day as the present application.

The invention will be further illustrated by a description, by way of example, of two forms of composite electromagnetic waveguide component in accordance with the invention and of three forms of transmission path incorporating waveguide components of the present invention with reference to the accompanying drawings, in which:

FIG. 1 is a sectional side view of one form of waveguide component with the inner tubular insulating layer omitted;

FIG. 2 is a fragmental diagrammatic sectional side view of a wall of the waveguide component shown in FIG. 1, drawn on an enlarged scale;

FIG. 3 is a sectional side view of a second form of waveguide component with the inner tubular insulating layer omitted;

FIG. 4 is a fragmental diagrammatic representation of one form of transmission path built up of waveguide components as shown in FIG. 3;

FIG. 5 is a fragmental diagrammatic representation of a second form of transmission path built up of a third form of waveguide component in accordance with the invention, and

FIG. 6 is a similar view of a third form of transmission path built up of a fourth form of waveguide component in accordance with the invention.

The waveguide component shown in FIGS. 1 and 2 is of circular cross-section and has an overall length of 3 metres (9.85 ft), an internal diameter of 5 cms (1.97 in) and an overall wall thickness of 5.2 mm (0.20 in). It comprises a waveguide comprising a continuous circumferential copper layer 4 having a thickness of $5\mu\text{m}$ (0.0002 in) and a length of 2.70 metres (8.86 ft) and a mode filter extending over the remaining part of the component and comprising 2400 copper rings 3 each having a thickness of $5\mu\text{m}$ (0.0002 in) and an axial length of 0.1 mm (0.004 in), the spacing between adjacent rings being 0.02 mm (0.00079 in). The copper layer 4 and copper rings 3 overlie an inner tubular layer 2 of polyethylene having a radial thickness of 0.2 mm (0.0079 in). A layer 5 of resin bonded glass fibre having a radial thickness of 0.1 mm (0.004 in) overlies the copper rings 3 and a lossy layer 6 of glass fibre tape rendered semi-conductive by the incorporation of graphite is applied over the layer 5 to a radial thickness of 0.9 mm (0.036 in). A body 7 built up of layers of resin bonded glass fibre is applied to the component throughout its length to the overall wall thickness of 5 mm (0.197 in), the body rendering the component substantially rigid.

The waveguide component 11 shown in FIG. 3 includes 2400 copper rings 13 constituting a mode filter and a copper layer 14 constituting a waveguide and is of similar construction to the waveguide component shown in FIG. 1 except that, at the end of the component remote from the mode filter, the bore of the component is enlarged to form a socket 18. The socket 18 has an internal diameter such that an end of a waveguide component of similar form, or an end of a substantially rigid waveguide of circular cross-section having an overall diameter equal to that of the component, will make a tight spigot and socket joint in the socket.

In using waveguide components 11 as shown in FIG. 3 to make the transmission path shown in FIG. 4, adjacent waveguide components are connected end to end with the end at which the mode filter 13 is formed making a spigot and socket joint in the socket 18 of the adjacent component. The transmission path so formed is substantially rigid throughout its length.

The transmission path shown in FIG. 5 is built up of waveguide components 21 of a third form in which a copper helix with closely spaced turns constituting the mode filter 23 is positioned between copper layers constituting waveguides 24 and each end of the component is enlarged to form sockets 28 and of waveguide components 31 of a fourth form which is similar to that of the components 21 but which is not enlarged at its

ends. Components 21 and 31 are arranged alternately along the length of the transmission path with each end of a component 31 making a spigot and socket joint with socket 28 of a component 21.

The transmission path shown in FIG. 6 is built up of waveguide components 31 each having its mode filter 33 positioned between waveguides 34 and neighbouring ends of the components fit into and make spigot and socket joints with opposite ends of a tubular connector unit 30 of insulating material.

The transmission paths shown in FIGS. 5 and 6 are both substantially rigid throughout their lengths.

Electromagnetic waveguide components in accordance with the invention have the important advantage of high dimensional accuracy because the dimensions of the bore of the component are determined by the dimensions of the mandrel which can be accurately ground to the required size. A further advantage arises from the fact that the outer screen, when present, can be substantially thinner than the conventional metal sheath or jacket hitherto employed in substantially rigid waveguides and consequently the component is therefore light in weight and easy to install. Furthermore, transmission path of any desired length can be formed with mode filters provided at frequent intervals by interconnecting by simple spigot and socket joints a plurality of similar composite waveguide components.

What we claim as our invention is:

1. A substantially rigid, composite electro-magnetic waveguide component of circular cross-section comprising an inner tubular layer of insulating material; at least one waveguide comprising a continuous circumferential electrically conductive coating extending over a part of the length of the outer surface of the tubular layer; a mode filter constituted by a plurality of mutually spaced, circumferentially continuous, electrically conductive rings or at least one electrically conductive helix with closely spaced turns, extending over the remaining part of the outer surface of the tubular layer; and a reinforcing body of electrically insulating material which surrounds, and extends beyond at least one end of, the component formed by the waveguide or waveguides and mode filter and renders the component substantially rigid, the projecting end of the reinforcing body being shaped to form a socket with a substantially smooth internal surface in which an end of a waveguide or of another waveguide component can make a spigot and socket joint.

2. A composite waveguide component as claimed in claim 1, wherein the reinforcing body projects beyond one end of the component to form a socket and the mode filter is located at the other end of the component.

3. A composite waveguide component as claimed in claim 1, wherein a single mode filter is located between the ends of the component.

4. A composite waveguide component as claimed in claim 1, wherein the reinforcing body projects beyond both ends of the component and each projecting end of the reinforcing body is shaped to form a socket.

5. A composite waveguide component as claimed in claim 1, wherein the waveguide or waveguides extends

or extend over a major part of the length of the component.

6. A composite waveguide component as claimed in claim 1, wherein the reinforcing body comprises a plurality of layers of resin bonded glass fibre.

7. A composite waveguide component as claimed in claim 1, wherein the mode filter is surrounded by at least one layer of lossy material.

8. A composite waveguide component as claimed in claim 1, having an outer conductive screen.

9. A composite waveguide component as claimed in claim 8, wherein the outer conductive screen comprises a thin steel jacket.

10. A composite waveguide component as claimed in claim 8, wherein the outer conductive screen comprises a braided wire sleeve.

11. A transmission path built up of a plurality of substantially rigid electro-magnetic waveguide components of circular cross-section connected end-to-end, each of which waveguide components comprises an inner tubular layer of insulating material, at least one waveguide comprising a continuous circumferential electrically conductive coating extending over a part of the length of the outer surface of the tubular layer, a mode filter constituted by a plurality of mutually spaced, circumferentially continuous electrically conductive rings or at least one electrically conductive helix with closely spaced turns, extending over the remaining part of the outer surface of the tubular layer, and a reinforcing body of electrically insulating material which surrounds, and extends beyond one end of, a component formed by the waveguide or waveguides and mode filter and renders the component substantially rigid, the projecting end of the reinforcing body of each waveguide component being shaped to form a socket with a substantially smooth internal surface, in which the other end of an adjacent waveguide component makes a spigot and socket joint.

12. A transmission path built up of a plurality of substantially rigid electro-magnetic waveguides of circular cross-section interconnected by a plurality of substantially rigid composite electro-magnetic waveguide components of circular cross-section, each of which waveguide components comprises an inner tubular layer of insulating material, at least one waveguide comprising a continuous circumferential electrically conductive coating extending over a part of the length of the outer surface of the tubular layer, a mode filter constituted by a plurality of mutually spaced, circumferentially continuous, electrically conductive rings or at least one electrically conductive helix with closely spaced turns, extending over the remaining part of the outer surface of the tubular layer, and a reinforcing body of electrically insulating material which surrounds, and extends beyond both ends of, the component formed by the waveguide or waveguides and mode filter and renders the component substantially rigid, the projecting ends of the reinforcing body each being shaped to form a socket with a substantially smooth internal surface in which an end of an adjacent waveguide makes a spigot and socket joint.

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