Oct. 18, 1955 D. D. GRIEG ET AL 2,721,312

MICROWAVE CABLE

Filed June 30, 1951

Fig.1

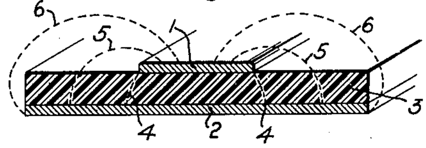


Fig.2

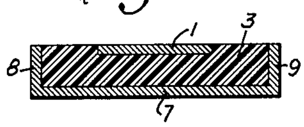


Fig.3

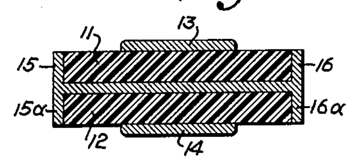


Fig.4

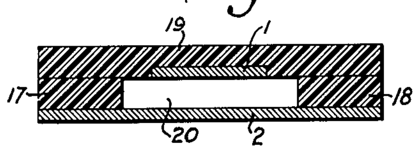


Fig.5

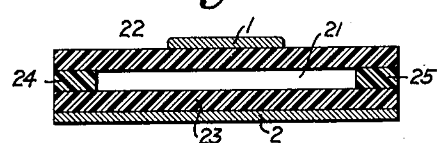


Fig.6

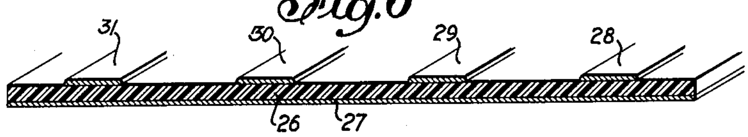


Fig.7

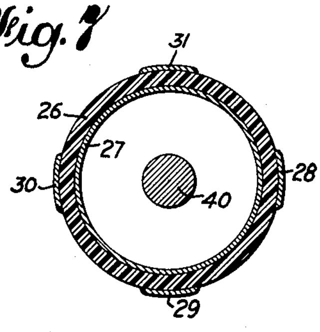


Fig.8

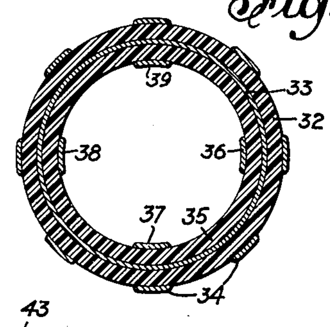
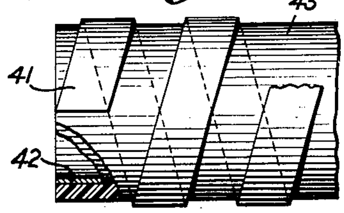


Fig.9



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MICROWAVE CABLE

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Application June 30, 1951, Serial No. 234,503

4 Claims. (Cl. 333—84)

This invention relates to microwave transmission systems and more particularly to transmission wires and cables for ultra high frequency signals.

In our copending application, Serial No. 227,896, filed May 23, 1951, a new principle of microwave 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, microwaves can be easily propagated by the TEM mode along the line-ground conductor system since the microwaves flow in the region of the concentrated electromagnetic field between the opposed surfaces of the line and ground conductors.

One of the objects of this invention is to provide 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 the invention is to provide a low loss transmission line or cable for use at ultra high frequencies.

The above-mentioned and other features and objects of this invention and the manner of attaining them 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 this invention;

Fig. 2 shows in cross-section another embodiment of the invention;

Fig. 3 is a cross sectional view of a two-channel cable;

Figs. 4 and 5 are cross-sectional views showing two forms of cable construction incorporating air space between the conductors;

Figs. 6, 7 and 8 show cross-sectional views of multichannel cables incorporating the principles of this invention; and

Fig. 9 shows in side elevation a line in which one of the conductors is in the form of a helix.

Referring to Fig. 1 of the drawings, the microwave transmission line 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 insllation 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 dielectric may be extruded and simultaneously or later coated on the two sides thereof with conductive material of the desired thickness and widths. Where the widths of the two coatings are the same and it is desired to reduce the width of one of the coatings, the portions of the two coatings 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 coatings are removed.

While the two conductive coatings **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 tranmission line is assured.

In the embodiment of Fig. 2, the width of the ground conductor is shown in one plane to be about twice the width of the line conductor. The conductive coating which comprises the ground conductor, however, is shown to extend up along the side edges of the dielectric layer **3**. In other words, the ground conductor comprises a flat coating **7** and two upright portions **8** and **9** thus forming a trough shaped conductor. This form also insures a low loss even though its width is smaller for a given size line conductor. The line conductor may be carried on the surface of the insulation **3** but as shown it may be partially imbedded therein.

A two-channel transmission line is shown in Fig. 3 which utilizes a common ground conductor **10**. The ground conductor **10** may be of the form shown at **2** in Fig. 1 and coated on each side with layers of insulation **11** and **12** which support line conductors **13** and **14**, respectively. If desired, the side edges of the dielectric **11** and **12** may be coated with conductive material as indicated at **15**, **15*a*** and **16**, **16*a*** similarly to the conductive portions **8** and **9** of Fig. 2. One of the transmission channels comprises the electromagnetic field which exists in the regions bounded by the line conductor **13** and the ground conductor portions **10**, **15** and **16**. The second channel exists in the region of the electromagnetic field bounded by the opposed surfaces of the line conductor **14** and the ground conductor portions **10**, **15*a*** and **16*a***. It will be clear that the two channels will be independent of each other and that the flow of currents will occur in skin depth only of the opposing surfaces of the conductors.

In the embodiment of Fig. 4 the loss is minimized by replacing part of the dielectric between conductors by an air space. As shown, the transmission line comprises conductors **1** and **2** as in Fig. 1 but the dielectric is made up of three parts, namely, two side strips **17** and **18** and a cover strip **19**. The two side strips **17** and **18** are formed on conductor **2** and secured thereto along the outer edge portions thereof. The upper layer **19** is preferably formed with conductor **1** embedded therein or coated thereon. The upper strip **19** is then applied to the other assembly either as shown in Fig. 4 with the conductor on the surface thereof opposed to the conductor **2**, or if desired, the conductor **1** may be on the outer surface of the layer **19**. In either case, an air space **20** is provided between the conductors **1** and **2** thereby maintaining the dielectric coefficient of the over-all region bounded by the opposed surfaces of the conductors **1** and **2** at a value close to the dielectric coefficient of air.

In Fig. 5 a similar transmission line arrangement is provided with a relatively wide air space **21**. In this form the conductor **1** is provided with an extended layer of dielectric **22** which corresponds to the width of the conductor **2**. The conductor **2** is likewise provided with a dielectric layer **23**. Interposed in the assembly at the outer edges thereof are two dielectric beads **24** and **25**, which may be rectangular or other shape in cross-section, thereby insuring a wide air space **21**. In this form the two dielectric layers **22** and **23** are interposed between the conductors **1** and **2**. If desired, the upper layer **22** may be inverted so as to place the conductive coating **1** on the side thereof bounding the air space **21**.

In Figs. 6, 7 and 8, three forms of multi-channel cables are illustrated. In Fig. 6, a layer of dielectric **26** is provided with a coating **27** of conductive material. A plurality of line conductors **28**, **29**, **30** and **31** are disposed in spaced parallel relation on the other side of layer **26**, each line conductor forming with the ground conductor **27** 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 **26**, either as it is being extruded or by a later application. Also, the flat cable shown in Fig. 6 may be made cylindrical as shown in Fig. 7 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 **28** to **31**, by two or more times their width, coupling therebetween will be practically avoided. Another channel is obtained in the embodiment of Fig. 6 by providing a center conductor **40** coaxially of the conductive coating **27**. Also, if desired, the conductors **28**—**31** may be spiralled on the cylinder **32**.

In Fig. 7 substantially the same cable construction shown in Fig. 6 is employed as indicated by tubular dielectric material **32**, conductive coating **33** and the outer springs of conductive material **34**. Centrally of the conductive coating **33** is a second tubing of dielectric material **35**. On the inner surface or embedded therein are conductive strips **36**, **37**, **38** and **39**. These latter strips coact with the common conductive cylinder **33** to form individual transmission lines or channels. The lateral spacing of the strips **36**, **37**, **38** and **39**, however, must be sufficiently wide to minimize coupling.

The transmission line of Fig. 9 is arranged to provide delay characteristics. The line comprises a line conductor **41** in the form of a helix and the ground conductor **42** in the form of a solid or hollow conductive cylinder with a layer of dielectric **43** disposed therebetween. The path of propagation follows the helix, the electric field being concentrated beneath and along the conductor **41**.

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 the accompanying claims. The species of Figs. 4 through 9 are the subject matter of our copending U. S. applications Serial No. 425,852, filed April 27, 1954, for "Radio Frequency Transmission Waveguides," and Serial No. 526,717, filed August 5, 1955, for "Microwave Transmission Lines."

We claim:

1. A transmission line for propagating energy comprising a first elongated conductor, a second elongated conductor having a planar surface disposed in substantially parallel, spaced relation to said first conductor and flange portions each extending from one of the sides of the planar surface at substantially right angles to said surface in the general direction of said first conductor, said second conductor terminating at the top of said flange portion leaving open the space above substantially the entire surface of the first conductor remote from said planar surface, the spacing between said first and second conductors being a small fraction of the wavelength of the mid-frequency of said micro-wave energy and the width of said second conductor being larger than the width of said first conductor but insufficiently wide to prevent substantial radiation losses, said losses being prevented by said flange portions and a layer of solid dielectric disposed therebetween substantially coextensive of said planar surface supporting said first conductor in parallel spaced relation with respect to said second conductor.

2. A transmission line according to claim 1, wherein the flange portions of the second conductor extend in overlapping engagement with respect to the side edges of said layer of dielectric.

3. A transmission line according to claim 1, further including a second layer of dielectric on the opposite side of said second conductor and a third conductor carried thereby in spaced relation to said second conductor, said third conductor being of a width smaller than the width of said second conductor.

4. A transmission line according to claim 3, wherein said second conductor has similar flange portions extending laterally in overlapping relation with respect to the side edges of the two layers of dielectric.

References Cited in the file of this patent

UNITED STATES PATENTS

2,149,387	Brown	Mar. 7, 1939
2,203,481	Zottu	June 4, 1940
2,246,188	Roder	June 17, 1941
2,409,449	Sanders et al.	Oct. 15, 1946
2,602,856	Rumsey	July 18, 1952
2,611,822	Bliss	Sept. 23, 1952

FOREIGN PATENTS

570,087	Great Britain	June 21, 1945
601,514	Great Britain	May 7, 1948