A connector for coupling a coaxial transmission line to a strip transmission line includes a coaxial structure having an inner conductor projecting beyond the end of the connector a predetermined distance. A portion of the dielectric annular ring of the coaxial structure also projects beyond the end of the connector contiguous with the projecting portion of the inner conductor. The inner conductor and dielectric projections have a flat across them which is urged into registration with a conductor of the strip transmission line. The contiguous projecting dielectric annular ring resists the bending of the inner conductor projection urged against the strip transmission line.

15 Claims, 4 Drawing Figures
COAX LINE TO STRIP LINE END LAUNCHER

The present invention relates to an electrical connector for coupling a coaxial transmission line to a strip transmission line.

In communications systems, it is frequently desirable to electrically connect transmission lines without introducing reflections which may adversely affect the voltage standing wave ratio (VSWR) of the line. Complete elimination of reflections at the connection is usually not possible, since an abrupt change in physical characteristics of a line causes an abrupt change in the line's characteristic impedance, which, in turn, causes reflections. These reflections became extremely objectionable when signals at microwave frequencies are transmitted, especially those in the higher ranges. At these higher frequencies, reflections lower the line efficiency and introduce distortion into the signal being transmitted.

A number of connectors are known for interconnecting a coaxial line and a strip line of a type in which flat conductors are spaced by a sheet of dielectric material.

One type of strip line, a relatively narrow center conductor lies on one side of a dielectric sheet and a relatively wide flat conductor is disposed on the opposite side of the dielectric sheet. To couple a coaxial line in axial alignment with this type of strip line, the center conductor of a coaxial connector of known type projects beyond the terminated end of the connector. The connector is then coupled to the strip line by placing the projection over the strip line center conductor contiguous therewith.

Another type of strip line is that in which all the conductors lie coplanar with each other on one side of a dielectric sheet. This type is of recent development, and is described in the 1969 International Microwave Symposium, GMIT (Group for Microwave Theory and Technique), Dallas, Texas, May, 1969, pages 110-115.

In these types of connectors, the inner conductor projection can not usually be maintained in perfect electrical contact with the strip line center conductor due to bending of the projecting center conductor when urged into registration with the strip line. This bending condition creates an air gap between the two conductors, causing an undesirable discontinuity therebetween. Attempts to correct this condition by soldering introduce additional electrical discontinuities and attendant losses. Other attempts, utilizing a pressure block of dielectric material against the projection to force the projection in registration with the strip line center conductor, are bulky and cumbersome.

However, regardless of the means used of the type described for coupling the projecting center conductor to the strip line conductor, voltage standing wave ratios (VSWR) below 1.1 could not readily be obtained in the x-band frequency range. In many communications systems, these reflection levels are acceptable; however in certain applications (for example, in experimental work in measuring isolation in directional couplers) a VSWR below 1.1 is necessary. Connectors for such applications usually are more complex and expensive than connectors of the type described.

An object of the present invention, therefore, is to provide an improved electrical connector for coupling transmission lines of different physical shapes.

Another object of the invention is to provide a low cost and simple connector for joining a coaxial transmission line to a strip transmission line while minimizing discontinuities which would otherwise have a deleterious effect on the voltage standing wave ratio of the coupled transmission line.

In accordance with the present invention, a connector for coupling a coaxial transmission line to a strip transmission line comprises an inner conductor having a longitudinal axis, a tubular outer conductor, and an annular ring of dielectric material disposed between the inner conductor and the outer conductor, the connector terminating at one end thereof. The inner conductor projects beyond the terminated end. The projecting portion of the inner conductor has a flat disposed at an angle to the terminated end, which flat extends a given distance from the terminated connector end to the projection end. The flat has a predetermined width substantially normal to the given distance.

Means are provided to couple the strip line to the flat by urging at least one of the strip line conductors against the flat in registration with the inner conductor. Other means integral with the connector and contiguous with the projecting portion of the inner connector are provided for resisting the bending of the inner conductor projection in response to a force against the flat imposed by the urging. The integral means includes a portion of the annular ring.

In the drawings:

FIG. 1 is a cross section view illustrating the principles of a connector according to the present invention.

FIG. 2 is an enlarged perspective view of the projecting inner conductor of the connector of FIG. 1.

FIG. 3 is a chart showing the relationship of frequency to voltage standing wave ratio when employing the connector of FIG. 1.

FIG. 4 is a perspective view of a connector according to an embodiment of the present invention.

In FIG. 1, a coaxial connector 20 is mounted in line with a strip transmission line 40 parallel to longitudinal axis x. Strip line 40 has a center conductor 42 having a width E (see FIG. 2) lying on one side of dielectric 44, and a wider conductor 46 lying on the other side of dielectric 40. The connector 20 has an inner conductor 22, and annular ring 24 made of solid dielectric material, and a tubular outer conductor 26. The annular ring 24 is disposed between the inner connector 22 and the outer conductor 26. The connector 20 terminates at end 30. Inner conductor 22 projects beyond the terminated end 30 a given distance B forming projection A disposed between connector end 30 and projection end 31.

Distance B is measured in the direction of arrow y, which in this case is parallel to the longitudinal axis x of the inner conductor 22. A portion B' of annular ring 24, which, of course, is integral with the connector 20, projects beyond the terminated end 30 an amount equal to the given distance B. In addition, portion C' of the outer conductor 26 also preferably projects beyond the terminated end 30 given distance B. The projecting portion B' of the annular ring 24 is contiguous with inner conductor 22 at junction 25 therebetween as is outer conductor 26 portion C' at junction 21.

Projection portion A' of the inner conductor 22 has a flat 27 preferably parallel to longitudinal axis x, the
angle of flat 27 to axis x being a function of the angle at which connector 20 and strip line 40 are coupled. In this case, for example, they are coupled in line, i.e. in axial alignment, and flat 27 is parallel to axis x. Flat 27 has a length defined by distance B and a predetermined width D into the drawing (see FIG. 2).

Center conductor 42 of strip line 40 has a predetermined width E (see FIG. 2) into the drawing of substantially the same size as that of flat 27. By urging conductor 42 against flat 27 of inner conductor 22 in the direction of arrow z, good electrical coupling can be obtained therebetween due to the mass of portions B\(^1\) and C\(^1\) in alignment therewith which mass resists the bending of portion A\(^1\) in the direction of arrow z. The masses of portions B\(^1\) and C\(^1\) permit higher contact pressures in the direction of arrow z than were possible heretofore in an integral one piece connector. By making distance B a predetermined length, not only is the resistance to bending of portion A\(^1\) maximized by increasing the resistance of conductor 22 to bending in direction z, but the same predetermined length minimizes the discontinuity in capacitance between the connector 20 and the strip line 40, as will be described.

Projection portion A\(^1\) may be more clearly described in conjunction with FIG. 2. In FIG. 2, flat 27 is a planar surface having a length B and a width D. This surface is illustratively shown substantially parallel to longitudinal axis x of the inner conductor 22. Edge 28 of the flat 27 is, in this instance, substantially parallel to axis x. Terminated end 30, as illustrated, preferably is a planar surface normal to flat 27, as is end 31. However, ends 30 and 31 need not necessarily be planar surfaces nor normal to flat 27.

Width D is substantially equal to the width E of strip line conductor 42, which is shown by dashed lines. The width D, by being of substantially the same size as width E of conductor 42, precludes any capacitance discontinuity which would otherwise occur therebetween. The width D of flat 27 may be slightly less than width E, but preferably not greater, the optimum condition being when they are of the same size.

The connector 20 of FIG. 1 preferably has a flange 90 extending outwardly from the periphery of the outer conductor 26. Flange 90 has a face 92 which may be coplanar with terminated end 30 of the connector, which is offset distance B from the projection end 31. The flange is secured to a housing 60 which secures the strip line 40 in a conventional manner by which outer conductor 26 of connector 20 is conductively coupled to strip line conductor 46 via housing 60. The flange mounting holes 96 are positioned with respect to flat 27, mounted strip line 44, and housing threads 65 such that flat 27 is urged against conductor 42 of the strip line when screws 101 and 102 are tightened against housing 60. Ordinarily, a force against conductor 22 projection A\(^1\) in the direction of arrow 2 would bend projection A\(^1\), causing a separation of projection A\(^1\) from conductor 42 in the z direction. However, projection B\(^1\) of annular ring 24, which is contiguous with the projection A\(^1\), resists the bending of projection A\(^1\). Further resistance to the bending is contributed by portion C\(^1\) of outer conductor 26, which is contiguous with portion B\(^1\). By terminating outer conductor portion C\(^1\), ring portion B\(^1\), and projection A\(^1\) at end 70 in a substantially planar surface, optimum resistance to the bending of conductor projection A\(^1\) in direction z is provided while maintaining the electrical integrity of the connection. The significance to be attached to the relationship between distance B and the discontinuity presented by the coupling of connector 20 to strip line 40 will now be described.

The percentage of incident voltage that is reflected is given by the coefficient of reflectively \(\rho\). The relation of \(\rho\) to the voltage standing wave ratio (VSWR) is given by:

\[
VSWR = \frac{1 + |\rho|}{1 - |\rho|}
\]

The incident voltage reflected in a connector according to the present invention will, in part, be a result of the differences in capacitance surrounding portion A\(^1\) of the inner conductor 22. That is, waves traveling along the periphery of conductor 22 in a direction y (see FIG. 1) in the TEM mode will experience a capacitance discontinuity at portion A\(^1\). The reason for discontinuity is that a cross section taken along line \(r\) across the connector perpendicular to axis x in to the drawing through flat 27 includes portion B\(^1\) of annular ring 24, and C\(^1\) of the outer conductor disposed above conductor 22 and portion D\(^1\) of the dielectric material 44 of the strip line 40 disposed below conductor 22. Portion D\(^1\) of the strip line 40 usually presents a higher capacitance than that of portion B\(^1\) due, in part, to the differences in the dielectric constants of the two portions. The discontinuity is aggravated by the relatively high dielectric constant (on the order, e.g., of 9) of dielectric 44 of strip line 40, as compared to the low dielectric constant (on the order, e.g., of 2) of the annular ring 24 of the connector.

These different dielectrics present a discontinuity in capacitance which is also a function of the distance B, in addition to the amount of disparity between the two dielectric constants in the area including portion B\(^1\) and D\(^1\) surrounding projection A\(^1\). Thus, the discontinuity in capacitance may be reduced by decreasing the disparity in capacitance along distance B. One way to decrease this disparity is to decrease distance B.

It has been determined that a distance B of approximately 0.012 inches results in a coefficient of reflectively \(\rho\) of about 0.024 or a VSWR of about 1.05 for the X-band frequency range. On the other hand, a distance of about 0.015 inches yields a \(\rho\) of about 0.05 or a VSWR of about 1.1. Thus a maximum value of B in the range of about 0.012 inches to 0.015 inches will yield a VSWR of between 1.05 and 1.1.

In those instances where a VSWR of greater than 1.05 can be tolerated, distance B may extend beyond the 0.012 dimension noted above, in accordance with the present invention. The distance B may be reduced to a size less than 0.012 inches, the only limitation being the actual physical capability of joining flat 27 of FIGS. 1 and 2 to conductor 42 of strip line 40.

As described, the mass of portions B\(^1\) and C\(^1\) disposed on one side of projection A\(^1\), which side is opposite to the side of conductor 22 at which flat 27 lies, resists the bending of portion A\(^1\) when portion A\(^1\) is subjected to forces against the flat in the z direction, which forces mechanically couple the flat 27 to the strip line conductor 42 ensuring a sound electrical connection.
Thus, the combination of the integral bend resisting portions B₁ and C₁, and the projection A₁ having a length B which is determined as described above for controlling the amount of reflection provide an integral one piece connector having an improved VSWR for strip line connections.

The construction as described for the connector of FIG. 1 results in a connection that is both electrically and mechanically sound. This condition is substantiated by actual measurements of voltage standing wave ratio (VSWR) in a transmission system in which a connector of the present invention was incorporated. FIG. 3 illustrates this VSWR as plotted against frequency. The VSWR varies from approximately 1.01 to 1.05 in the frequency range from 7.5 to 12.0 gigahertz.

In arriving at the data of FIG. 3, an OSM (trade name for Omni Spectra, Inc.) 204 CC coaxial connector was modified in accordance with the present invention. A flat on the inner conductor was projected a distance of about 0.012 inches beyond the end of the connector. The flat was urged into registration with the center conductor of a 50-ohm microstrip transmission line made of 0.025 inches thick aluminum substrate (Dimension F FIG. 1). The strip line center conductor and the flat had a common width of 0.025 inches.

As described above, distance B of FIG. 1 is predetermined to provide a voltage standing ratio (VSWR) of about 1.05 in the X-band frequency range. However, the length of distance B is not limited to the 0.012 inch size to prevent the bending of inner conductor projection A₁ in the direction z as readily appreciated. Prior art coaxial connectors have a center conductor which usually projects beyond the end of the connector 0.050 to 0.100 inch. But the annular ring and the outer conductor do not project beyond the connector end to support the inner conductor at the boundary thereof in contact with the stripline. Thus, the projecting inner conductor of the prior art is subjected to deleterious bending unless soldered or forced into contact by additional means which have the disadvantages noted. The result of the present invention, therefore, is a simple, inexpensive and reliable connector.

The connector of FIG. 4 is a preferred embodiment of an X-band connector incorporating the features of the invention illustrated by the connector of FIGS. 1 and 2. The connector of FIG. 4 is of the type for which the plot of FIG. 3 was obtained. In FIG. 4, the inner conductor 122 has an overall diameter of 0.050 inch having a flat 127 of a length B and a width D. Common to flat 127 is flat 128 of annular ring 124 and flat 129 of outer conductor 126. The connector terminates at end 170 in a planar surface which is preferably normal to the longitudinal axis of the inner conductor 122.

Common flats 127, 128 and 129 are parallel to axis x, the length 13 being parallel to axis x and preferably normal to surface 170. Edge 121 of flat 127 is contiguous with planar surface 170, as are edges 131 and 141 of flats 128 and 129, respectively.

Only a portion of outer conductor 128 need form flat 129, the remainder may terminate at end 130. Flange 190 extends from the outer conductor 126 as described above. Face 192 of the flange is coextensive with end 130, which is here shown as a planar surface. Alternatively, face 192 could be disposed in any desired position with respect to end 130.

The annular ring, in this case, has an outer diameter of 0.162 inch and has a dielectric constant of about 2. The inner conductor is made of copper and the outer conductor of any suitable material. Distance B is about 0.012 inch and width D is about 0.025 inch for registration with a strip line conductor having a width of 0.025 inch. This type of connector is extremely suitable for use with the coplanar strip transmission line noted above since the outer conductor flats may readily contact the coplanar outer conductors of the strip line.

Other embodiments, not shown, also could be readily devised. One such other embodiment could be similar to the connector of FIG. 4 except that flats 128 and 129 could be disposed at some angle to flat 127. In this form, only flat 127 would then be in registration with a mating strip transmission line.

In the chart of FIG. 3, the plot of frequencies under 7.5 gigahertz is not shown. However, it is to be understood that VSWR increases with an increase of frequency, and conversely, VSWR decreases with a decrease of frequency. Consequently, the lower frequency ranges will be within the desired limits with respect to the VSWR when the upper frequencies are within those limits.

What is claimed is:

1. A connector for coupling a coaxial transmission line to a strip transmission line of a type in which a pair of conductors in spaced relationship are separated by dielectric material, said connector comprising:
   an inner conductor having a longitudinal axis,
   a tubular outer conductor,
   an annular ring of dielectric material disposed between the inner conductor and the outer conductor,
   said connector terminating at one end thereof, said inner conductor projecting beyond said terminated end, said projecting portion of the inner conductor having a flat, said flat being angularly oriented with respect to said axis,
   coupling means connected to said connector for urging said flat against at least one of said strip line conductors when said connector is coupled to said strip line, and
   means integral with said connector and contiguous with the projecting portion of said inner conductor for resisting the bending of said inner conductor projection in response to a force against said flat imposed when said one strip line conductor is urged against said flat in registration with said inner conductor, said integral means including a portion of said annular ring.

2. The connector of claim 1 wherein said integral means includes a portion of said outer conductor disposed contiguous with said annular ring portion.

3. The connector of claim 1 wherein said integral means has a flat disposed substantially coplanar with said projecting inner conductor flat.

4. The connector of claim 3 wherein said integral means includes said annular ring and at least a portion of said outer conductor.

5. The connector of claim 1 wherein said flat is defined by a length along said axis and a width, said strip line conductor in registration with said inner conductor flat having a width no greater than said flat width.
6. A connector for coupling a coaxial transmission line to a strip transmission line of a type in which a pair of conductors lying in spaced relationship are separated by a dielectric material, said connector comprising:

an inner conductor having a longitudinal axis,

a tubular outer conductor,

an annular ring of dielectric material disposed between the inner conductor and the outer conductor,

said connector terminating at one end thereof, said inner conductor projecting beyond said terminated connector end, said projecting portion of the inner conductor having a flat defined by a length and width, said flat being disposed at an angle to said terminated end and extending from said terminated connector end to the projection end along said length a predetermined distance,

coupling means connected to said connector for urging said flat against at least one of said strip line conductors when said connector is coupled to said strip line, and

means integral with said connector and contiguous with the projecting portion of said inner conductor for resisting the bending of said inner conductor projection in response to a force against said flat imposed when said one strip line conductor is urged against said flat in registration with said inner conductor, said integral means including a portion of said annular ring.

7. The connector of claim 6 wherein said integral means includes a portion of said outer conductor disposed contiguous with said annular ring portion, said integral means having a flat disposed coplanar with said inner conductor flat.

8. The connector of claim 6, wherein said annular ring is a solid material.

9. A connector for coupling a coaxial transmission line to a strip transmission line of a type in which a pair of conductors of a given width lying in spaced relationship are separated by dielectric material, said connector comprising:

an inner conductor having a longitudinal axis,

a tubular outer conductor, and

an annular ring of dielectric material disposed between the inner conductor and the outer conductor,

said connector terminating at one end thereof in a planar surface angularly oriented with respect to said longitudinal axis of said inner conductor, said inner conductor having a flat defined by a length and width, said flat being in contact with said surface along the width edge of said flat and oriented substantially parallel to said axis,

said length being sufficiently small so that the VSWR between said connector and said strip line is no greater than 1.1 when one of said strip line conductors is urged against said flat in registration with said inner conductor.

10. The connector of claim 9 wherein said flat width is normal to said length and of substantially the same size as said one conductor width.

11. The connector of claim 9 wherein said connector further includes coupling means connected to said connector for urging said flat against said one strip line conductor.

12. A connector for coupling a coaxial transmission line to a strip transmission line of a type in which a pair of conductors of a given width lying in spaced relationship are separated by dielectric material, said connector comprising:

an inner conductor having a longitudinal axis, a tubular outer conductor, an annular ring of dielectric material disposed between the inner conductor and the outer conductor, said connector terminating at one end thereof in a planar surface of said width being in contact with said planar surface, said flat being oriented at a second angle with respect to said planar surface, and means coupled to said connector for coupling said strip line to said flat by urging at least one of said strip line conductors against said flat in registration with said inner conductor, said length being sufficiently small so that the VSWR between said connector and said strip line is no greater than 1.1.

13. The connector of claim 12 wherein said length is substantially normal to said planar surface.

14. The connector of claim 13 wherein said edge of said flat is no greater than said one strip line conductor width.

15. The connector of claim 12 wherein said length has a maximum value in the range of about 0.012 to 0.015 inches.