STRIPLINE TERMINATION DEVICE HAVING A RESISOR THAT IS SHORTER THAN ONE QUARTER WAVELENGTH
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This invention relates to a resistive device for microwave circuitry and particularly to a termination device for a stripline to interpose an adapter into stripline circuitry, converting it to coaxial circuitry in order to interpose a properly matched resistor. This is undesirable from a labor and circuit reliability viewpoint as well as from space considerations and tends to destroy the advantages of stripline circuitry.

In accordance with the present invention, the resistive device is constructed so that the line impedance changes along the resistor path in order that it always be equal to the resistance to ground from that point on the resistor path. This resulting match between resistor and line yields a very low VSWR across a broad band, such as from DC to microwave frequencies in excess of 100. The desirable matching characteristics of resistors made in accordance with the present invention are achieved by providing a conductive body with a substantially wedge shaped cavity extending in from the side wall of the conductive body and mounting a flat resistor symmetrically within the cavity, which resistor is to be connected with the stripline circuitry. The resistor is conductively connected to the metal body at the apex of the wedge shaped notch.

It is therefore the main object of the present invention to provide a resistive device for use in stripline microwave circuitry, which device provides a continuous match between the resistance from the resistor to ground at any point along its length and the line impedance at that point.

Another object of the present invention is the provision of a new and improved resistive device for stripline circuitry, which device is made of a conductive body having two spaced apart ground planes which are connected by a peripheral side wall, the conductive device having a symmetrical substantially wedge shaped cavity extending therein from the peripheral side wall with a resistor disposed symmetrically within the wedge shaped cavity and being connected to the conductive body of the device at the apex of the wedge.

Still another object of the present invention is the provision of a new and improved termination device for stripline microwave circuitry.

Yet another object of the present invention is the provision of a new and improved resistive attenuator for stripline microwave circuitry.

The above and other objects, characteristics and features of the present invention will be more fully understood from the following description taken in connection with the accompanying illustrative drawing.

In the drawing:

FIG. 1 is a perspective view of a stripline termination device embodying the present invention;
FIG. 2 is a top plan view thereof;
FIG. 3 is a sectional view taken along the line 3—3 of FIG. 2;
FIG. 4 is a view similar to FIG. 3 showing a modified form of the present invention;
FIG. 5 is another view similar to FIG. 3 showing another modified form of the present invention;
FIG. 6 is a perspective view of a T-pad attenuator for stripline microwave circuitry embodying the present invention;
FIG. 7 is a top plan view of the device of FIG. 6;
FIG. 8 is a sectional view taken along the line 8—8 of FIG. 7; and
FIG. 9 is a sectional view taken along the line 9—9 of FIG. 7.

Referring now to the drawing in detail, and especially to FIGS. 1 to 3 thereof, a termination device for incorporation in stripline microwave circuitry is shown in FIGS. 1 to 3 and is generally designated by the reference numeral 10. Termination device 10 includes a conductive body 12 having upper and lower surfaces 14 and 16, respectively, and a peripheral side wall 18. Preferably, the conductive body 12 is made out of a suitable conductive metal such as brass, although copper, aluminum, and other metallic conductors could be employed. While the surfaces 14 and 16 are here shown as planar, which is desirable from convenience viewpoint, other types of surfaces could be employed without departing from the present invention. However, the spacing of surfaces 14 and 16 should not be less than the ground plane spacing.

The metal body 12 is provided with a substantially wedge shaped cavity 20 which extends in from the peripheral side wall 18 and which is symmetrical about a central plane extending from the apex of the wedge shaped cavity. As is shown, the maximum width of the wedge shaped cavity 20 is at the peripheral side wall 18 with the surfaces 22 and 24 defining the wedge shaped cavity being in converging relation as they extend in from the periphery of the metallic body 12. At the apex of the wedge shaped cavity 20 there is a substantially planar slot 30 adapted to receive a flat resistor 32 to be described in greater detail hereinafter. For convenience of fabrication, cavity 20 and planar slot 30 extend the
full width of the metal body 12, as best seen in FIGS. 1 and 2. As previously noted, a flat resistor 32 having a width equal to the width of the stripline circuitry into which it is adapted to be connected and a resistance substantially equal to the line impedance is disposed within the wedge shaped cavity 20 and is connected to the metal body 12 by disposition in the planar slot 30 and by added connective means such as solder or the like. The resistor 32 extends outwardly from the slot 30 toward the peripheral side wall 18 of the body 12 a substantial distance to be defined hereinafter but does not extend all the way to the periphery 18 of the metallic body 12. The resistor 32 is disposed along the plane of symmetry of the wedge shaped cavity 20. Connected to the resistor 32 adjacent the end closest to the peripheral wall 18 of the body 12 is a conductive tab 34 which is adapted to be directly connected into the stripline circuitry. Preferably the tab 34 is tinned copper which is readily solderable to a surface of the resistor 32 and to the stripline circuitry on a circuit board not seen herein.

In order to hold the resistor 32 and the tab 34 in their relative position along the plane of symmetry 14 of the wedge shaped cavity 20, it is preferred that the cavity is filled with a suitable dielectric material, preferably one which has a dielectric constant which matches the dielectric constant of the circuit board upon which the stripline circuitry is mounted. That is to say that if the stripline circuitry is mounted on epoxy bonded fiberglass, then the back fill material 36 is either epoxy or glass fiber filled epoxy. However, other dielectric materials can provide a suitable match, and I have successfully filled cavity 20 with glass ceramic, polypropylene, other plastics and other suitable dielectric materials. Moreover, in certain applications, the cavity can be left unfilled, in which case air will serve as the dielectric material. In addition, the cavity may be filled with a combination of different dielectric materials to serve simultaneously several functions. For example, a portion of a cavity may be filled with air to match the air dielectric of the stripline, another portion with alumina to match the resistor substrate, and a third portion of benxilla for its dielectric and heat conducting properties.

It is obvious that the value of the resistor 32 must be carefully controlled. The most convenient way to provide a closely controlled resistor 32 is to make the resistor as a resistive film on a ceramic base by utilizing vapor deposition techniques. Moreover, such a resistor may be fabricated earlier in the process of fabricating the termination device 10. When using a vapor deposited resistor, it is generally preferable to take a flat ceramic base, deposit a layer of resistive material such as nickel chromium alloy onto a surface of that base for a sufficiently long period to provide a resistor of desired resistance value.

The effective length of the resistor 32 is of great importance in order to render the device effective. By effective length, I mean that portion wherein the resistor alone transmits energy. Thus, the effective length of resistor 32 is the length between the right hand end of the slot 30 as viewed in FIG. 3 and the left hand end of the conductive tab 34 as viewed in said FIG. 3, that length being the length in between which the resistor actually functions as the resistive load, the remainder of the resistor 32 being employed merely to provide connecting areas to the slot 30 and the tab 34. In order to have a termination device of suitable quality it is necessary for the effective length of the resistor 32 to be less than one-quarter of the shortest wave length to be encountered in the operating frequency range of the circuitry to which the device will be incorporated. Preferably, the effective length of the resistor 32 should be less than one-tenth of the shortest wave length to be encountered and most preferably less than one-twentieth thereof.

While a true wedge shaped cavity 20 as shown in FIG. 3 gives excellent results for the termination device 10, other cavity configurations approximating a wedge can be employed within the scope of the present invention. Thus, in FIG. 4 the device 10' is modified only with respect to the shape of the cavity 20'. The cavity 20', although approximating a wedge shape, is not a true wedge as is the cavity 20 of FIG. 3. Specifically, the upper surface 22' and the lower surface 24' of the cavity 20' are slightly arcuate rather than planar, as was true in the FIG. 3 construction. Such a modification may at times be useful for providing corrections for ground plane spacing as when taking into account line impedance errors due to fringing capacitance.

Referring now to FIG. 5, another modified form of a substantially wedge shaped cavity is shown in the termination device 10". This cavity, herein designated 20'', is wedge shaped but only along the effective length of the resistor 32 as above described. The remainder of the cavity is substantially rectangular in cross section. Thus, the upper wall 22" is made of two portions 22''a and 22''b, the first of which is substantially parallel to the upper surface 16 of the body 12 and the second of which, the portion 22''b, extends outwardly to the peripheral surface. Likewise, the lower surface 24"' has two portions 24''a and 24''b, the first of which is substantially parallel to the surface 16 and the second of which extends outwardly at an angle therewith. It is only the portions 22''b and 24''b which provide the actual wedge shape of cavity effect, the remainder of the cavity being substantially rectangular as previously stated. In constructing such a cavity 20'', it is desirable for the portions 22''a and 24''a to be as close to the upper and lower surfaces 14 and 16, respectively, as manufacturing procedures will allow.

Other modified wedge shaped cavities 20 will readily suggest themselves to those skilled in the art. However, irrespective of the precise configuration of the cavities 20, it is necessary for the cavity to have a general substantially wedge shape in order to conform to the teaching of the present invention.

As previously mentioned in this description, the principle of maintaining a matched impedance between line and resistor to ground along the entire path of a resistive stripline microwave circuit can be employed in resistive devices other than termination devices. An example of another application of this principle is shown in FIGS. 6 through 9. FIG. 9 is a side view of the stripline microwave circuitry is illustrated. A T-pad attenuator is normally connected into a stripline circuit to limit the amount of energy being conducted along the circuit. While an ordinary resistor could perform such a function, it will be obvious that the interposition of an ordinary resistor in such a circuit would range the line impedance of the circuit and thereby be completely unacceptable. Thus, what is normally done is to introduce into the circuit an attenuator which is adapted to shunt excess energy off to ground without significantly changing the impedance of the stripline circuit. In prior art devices, while at relatively low frequency levels a T-pad attenuator would function well, at higher frequencies, due to a mismatch between line and ground impedance along the length of the attenuator, there would be significant reflected energy, which would give rise to a standing wave and hence destroy the operating quality of the circuit. In the present invention the tendency to reflect significant amounts of energy which might give rise to the standing wave is reduced by utilizing the technique previously described for maintaining a constant impedance match along the length of the resistor by the shaping of a cavity in a grounded conductive body through which the attenuator resistor passes.

The T-pad attenuator shown in FIGS. 6 through 9 is generally designated by the reference numeral 110 and includes a conductive body 112. The body 112 is prefer-
ably metallic and may be made of any suitable conductive metal such as brass, aluminum, copper and the like. The conductive body 112 has an upper ground surface 114, a lower ground surface 116 and a peripheral side wall 118, here shown to be square in configuration. Metallic body 112 has within it a cavity 120 having a straight through cavity portion 121 and a dead ended portion 123 perpendicular thereto. Disposed within the straight through cavity portion 121 is a flat series resistor 125 which is preferably constructed in the same manner as resistor 120 above described. That is, the resistor has a ceramic base on which is vapor deposited a conductive material the thickness of which is carefully controlled to yield desired resistance. The width is substantially equal to that of the external stripline circuitry. As shown herein, the flat series resistor 125 is actually made of two flat abutting resistor portions 125a and 125b which are joined together by a strip of contact material such as copper 127. Each end of resistor 125 is connected in electrically conducting relation to a conductive tab 134 which is preferably tinned to facilitate its connection with the stripline of the microwave circuitry.

As may be seen in FIG. 8, the cavity portion 121 of cavity 120 is made up of two wedge shaped portions 121a and 121b with the series resistor portions 125a and 125b disposed respectively therein and along the plane of symmetry of the two opposed wedges 121a and 121b. It will be noted that the form of the wedge shaped cavities 121a and 121b is similar to the form of cavity 20 in FIG. 5, although other forms of substantially wedge shaped cavities might be employed in accordance with the present invention. This wedge shaped configuration especially along the effective lengths of resistor portions 125a and 125b yields a constant match between the impedance and the impedance from resistor to ground along the entire length of the resistor portions. In addition, a flat shunt resistor is provided to shunt excess energy from the resistor 125 to the grounded conductive body 112 of the attenuation device. This shunt resistor is designated by the reference numeral 130 and is of substantially the same width as the stripline circuitry and extends from the series resistor portion 125 to electrical conductive connection with the conductive body 112 at the apex of the wedge shaped cavity portion 123. It will be noted that the shunt resistor 130 is also disposed along the plane of symmetry of the cavity 120 and especially of the cavity portion 123 thereof. Electrical connection to the straight through series resistor portion 125 is shown to be effected by the conductive tab 127. With the shunt resistor 130 disposed along the line of symmetry of wedge shaped cavity 123 as above described, there will always be an impedance match between the line impedance and the resistance to ground along the shunt resistor 130 to thereby greatly reduce any tendency to set up a standing wave. As may be seen in FIGS. 7 and 8, the entire portion of cavity 120 unoccupied by the resistors or connective members is filled with a dielectric material of the same type as the dielectric material 36 above described. This dielectric material is herein designated by the reference numeral 136.

While the manner of fabricating a cavity 120 may be left to anyone skilled in the art, as shown herein the cavity portion 121 is constructed by machining out from the two oppositely wedge shaped portions 121a and 121b, and a portion of this machining may be accomplished by coming in through the surface extending parallel to the line of extent of said cavity 121, namely through the surface 135 (FIG. 6). Moreover, the opening 137 in surface 135 may be enlarged as illustrated to form rectangular cavity section 123 extending perpendicular to the cavity portion 121 above discussed.

It will be obvious that the cavity 120 could be modified in accordance with the teachings of FIGS. 3 and 4 above and need not be constructed in accordance with FIG. 5 above. That is to say, the tapering of the wedge shaped portions 121a and 121b could commence at the left and right hand sides of the cavity portion 121 as viewed in FIG. 8 and could join at an apex which is central of the cavity rather than have the planar or non-tapering portions in the area of non-effective resistance. Alternatively, the tapering surfaces need not be flat but could be arcuate as suggested above with regard to FIG. 4.

It is also obvious that having had the above invention relating to stripline resistive devices described in connection with a termination device and a T-pad attenuation device, other stripline resistive devices wherein the matching of line impedance along the resistor with the impedance to ground is important may be designed within the scope of the present invention. For example, power splitting resistors and pad attenuators could readily be designed in accordance with the teachings of the present invention.

While I have herein shown and described several forms of the present invention and have suggested modifications thereof, other changes and modifications within the scope of the appended claims without departing from the spirit and scope of this invention.

What I claim is:

1. A resistive device for a line of stripline microwave circuitry, comprising a conductive body having top and bottom surfaces and a peripheral side wall, said conductive body having a substantially wedge shaped cavity extending in from said peripheral side wall, said cavity being of maximum thickness at said peripheral side wall and being symmetrical with respect to a plane including the apex of said wedge shaped cavity, a flat resistor disposed wholly within said cavity along said plane and being connected at one end to said conductive body in electrically conducting relation at the apex of said cavity, and means for connecting the other end of said resistor in electrically conducting relationship with stripline circuitry external of said device, the effective length of said resistor being shorter than one-quarter of the shortest wave length in the operating frequency range thereof.

2. The device of claim 1, wherein said device is a termination device which further comprises dielectric material in said cavity for holding said resistor in said cavity along said plane.

3. The device of claim 2 wherein the effective length of said resistor is shorter than one-tenth of the shortest wave length in the operating frequency range thereof.

4. The device of claim 2, wherein the resistance of said resistor is substantially equal to the impedance of said line.

5. An attenuation device for stripline microwave circuitry, comprising a conductive body having upper and lower surfaces and a peripheral side wall, said conductive body having a cavity therein, said cavity having a first longitudinal portion intersecting said peripheral side wall at two distinct areas, said first cavity portion having two substantially wedge shaped parts with the maximum widths thereof at said areas of intersection with said peripheral side wall, said cavity having a second portion perpendicular to and in intersecting relation with the first and having one end terminating within said conductive body, the part of said second portion extending between said first portion and said one end being substantially wedge shaped cavities, a first flat resistor disposed within said first cavity portion along said plane of symmetry, a second flat resistor disposed within said second cavity portion along said plane of symmetry, said second resistor having one end connected to the apex of the wedge shaped cavity portion 123 extending perpendicular to the cavity portion 121 above discussed.
flat electrically conductive member connected to one end of said first resistor and extending out of said conductive body through one end of said first cavity portion, another flat electrically conductive member connected to the other end of said first resistor and extending out of said conductive body through the other end of said first cavity portion, the effective length of each of said two resistors being shorter than one-quarter of the shortest wavelength in the operating frequency range thereof.

6. The attenuation device of claim 5, wherein said first flat resistor includes two separate resistive parts, and conductive means for electrically connecting said two parts, said last mentioned means further being for connecting said first resistor to said second resistor.

7. The attenuation device of claim 6, wherein said two resistor parts and said second resistor all have effective lengths shorter than one-tenth of the shortest wavelength in the operating frequency range of said device.

References Cited
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