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TERMINATION FOR STRIP TRANSMISSION LINES

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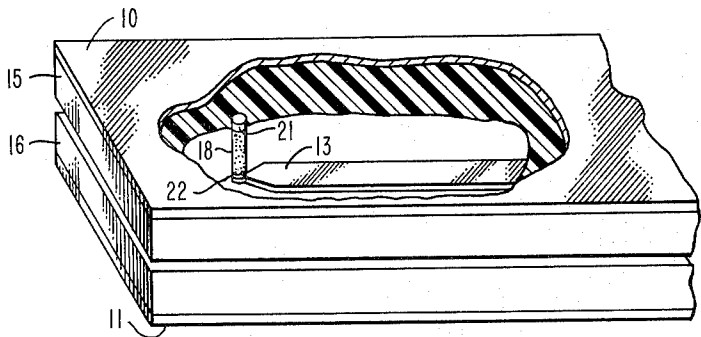


FIG.-1

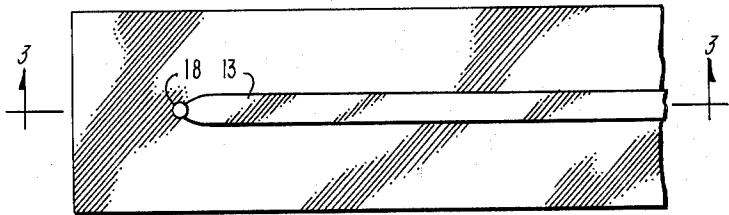


FIG.-2

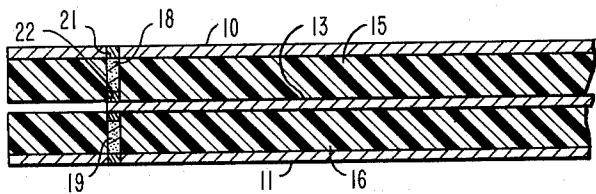


FIG.-3

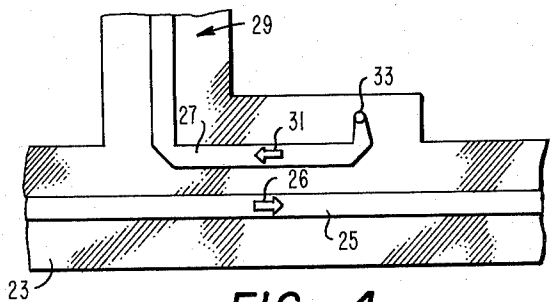


FIG.-4

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2

3,209,284

TERMINATION FOR STRIP TRANSMISSION LINES

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8 Claims. (Cl. 333-10)

This invention relates to microwave transmission line terminations and more particularly to terminations for strip transmission lines of the type disclosed in U.S. Patent No. 2,913,686 issued November 17, 1959, which types essentially consist of two spaced apart parallel ground plates of a conductive material with at least one center conductor having a width substantially less than that of the ground plates, disposed midway between the plates and separated therefrom by a dielectric material.

Presently, strip transmission line components are finding wide use in the microwave field since they offer many advantages over other microwave transmission devices. Strip transmission line components are easily and cheaply manufactured by printed circuit techniques, if desired, and are specially suited to achieving light weight and miniaturized circuit construction.

Certain microwave techniques, such as those employing directional couplers, require the use of transmission line terminations. The terminating element should ideally provide a good impedance match for the line over a broad frequency band while having structural characteristics compatible with the physical configuration of the microwave transmission line.

Previously, terminating elements employed for the newly developed strip line microwave transmission techniques have not provided the broad band and compatible construction of terminations available for use with other microwave transmission line techniques, such as the disc termination used with coaxial lines. For this reason, prior attempts have been made to provide a suitable strip line terminating element by first converting the energy field into a coaxial or other configuration to permit use of the disc terminating element or the like. However, the energy field transformation, among other things, requires use of mode suppression studs to surround the junction to prevent the occurrence of undesired modes, and the line unbalance resulting at the junction limits the acceptable band width of the termination.

In the prior art, extensive use has been made of a strip line terminating element composed of a triangular shaped, thin film of lossy material overlying a tapered end portion of the center conductor. For proper band width response, the triangular element must be made at least four to eight inches long, depending on the frequency of operation, and therefore requires excessive space when considered in light of the miniaturization sought by use of the strip line technique.

In some cases, use has been made of a cylindrical shaped element of lossy material attached as an extension of the center conductor with the other end being connected by means of a metallic plate to the outer conductors. However, because of the change to a third dimension from the flat center conductor, high order modes are built up around the resistive element thus making the termination very frequency sensitive, that is, the termination functions correctly only in a very narrow band of frequencies. In addition, the length and diameter of the cylindrical termination must be varied with frequency for proper operation, and may thus be excessively long for proper miniaturization.

Therefore, it is an object of the present invention to provide an improved termination element for strip type microwave transmission lines.

Another object of this invention is to provide an improved terminating element for strip transmission line

components having broad band frequency characteristics and small space requirements.

A further object of this invention is to provide an improved termination for use in microwave strip transmission line components, such as directional couplers, whereby the component exhibits broad band frequency characteristics and miniature size.

In accordance with the present invention, a termination element for a strip transmission line is provided by a pair of cylindrical resistors composed by a lossy material, each resistor being equal to an impedance value approximately twice that of the strip line and connected between the end of the center conductor and an associated one of two ground plates. The end of the center conductor, in accordance with another aspect of the invention, is tapered to a width approximating the diameter of the two cylindrical resistors so that the electric field will be concentrated within the lossy material. Among the advantages of using terminations in accordance with the present invention are its simple construction, very precise balanced impedance match over a broad band of frequencies, and space conservation which results from the fact that the terminating element requires no additional space beyond the terminating point of the strip line section.

The foregoing and other objects of the invention will be apparent from the following detailed description of the invention, and illustrated in the accompanying drawings, in which:

FIG. 1 is a perspective view of a portion of a strip transmission line containing the termination element of the present invention with a portion of the upper ground plate and upper dielectric layer removed;

FIG. 2 is a top plan view of a strip transmission line similar to that illustrated in FIG. 1, including the termination element of the present invention, but with the upper plate and upper dielectric layer removed to show the connection of the termination element to the tapered portion of the center conductor;

FIG. 3 is a longitudinal cross-sectional view of the strip transmission line with the termination element of the present invention taken along line 3—3 which bisects the center conductor; and,

FIG. 4 is a top plan view of a strip line directional coupling having a termination element in accordance with the present invention.

Referring now to FIGS. 1, 2 and 3, wherein corresponding parts in the various figures are indicated by the same reference numeral, there is illustrated a conventional strip transmission line including a pair of electrically conductive ground plates 10 and 11 spaced apart and arranged in a parallel relationship. A flat center conductor 13 or conductors having a width substantially less than the width of the conductive ground plates 10 and 11 is held in a position midway between the lower and upper ground plates 10 and 11 and separated therefrom by a lower layer 15 and an upper layer 16 of dielectric material, such as, glass, impregnated Teflon, air, or the like.

A strip transmission line may be constructed by any of a number of well-known techniques whereby the aforementioned arrangement of the conductors 10, 11 and 13 may be realized. Preferably, the strip transmission line may be conveniently fashioned by utilizing conventional printed circuit techniques to deposit copper strips on both sides of an elongated solid dielectric sheet, the copper deposited on one side comprising one of the ground plates 10 or 11 and the thinner strip of copper etched on the other side comprising the center conductor 13. A second sheet of the solid dielectric has copper deposited on one side only to provide the other ground plate. The sheets may then be assembled with the use of suitable fasteners to form the strip transmission line.

Alternatively, strip transmission lines using an air dielectric may be constructed by depositing at least one center conductor strip on a thin layer of dielectric material which is separated from the ground plates by dielectric spacers or by any other suitable technique.

In accordance with the present invention, an improved terminating element may be provided for a strip transmission line by using two resistive plugs 18 and 19, preferably cylindrically shaped, each extending perpendicularly from opposite sides of an end point on the center conductor 13 to contact the upper and lower ground plates 10 and 11. Each plug consists entirely of or is coated with a lossy material, such as a thin metal film or carbon particles held together by an appropriate binder, and has an electrical impedance equal to approximating twice Z_0 , where Z_0 is equal to the characteristic impedance of the strip transmission line. The plugs 18 and 19 may be inserted within holes drilled or otherwise formed to extend through the thickness of the ground plates 10 and 11 to the surface of the center conductor 13. The plugs 18 and 19 may have short metallic end sections 21 and 22, and small amounts of solder or silver paint (not shown) may be used at both ends to secure the plugs in position and assure good electrical contact with the conductors 10, 11 and 13.

The best termination characteristics are achieved in accordance with a preferred form of the invention by using resistive plugs having diameters approximately one-quarter of the width of the center conductor 13 and insuring that the entire electrical field in the transmission line is concentrated through the lossy material of the plugs 18 and 19. Plugs having a diameter in the order of one-quarter to one-eighth the width of the center conductor 13 have been found to provide the best broad band match as a probable result of lower capacitive coupling between the center conductor 13 and the surfaces of the plugs 18 and 19. However, to achieve proper field concentration through the plugs, an end portion of the center conductor 13 in the order of one-sixteenth to one-eighth of a wave length long is tapered to a width approximating the lesser diameter of the resistive plugs 18 and 19. In this way almost all of the electric field may be concentrated through the resistive material of the post to provide excellent termination characteristics.

As will be obvious to those skilled in the art, the two resistive plugs 18 and 19 are the electrical equivalent of the two halves of a single plug extending from the upper ground plate 10 to the lower ground plate 11, and being contacted at its center by the end section of the center conductor 13. Therefore, a terminating element in accordance with this invention may be constructed using a single plug inserted into a hole extending through the entire transmission line with electrical contact being maintained with the center conductor 13 through a short central metallic portion of the plug, and with the upper and lower ground plates 10 and 11 through short end metallic portions.

It should be noted that the terminating elements constructed in accordance with this invention form a terminating junction balanced with respect to the center conductor 13 so that any undesired modes resulting from the right angle junction on one side are cancelled by those on the other thus obviating the need for suppression studs to suppress unwanted modes as required at an unbalanced junction. It has been determined that strip transmission line components having such terminations offer an excellent impedance for operating band widths in excess of 1000% of the center design frequency of the line.

Referring now to FIG. 4, which illustrates a strip line directional coupling unit in accordance with this invention, it will be assumed that energy is transmitted along a portion of a primary strip transmission line 23 containing the center conductor 25 in the direction indicated by the arrows 26. In order to measure the amount of

power being transmitted in that direction, a unidirectional coupler is employed which consists of a short section of center conductor 27 disposed adjacent to and in parallel relation with the center conductor 25 in the primary line. In accordance with well-known principles, an inverse mode is induced in this parallel section 27 so that some of the microwave energy travelling in the direction indicated by the arrows 26 is coupled to travel along a secondary strip transmission line 29 in the opposite direction parallel to the main line 23, as indicated by the arrow 31. A termination at the other end of the parallel section 27 is provided in accordance with this invention by a resistive plug arrangement 33 connected to a short tapered end section of the center conductor 27. In this manner, the line termination required for a unidirectional coupler is achieved with minimum space requirement, that is, in an area no more than required in providing the parallel strip line section 27, thereby permitting significant reduction in the size of the coupling component.

Although there has been described a preferred embodiment of the invention, it will be understood that various changes in the details, which have been herein described and illustrated in order to explain the nature of the invention, may be made by those skilled in the art within the principle and scope of the invention as expressed in the appended claims.

What is claimed is:

1. A microwave termination comprising a pair of conductive ground plates disposed in spaced apart parallel relationship, a center conductor disposed midway between said ground plates in parallel relation thereto, said center conductor having a normal width substantially less than the width of said ground plates and having an end portion, a pair of cylindrically shaped resistive plugs with a diameter less than the normal width of said center conductor disposed at said end portion of said center conductor perpendicularly to the ground plates to electrically connect the end portion of said center conductor to each of the ground plates, said end portion being tapered to a final width matching the diameter of said plugs connected thereto, whereby the electric field established between the center conductor and the ground plates is concentrated through said resistive plugs.

2. A microwave termination for a microwave transmission line comprising a pair of conductive ground plates disposed in the spaced apart parallel relationship, a center conductor disposed midway between said plates in a parallel relationship, said center conductor having a normal width substantially less than the width of said ground plates and having an end portion, a column of resistive material having a diameter less than the normal width of said center conductor disposed perpendicularly to said ground plates and electrically connecting both ground plates to the end portion of the center conductor, said column of resistive material having an impedance between said center conductor and one of said ground plates equal to approximately twice the characteristic impedance of a transmission line composed of said conductive ground plates and said center conductor, said end portion being tapered to a width less than the normal width of the center conductor at the point of connection to said column of resistive material to concentrate the electric field within the resistive material of said column, whereby the electric field for microwave energy transmitted is dissipated through said column of resistive material.

3. In a strip line transmission system with a pair of conductive ground plates disposed in spaced apart parallel relationship and center conductor means disposed midway between said plates in parallel relationship and having an end section, said center conductor means having a normal width substantially less than said ground plates, a termination element comprising a tapered end section and a column of resistive material disposed perpendicular to said ground plates and electrically con-

necting the tapered end section of said center conductor means at the point of least width to each of said ground plates, said column having a width approximately equal to the least width of the tapered end section of said center conductor means and having an impedance to match the impedance of said transmission line.

4. In a strip transmission line system having a pair of conductive ground plates disposed in spaced apart parallel relationship and having a center conductor means having a normal width substantially less than said ground plates for carrying electrical energy disposed midway between said plate in parallel relationship, a terminating element comprising means for providing a column of resistive material disposed perpendicular to said ground plates and electrically connecting said center conductor means with each of said ground plates, and including a tapered section of said center conductor means in which the width of said center conductor means is reduced to approximately correspond to the width of said column at the point of connection, the width of said column being substantially less than the normal width of said center conductor, whereby the electric field of the electric energy is dissipated through said column of resistive material.

5. In a strip transmission line having a pair of conductive ground plates disposed in spaced apart parallel relationship with a center conductor for carrying electrical energy disposed midway between said plates in a parallel relationship, said center conductor having a normal width substantially less than the width of said ground plates, a terminating element comprising a tapered end section of said center conductor with a smaller width, and means for providing a cylindrically shaped column of resistive material having a diameter less than the normal width of said center conductor disposed perpendicular to said ground plates and to said center conductor for establishing electrical contact between the tapered end section of said center conductor and each of said ground plates, said resistive material having an impedance between said center conductor and one of said ground plates equal to approximately twice the characteristic impedance of said transmission line, whereby the electric field established between said center conductor and said ground plates is concentrated by the tapered end section through said column means to each of said ground plates.

6. In a strip transmission line system including a pair of conductive ground plates disposed in spaced apart parallel relationship with a center conductor means having a normal width substantially less than said ground plates disposed midway between said ground plates and in parallel relationship thereto for transmitting electrical energy, the termination element comprising means composed essentially of a resistive material disposed perpendicularly to the ground plates and electrically connecting each of said ground plates to the center conductor at a connection point, said resistive material being cylindrically shaped with a diameter less than the normal width of said center conductor, and means including a shaped end section of the center conductor with a tapered width for concentrating the electrical energy transmitted in the resistive material of the connecting means at the connection point.

7. In a unidirectional microwave coupling component having a pair of conductive ground plates disposed in spaced apart parallel relationship, a primary center conductor disposed in a plane midway between and parallel

to said ground plates for transmitting electrical energy from a first point to a second point in space, and a secondary center conductor having a normal width disposed adjacent to and in the same plane as said primary center conductor and having a section disposed adjacent to and parallel with said primary center conductor to transmit a portion of the electrical energy transmitted by said primary center conductor to a third point, the improvement comprising a column of resistive material less than the normal width of said secondary center conductor disposed perpendicularly to said ground plates for electrically connecting one end of said secondary center conductor to each of the ground plates, and a tapered end section on the center conductor for concentrating the electrical field being transmitted by said secondary center conductor through said column.

8. In a unidirectional microwave coupling component for a stripline transmission system, said coupling component having a pair of conductive ground plates disposed in spaced apart parallel relationship with primary and secondary center conductors disposed adjacent and parallel to one another in a plane midway between and parallel to said ground plates so that the secondary center conductor transmits a portion of the electrical energy transmitted by said primary center conductor, an improved termination element for one end of the secondary center conductor comprising a tapered end section at said one end of said secondary conductor, and a column of resistive material disposed perpendicular to said ground plates and electrically connecting the end of the tapered end section with each of said ground plates, the width of said column corresponding to the width of the end of the tapered end section which is substantially less than the untapered portion of said second center conductor, whereby the electric field of the electrical energy transmitted toward the tapered end section of the center conductor is dissipated in said column of resistive material.

References Cited by the Examiner

UNITED STATES PATENTS

2,408,435	10/46	Mason	333—22
2,409,599	10/46	Tiley	333—22
2,494,722	1/50	Rosen	333—22
2,498,335	2/50	Hunt	333—22
2,597,867	5/52	Hansen	333—22
3,065,435	11/62	Jones	333—81
3,113,277	12/63	Casper et al.	333—84

FOREIGN PATENTS

722,660	1/55	Great Britain.
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OTHER REFERENCES

Lawrence, Jr.: Tunnel Diode Memory Package, IBM Technical Disclosure Bulletin, vol. 5, No. 7, December 1960, page 29 relied on.

Packard: Machine Methods Make Strip Transmission Line, Electronics, vol. 27, No. 9, September 1954, page 148 relied on.

Wild et al.: Handbook of Tri-Plate Microwave Components, Sanders Associates, Inc., Nashua, N.H., copyright 1956, pages 53—56 relied on.

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