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D. D. GRIEG ET AL
MICROWAVE TRANSMISSION LINES

2,915,718

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Fig. 1

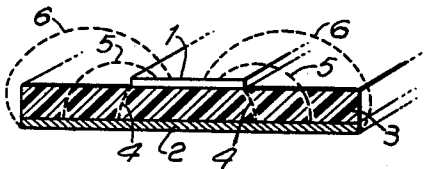


Fig. 2

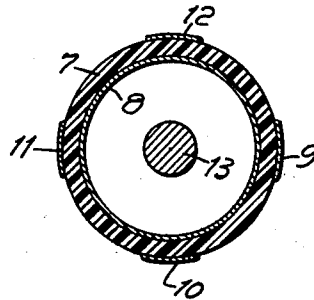


Fig. 3

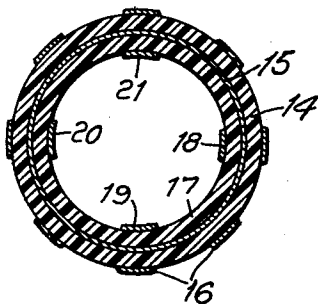


Fig. 4

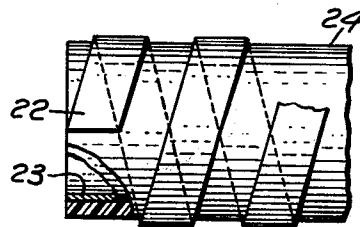


Fig. 6

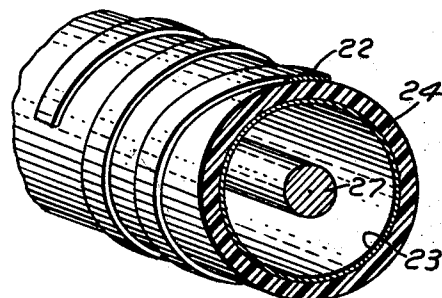
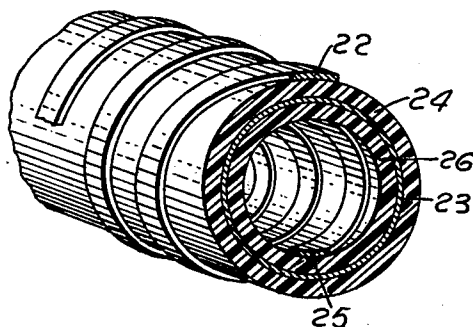


Fig. 5



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MICROWAVE TRANSMISSION LINES

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Application August 5, 1955, Serial No. 526,717

12 Claims. (Cl. 333—84)

This invention relates to microwave transmission lines and more particularly to transmission waveguides for ultra-high frequency signals. This is a continuation in part of our copending application Serial No. 234,503 filed June 30, 1951, now Patent No. 2,721,312.

In our copending application, Serial No. 227,896, filed May 23, 1951, a new principle of waveguide transmission is disclosed, comprising in its simplest form two conductors, one as a "ground conductor" and the other as a "line conductor," spaced close together in substantially parallel relation. The so-called "ground conductor," which may be at ground potential or some other given potential, is considerably wider than the line conductor so that the surface thereof provides in effect an image reflection of the line conductor, whereby the distribution of the electric and magnetic fields between the conductors is substantially the same as the distribution between one conductor and the neutral plane of a theoretically perfect two-conductor parallel system. Small variations in size and shape of the line conductor may produce variations in the characteristic impedance of the system but the field distribution with respect to the ground conductor is not materially disturbed. Likewise, certain variations in the surface of the ground conductor do not materially disturb the field distribution with respect to the surface thereof since such variations either neutralize each other or do not adversely affect the field distribution between the two conductors. By this system, radio frequency waves can be easily propagated by a mode closely simulating the TEM mode along the line-ground conductor system.

One of the objects of this invention is to provide microwave transmission lines or cables, either single or multiple channel, for transmission of microwave energy in accordance with the principle of wave propagation referred to above.

Another object of this invention is to provide a multiple channel transmission line using a single common ground plane conductor.

A further object of the present invention is the provision of a cylindrical ground plane conductor whose inner surface serves as a ground plane for an inner transmission line and whose outer surface serves as a ground plane for an outer transmission line, at least one of said lines being of the type described in application Serial No. 227,896 and usually referred to as a "microstrip line."

The above-mentioned and other features and objects of this invention will become more apparent by reference to the following description taken in conjunction with the accompanying drawings, wherein:

Fig. 1 is a cross-sectional view of one form of transmission line in accordance with the principles of our copending application Serial No. 227,896;

Figs. 2 and 3 are cross-sectional views of multi-channel lines incorporating the principles of this invention;

Fig. 4 is a side elevational view of a line in which one of the conductors is in the form of a helix; and

Figs. 5 and 6 are cross-sectional views of other lines in which one of the conductors is in the form of a helix.

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Referring to Fig. 1 of the drawings, the radio frequency transmission waveguide illustrated is of the printed circuit type comprising a first or "line" conductor 1 and a second or "ground" conductor 2 with a layer 3 of dielectric material therebetween. The conductive material may be applied to the layer of dielectric, such as polystyrene, polyethylene, "Teflon" or other flexible insulation of high dielectric quality, in the form of conductive paint or ink, or the conductive material may be chemically deposited, sprayed through a stencil or dusted onto selected prepared surfaces of the dielectric according to known printed circuit techniques. For relatively short lengths of lines the conductive strips may be cut and applied by a die-stamping operation. In some cable manufacturing processes, the insulation may be extruded and simultaneously or later provided on the two sides thereof with conductive material of the desired thickness and widths. Where the widths of the two conductive layers are the same and it is desired to reduce the width of one of the layers, the portions of the two layers that are to be retained may be coated with a chemically inert material exposing the parts to be removed, and thereafter passing the cable through an etching bath, whereupon the exposed portions of the layers are removed.

While the two conductive layers 1 and 2 are shown in cross-section to be substantially rectangular, they may comprise different shapes so long as the ground conductor 2 presents a wide extended surface with respect to the line conductor. Preferably, the ground conductor should be from two to three times the width of the line conductor 1, although wider dimensions give still lower loss. In Fig. 1, the broken lines 4, 5 and 6 indicate substantially the percentage of distribution of the electric field between the two conductors for a conductor relation wherein the ground conductor 2 is approximately three times the width of the line conductor, and the line conductor is wider than the spacing between conductors. The electric field concentrated within the lines 4 is from about 75 to 80%, within the lines 5 it is from about 90 to 95%, and within the lines 6 it is approximately 99%. From the foregoing it is clear that a narrow ground conductor may be used without much radiation loss, and where it can be three or more times the width of the line conductor an exceptionally low loss transmission is assured.

In Figs. 2 and 3 two forms of multi-channel cables are illustrated. In Fig. 2 a tubular (cylindrical) layer of insulation 7 is provided with a coating 8 of conductive material. A plurality of line conductors 9, 10, 11 and 12 are disposed in spaced parallel relation on the other side of layer 8 equidistantly around the circumference thereof, each line conductor forming with the ground conductor 8 a separate channel. This may be formed by applying conductive wire, strips or lines of finely divided conductive material, in a carrier medium if desired, to the insulating layer 7, either as it is being extruded or by a later application. The cylindrical cable of Fig. 2 may be made from a flat cable such as shown in Fig. 6 of said copending application Serial No. 234,503 by passing it through a suitable die, or it may be made directly into cylindrical form during an extrusion operation. By properly spacing the line conductors 9 and 12, by two or more times their width, coupling therebetween will be practically avoided. Another channel is obtained in the embodiment of Fig. 2 by providing a center conductor 13 coaxially of the conductive coating 8 to form a coaxial transmission line. Also, if desired, the conductors 9—12 may be spiralled on the cylinder 13.

In Fig. 3 substantially the same cable construction shown in Fig. 2 is employed as indicated by tubular insulation 14, conductive coating or cylinder 15 and the outer strips of conductive material 16. Centrally of the

conductive coating 15 is a second tubing of insulating material 17. On the inner surface or embedded therein are conductive strips 18, 19, 20, and 21. These latter strips coact with the common conductive cylinder 15 to form individual transmission lines or channels. The lateral spacing of the strips 18, 19, 20 and 21, however, must be sufficiently wide to minimize coupling.

The transmission line of Fig. 4 is arranged to provide delay characteristics. The line comprises a line conductor 22 in the form of a helix and a ground conductor 23 in the form of a solid or hollow conductive cylinder with a layer of insulation 24 disposed therebetween. The path of propagation follows the helix, the electric field being concentrated beneath and along the conductor 22.

The transmission line of Fig. 5 is similar to that of Fig. 4 with the addition of a second line conductor 25 in the form of a helix inside the ground conductor 23 and separated therefrom by a tubular insulation 26. This provides two delay lines using a single common ground conductor.

In Fig. 6 there is disclosed a transmission line similar to that of Fig. 4 with the additional feature that there is provided a central conductor 27. This central conductor 27 together with the inner surface of ground plane conductor 23 form a coaxial transmission line. Thus, the structure of Fig. 6 provides not only a delay line but also, using the same ground plane conductor, provides a coaxial transmission line.

While we have described above the principles of our invention in connection with specific apparatus, it is to be clearly understood that this description is made by way of example only and not as a limitation to the scope of our invention, as set forth in the objects thereof and in accompanying claims.

We claim:

1. A microwave transmission line comprising a hollow cylindrical dielectric member, a hollow cylindrical ground plane conductor covering one surface of said dielectric cylinder, ribbon-like conductive means on the opposite surface of said dielectric cylinder, said conductive means consisting of elongated conductive portions at different circumferential positions around said dielectric cylinder, one surface of said portions being in curved contact relation with said opposite surface, each said portion constituting with said cylindrical ground plane conductor a discrete waveguide, the distance between the opposed surfaces of said elongated conductive portions and the ground plane conductor being a fraction of a wavelength at the mean operating frequency, said conductive means comprising a plurality of separate elongated conductors in spaced relation with each other, the spacing of said elongated conductors being such as to subdivide said ground plane conductor into conductive surfaces for the respective elongated conductors, each such conductive surface being of a width substantially greater than the width of each line conductor.

2. A microwave transmission line according to claim 1, wherein said conductive means comprises an elongated conductor in the form of a helix.

3. A microwave transmission line according to claim 2, further including an elongated conductor inside and coaxially spaced with respect to said cylindrical ground conductor, and forming therewith a coaxial transmission line.

4. A microwave transmission line according to claim 1, further including a second dielectric cylinder on the surface of said ground plane conductor opposite said first dielectric cylinder, and at least one elongated ribbon-like conductor on said second dielectric cylinder on

the side thereof opposite said ground plane conductor and forming with said ground plane conductor a transmission line, said elongated conductor being in curved contact relation with said second dielectric cylinder.

5. A microwave transmission line according to claim 4, wherein said one elongated conductor on said second dielectric cylinder, and said conductive means on the first mentioned dielectric cylinder are both helices.

6. A microwave transmission line according to claim 1, further including a conductor disposed coaxially of said ground plane conductor.

7. A microwave transmission line according to claim 1, further including a second cylinder of dielectric disposed on the inner surface of said ground plane conductor and at least one additional elongated ribbon-like conductor carried by said second dielectric cylinder in spaced relation to said ground plane conductor, said elongated conductor being in curved contact relation with said second cylinder and constituting with said ground plane conductor a waveguide, said dielectric cylinder being on the side of said ground plane opposite said second dielectric cylinder.

8. A multiple channel microwave cable comprising a hollow cylindrical conductor, a layer of dielectric coating one of the surfaces of said cylindrical conductor and a plurality of ribbon-like line conductors carried by said layer of dielectric in spaced relation to each other and to said cylindrical conductor, the spacing between said line conductors and said cylindrical conductor being a small fraction of a wavelength of the microwave energy propagated therealong, each said line conductor being in curved contact relation with said layer of dielectric and constituting with said cylindrical conductor a discrete waveguide.

9. A multiple channel microwave cable according to claim 8, wherein said layer of dielectric is disposed on the outer surface of said cylindrical conductor and the line conductors are disposed on the outer surface of said layer of dielectric.

10. A multiple channel microwave cable according to claim 9, wherein a conductor is disposed coaxially of said cylindrical conductor.

11. A multiple channel microwave cable according to claim 8, wherein the layer of dielectric is disposed on the inner surface of said hollow cylindrical conductor and said line conductors are disposed on the inner surface of said layer of dielectric.

12. A multiple channel microwave cable according to claim 11, further including a layer of dielectric on the outer surface of said hollow cylindrical conductor and a plurality of ribbon-like line conductors carried in spaced relation on the outer surface of said second layer of dielectric, each of said plurality of line conductors being in curved contact relation with said outer surface of said layer of dielectric and constituting with said hollow cylindrical conductor a discrete waveguide.

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