IMPEDANCE MATCHING MEANS AND METHOD

Filed Sept. 9, 1964 2 Sheets-Sheet 1

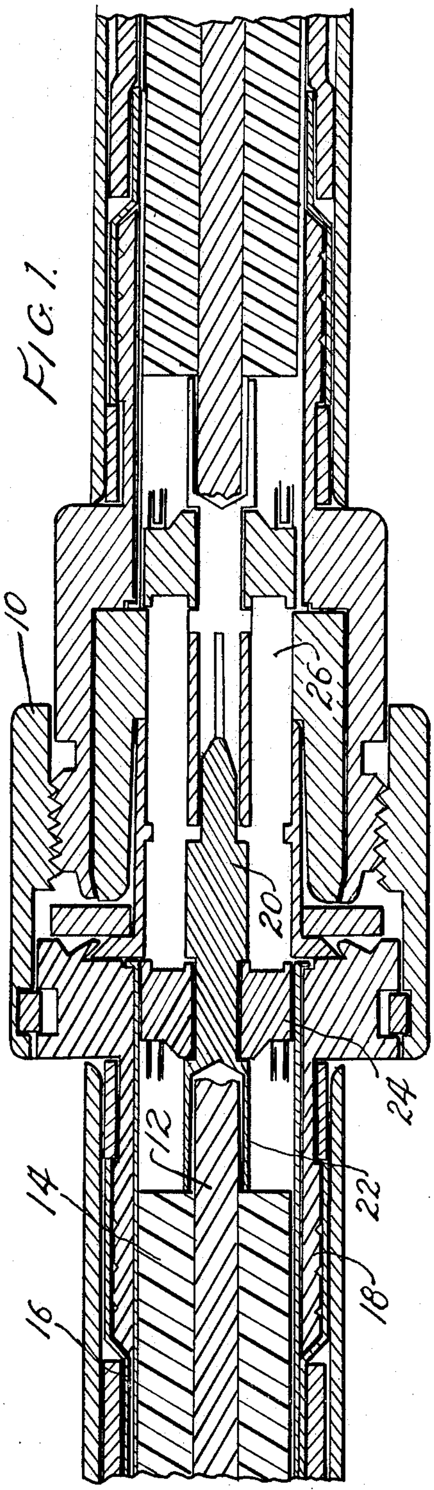

FIG. 1.

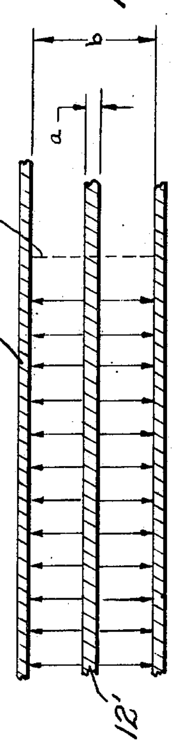

FIG. 2a

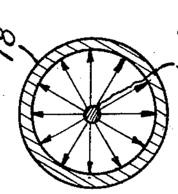

FIG. 2

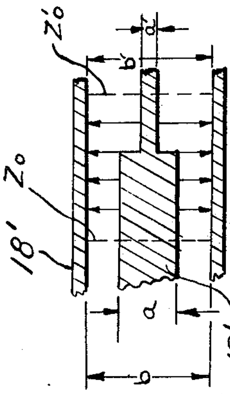

FIG. 3.

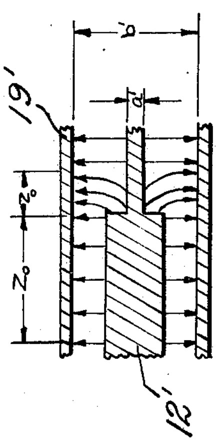

FIG. 4.

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IMPEDANCE MATCHING MEANS AND METHOD

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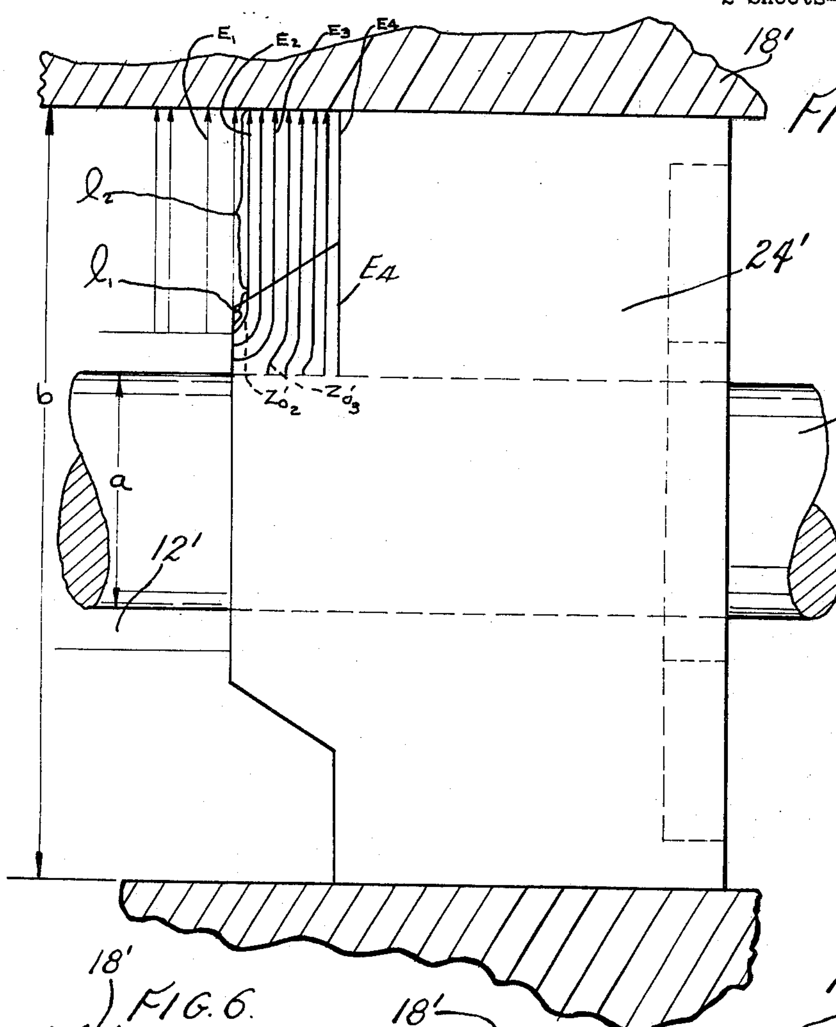


FIG. 5.

18'

FIG. 6.

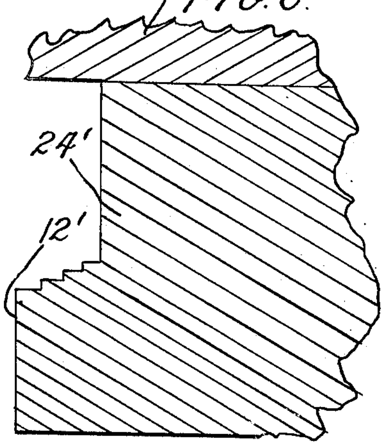
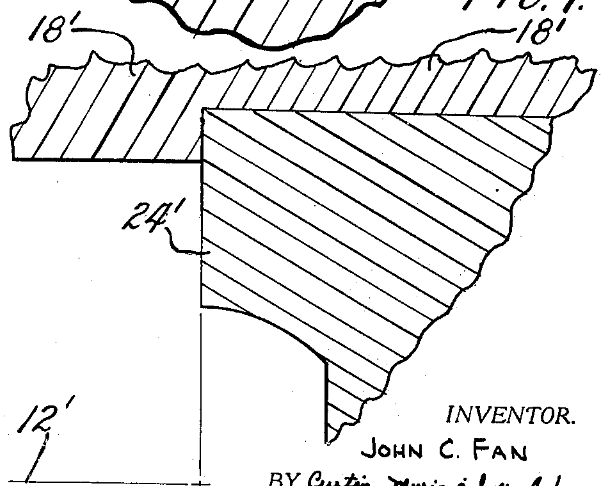


FIG. 7.



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3,492,604
IMPEDANCE MATCHING MEANS AND METHOD
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U.S. Cl. 333—33 7 Claims

ABSTRACT OF THE DISCLOSURE

A technique is disclosed for providing compensation for abrupt changes in the diameters of inner or outer conductors of high frequency transmission lines or connectors by postulating the length of electric field lines in the zone of field distortion caused by abrupt change and based thereon providing a composite dielectric medium of different dielectric materials to yield an ϵ quantity balancing the term log b/a so as to maintain characteristic impedance constant through the relationship

$$Z_0=\frac{138}{\sqrt{\epsilon}}\log\frac{b}{a}$$

This invention relates to a means and method for improving the energy transmission characteristics of microwave transmission lines, particularly with respect to connectors adapted to serve such lines.

It is one object of the invention to provide a means and method for accommodating physical discontinuities in transmission paths such as in connectors with less energy loss than heretofore possible.

It is a further object to provide a means and method for reducing the electrical discontinuity occasioned by a physical discontinuity in a microwave connector or like device.

It is yet another object of the invention to provide a new method for designing dielectric inserts for microwave connectors and like devices.

It is possible to think of the power transmitted along a power line in the microwave frequency ranges in terms of the characteristics of electric field extending between conductors. This concept is implemented by a vector representation of electric field extending between line conductor surfaces with ingress and egress in a transverse sense and is a useful tool in thinking about and designing for the phenomena occasioned by microwave signal transmission.

The present invention makes use of the foregoing concept to develop a theoretical optimum shape for dielectric material at points of discontinuity in a transmission path between the inner and outer conductive paths. The present invention, however, does not solely depend upon the correctness of theory, since empirical data has been developed to confirm a distinctive advance in the art of reducing transmission losses in connectors and like devices.

In the drawings:

FIGURE 1 is a longitudinal section of a type N connector employing one embodiment of the means of the invention;

FIGURES 2–2*a* are schematic diagrams showing electric field representations in a typical transmission line;

FIGURE 3 is a schematic representation of a physical discontinuity creating an abrupt change in conductor spacing in a transmission line and the field disposition as utilized in accordance with prior art compensation;

FIGURE 4 is a schematic representation of a physical discontinuity showing a resulting electrical field distortion in such transmission line;

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FIGURE 5 is schematic diagram depicting the means and method of the invention relative to compensating for a physical discontinuity in a transmission line;

FIGURE 6 is an alternative embodiment of the means of the invention; and

FIGURE 7 is a further alternative embodiment of the invention.

Referring to FIGURE 1, there is shown what is known as a type N connector. The type N connector is a standard in the electronic industry for connecting coaxial cables of the type having a generally cylindrical center conductor of solid or tubular material surrounded by dielectric and a cylindrical or tubular outer conductor comprised of a metal sheath or braid. The more recent type N connector designs are employed in uses wherein the signal frequencies transmitted are in the range from 1000 to 10,000 megacycles, with cables having a characteristic impedance of $Z_0=50$ ohms or 75 ohms.

The type N connector shown in FIGURE 1 as element **10** includes a number of features to accomplish a mechanical and electrical connection of two cable halves each including, as denominated, relative to FIGURE 1, a center conductor **12**, a dielectric **14** and an outer conductor **16**. The connector **10** includes a metal extension **18** which has an inner bore as indicated, to mechanically support the cable outer conductor and to be terminated thereto electrically. Other metallic portions are provided which extend through the connector to define a transmission path of a diameter approximating the inner diameter of the outer conductor of the cable. Further, the connector **10** includes a center contact assembly shown generally as **20** adapted to intermate as indicated and to be terminated to the center conductor **12** of the cable by a pin member **22**, crimped or otherwise fastened to a portion thereof. In the zone proximate the termination of **22** to **12** and surrounding a length of the rear portion of **22** is a space wherein the dielectric is air. To support the center pin member **22** there is provided a dielectric insert shown as **24** which mates with a further dielectric insert shown as **26** in the center part of the connector. Insert **24** is locked to pin **22** by an annular recess which creates a physical change in the spacing between inner and outer conductive paths.

The construction shown relative to FIGURE 1 is in general typical of type N connectors and of many other standard connectors. The description hereinafter to follow is related specifically to connectors of the type shown in FIGURE 1 and is general to any transmission path wherein a physical discontinuity is of necessity occasioned by design requirements as it is by the requirement in the type N for a change in diameter of inner and outer conductive portions to provide a mechanical holding of the components of the connector.

Referring now to FIGURES 2 and 2*a*, a representation of a section and segment of a transmission path is shown relative to an outer conductor **18'** and an inner conductor **12'** spaced apart. The transverse lines shown represent the electric field disposition created by microwave signal energy being transmitted along the path formed by **12'** and **18'**. These field lines emerge and enter from the conductive surfaces of **12'** and **18'** in a perpendicular sense.

Considering the space between **12'** and **18'** to be a dielectric material the characteristic impedance Z_0 of the line is expressed as in ohms through the empirically developed relationship:

$$Z_0=\frac{138}{\sqrt{\epsilon}}\log\frac{b}{a}$$

where 138 is a constant, ϵ is the dielectric constant of material, b is the outer conductor **18'** inner diameter and a is the inner conductor **12'** outer diameter. From this it will be apparent that the length of the electric field line which is in a distortionless path equal to $b-a$ is directly related to Z_0 through the quantity log b/a.

In FIGURE 3 there is shown a section of conductors **12'** and **18'** wherein a physical discontinuity occurs of the type depicted in FIGURE 1 relative to the center pin member thereof and its termination to the inner conductor **12**.

The prior art approach to compensation for this discontinuity has been to provide a change in dielectric material along the changed diameter portion to balance the Z_0' thereof such that $Z_0'=Z_0$. Where the line has air as a dielectric material which has an $\epsilon=1.0$ the approach has been merely to shape a dielectric insert so that equality is developed.

$$Z_0=\frac{138}{\sqrt{\epsilon}}\log\frac{b}{a}=\frac{138}{\sqrt{\epsilon'}}\log\frac{b'}{a'}=Z_0'$$

The electric field lines shown in FIGURE 3 are not consistent with the theoretical physical disposition of electric field in the zone of change of diameters, however, and compensation made for the reduction in diameter of the center conductor path is not accurate and cannot be accurate within the theory.

In FIGURE 4 a similar representation of a discontinuity is shown wherein an approach to the theoretical field disposition is followed with the lines emerging and entering from the conductive material in a transverse sense. From FIGURE 4 it can be appreciated why the prior approach which ignores the distortion of the electric field lines in the change zone cannot adequately compensate. With respect to the characteristic impedance Z_0' of the change zone shown in FIGURE 4 and in general there is a variation which with air as the dielectric material would vary directly with log b/a, the relationship becoming:

$$Z_0'=\frac{138}{\sqrt{\epsilon'}}\log\frac{b'}{a'}=\frac{138}{\sqrt{\epsilon}}\log\frac{b}{a}$$

Now the value b/a which, in the expression represents the actual spacing between the two conductors as heretofore used can be derived for the virtual length between the outer surface of the inner conductor and the inner surface of the outer conductor as measured by the virtual length of the electric field lines. Using this the relationship

$$\epsilon=\left(\frac{138}{Z_0}\log\frac{b}{a}\right)^2$$

will yield a value which can be practically produced by an infinite number of combinations of different dielectric material path lengths i.e. a compound dielectric material path seen by the electric field.

Referring now to FIGURE 5, the invention is depicted in one embodiment showing postulated field lines E as they exist before, in and after a discontinuity. Thus it will be apparent that the spacing between inner conductor **12'** and the inner surface of the outer conductor **18'** represented by the length of line E_1 is considerably shorter than the field line E_2 and that E_2 is shorter than E_3 which is longer than E_4 which represents the spacing from the reduced diameter portion of the center conductor to the inner surface of the outer conductor. From this a graphic solution is indicated wherein for a given discontinuity the theoretical line configuration may be plotted and considerably enlarged with incremental lines E_2, E_3 . . . E_4 placed thereon following the rules of emergence and entry. Then, physical measurements of the length of the lines representing a virtual b'/a' throughout the zone of discontinuity can be made to yield values of E_2', E_3' . . . E_4' from

$$\epsilon'=\left(\frac{138}{Z_0'}\log\frac{b'}{a'}\right)^2$$

where Z_0' is made to be that of the line. With the various values of ϵ' resulting from this a dielectric insert configuration may be derived which yields a better approach to Z_0. Thus in FIGURE 5 the dielectric insert **24'** is shaped to provide a first length l_1 seen by E_2 of a dielectric constant greater than that of air such as that of Teflon ($\epsilon=2.1$) and then a second length l_2 seen by E_2 of a dielectric constant equal to that of air ($\epsilon=1.0$); to yield a net ϵ_2' so that $Z_{02}=Z_0$. Similarly, the insert can be made to provide a $Z_{03}'=Z_{02}'=Z_0$. This may be done to any degree of accuracy by increasing the samples E. Also various shapes with different dielectric materials may be used by selecting on common terms the related solutions associated with a distinct increment of line length. The dielectric insert shown as **24'** in FIGURE 5 is an actual solution for a type N connector enlarged to a scale of twenty-to-one for a Teflon insert. The connector was for use with 50 ohm cable wherein the a value of the center conductor prior to discontinuity was approximately 90 thousandths of an inch and the b and b' values were approximately 290 thousandths of an inch with a' values being 125 thousandths of an inch.

FIGURE 6 shows an alternative arrangement which may be less expensive to manufacture in that there is an approximation of the configuration which results from the above method to produce a step configuration through the zone of shaping of the insert rather than the tapered portion shown in FIGURE 5 and shown dotted in FIGURE 6. The stepped configuration is more readily reproduced in certain dielectric materials which require machining techniques than is the bevelled portion. If the dielectric material may be molded, cast or otherwise produced, the bevelled portion embodiment is preferred.

FIGURE 7 shows yet a further embodiment wherein the discontinuity occurs in the outer conductive path and the compensating shaping is accomplished in the inner path of the dielectric insert. It is contemplated by the invention that the above method may be employed with respect to discontinuities in the inner path or in the outer path or in both paths, with compensation being accomplished by shaping the dielectric insert to provide a resultant path length in the dielectric material of the insert to accommodate the bending and lengthening or shortening of the electric field lines as indicated in FIGURE 5.

It should be appreciated that the above mentioned graphical method may be rendered mathematically through a series of equations having increments as small as is desired.

An approximation of the method may be accomplished by employing for each point throughout the zone lengths $b-a$ which increase in equal amounts from the diameters preceding the discontinuity up to the diameters following the discontinuity.

Changes in construction will occur to those skilled in the art and various apparently different modifications and embodiments may be made without departing from the scope of the invention. The matter set forth in the foregoing description and accompanying drawings is offered by way of illustration only. The actual scope of the invention is intended to be defined in the following claims when viewed in their proper perspective against the prior art.

What is claimed is:

1. In a transmission line wherein the characteristic impedance at a given point is

$$Z_0=\frac{138}{\sqrt{\epsilon}}\log\frac{b}{a}$$

ϵ being the effective dielectric constant of the medium between the line outer conductor inner diameter b and the inner conductor outer diameter a, there being an abrupt change in b or in a defining a radial surface therebetween to create a zone of electric field lines curved in said zone to enter the conductive surfaces at right angles thereto so as to have lengths different from the radial spacing between inner and outer conductors in said zone developing a non-radial distortion of the electric field extending from said radial surface along said zone, a dielectric medium in said line extending along said zone comprised of materials of different ϵ values, said materials having relative proportions radially of the axis of the line which vary proportionally to the field distortion at incremental steps axially along the zone to balance the quantity $\sqrt{\epsilon}$ in the above relationship against the change in the quantity log b/a caused by the abrupt change in b or in a defining said radial surface so that the characteristic impedance in said zone is substantially equal to Z_0, the varying proportions of the materials defining a curve, the slope of which at all points along the zone represents an angle of substantially more than 0° and substantially less than 90° with respect to the line axis.

2. The line of claim **1** wherein the materials of different ϵ values are formed of alternating sections along a radial path.

3. The line of claim **1** wherein the materials of different ϵ values are formed of two adjacent sections along a radial path.

4. The line of claim **3** wherein one of the materials forms a tapered surface of increasing diameter in an axial sense.

5. The line of claim **3** wherein one of the materials increases in diameter in a series of steps in an axial sense.

6. The line of claim **3** wherein the material of higher ϵ value is disposed within the other material in a radial sense.

7. The line of claim **3** wherein the material of higher ϵ value is disposed about the other material in a radial sense.

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U.S. Cl. X.R.

333—73, 96; 339—177