Nov. 21, 1967 M. STEIDLITZ 3,354,412

STRIPLINE TERMINATION DEVICE HAVING A RESISTOR THAT IS SHORTER THAN ONE QUARTER WAVELENGTH

Filed Nov. 1, 1965

FIG. 1.

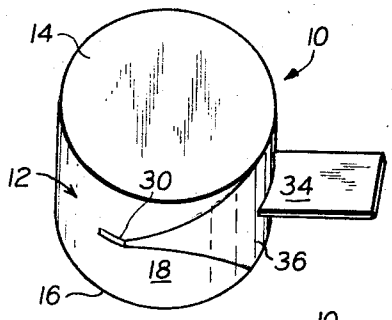



FIG. 2.

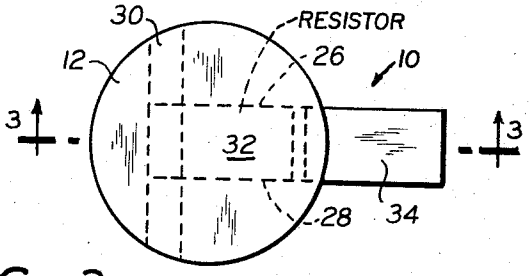



FIG. 3.

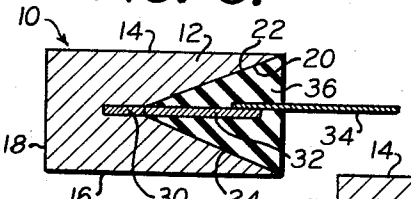



FIG. 4.

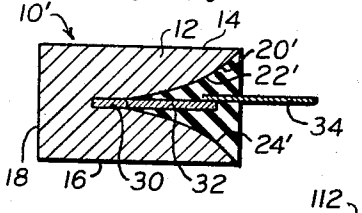



FIG. 5.

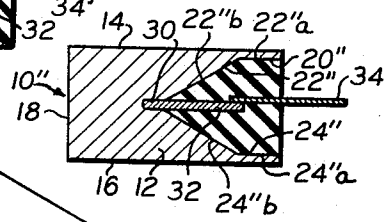



FIG. 6.

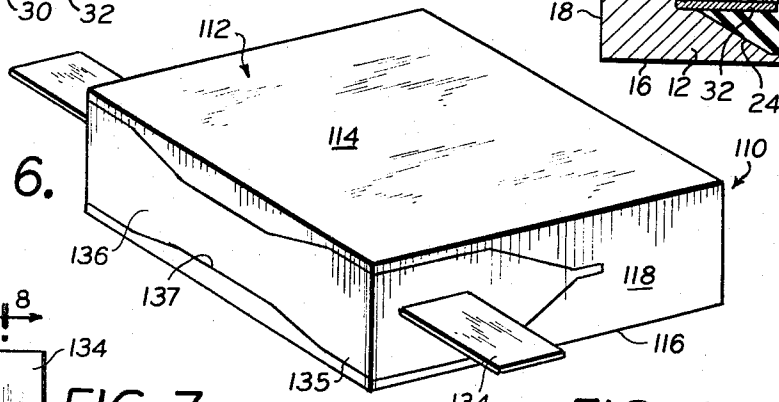



FIG. 7.

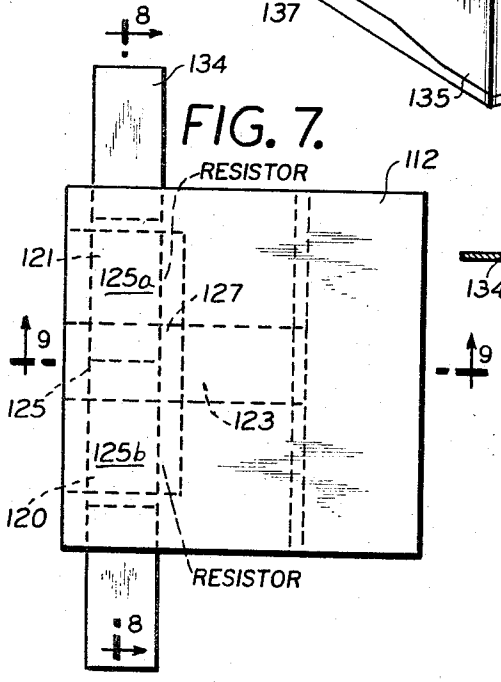



FIG. 8.

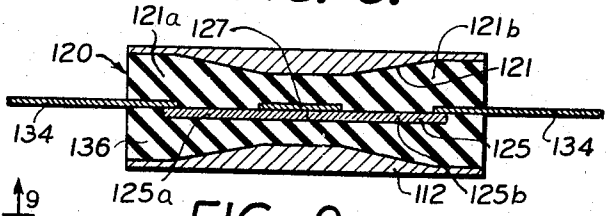
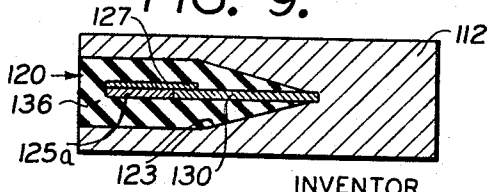



FIG. 9.




INVENTOR
MARK STEIDLITZ
BY Hubbell, Cohen, Stiefel & Fidler
ATTORNEYS.

United States Patent Office 3,354,412 Patented Nov. 21, 1967



3,354,412

# STRIPLINE TERMINATION DEVICE HAVING A RESISTOR THAT IS SHORTER THAN ONE QUARTER WAVELENGTH

Mark Steidlitz, Cherry Hill, N.J., assignor to EMC Technology, Inc., Philadelphia, Pa., a corporation of Pennsylvania

Filed Nov. 1, 1965, Ser. No. 505,779
7 Claims. (Cl. 333—22)

This invention relates to a resistive device for microwave circuitry and particularly to a termination device for a microwave stripline transmission line. Most particularly, the present invention relates to a termination device for stripline microwave circuitry having broad band characteristics. The present invention also has applications as a general resistive device in stripline circuitry such as, for example, T-pad and $\pi$-pad attenuators, as well as power splitting resistors and so forth.

In microwave circuitry it is necessary for any resistors interposed therein to match the resistance in the line with the nominal impedance of the line, the nominal impedance being determined by the physical dimensions of the line, the ground plane spacing, and the dielectric constant of the material on which the transmission line is mounted. If there is any serious mismatch between the resistance in the line and the impedance in the line, there normally results a reflected energy wave which destroys the transmitting characteristics of the line. Thus, the match of resistance and impedance is necessary to obtain a low voltage standing wave ratio (VSWR) across a broad band. Termination resistors and other microwave resistors in coaxial microwave circuitry have been designed to yield low VSWR across a broad band. However, for stripline microwave circuitry this has not been the case prior to the present invention. As a matter of fact, it is often necessary to interpose an adaptor 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 10 gc. The desirable matching characteristic 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 a further 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 adjacent the end closest to the peripheral wall **18** of the body **12***a* 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 relationships along the plane of symmetry 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 beryllia 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 fabricated resistor gives easier handling properties for fabricating the termination device **10**. When using a vapor deposited resistor, it is generally preferable to take a flat ceramic base, deposite 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 into 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 **14** of the body **12** and the second of which, the portion **22''***b*, extends at an angle away from that 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 upwardly at an angle therefrom. 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 resistor 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, wherein a T-pad attenuator for 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 change 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 frequency, 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 a standing wave is greatly 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 **32** above described. That is, the resistor **125** 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 **125***a* and **125***b* 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 best be seen in FIG. 8, the cavity portion **121** of cavity **120** is made up of two wedge shaped portions **121***a* and **121***b* with the series resistor portions **125***a* and **125***b* disposed respectively therein and along the plane of symmetry of the two opposed wedges **121***a* and **121***b*. It will be noted that the form of the wedge shaped cavities **121***a* and **121***b* 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 **125***a* and **125***b* yields a constant match between the line 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 impedance 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 sides thereof the two separate wedge shaped portions **121***a* and **121***b*, 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 facilitate the access for machining the wedge shaped cavity portion **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 **121***a* and **121***b* could commence at the left and right hand ends 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 $\pi$ 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 therein, other changes and modifications may be made therein 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, said cavity being symmetrical about a plane including the apexes of said two 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 part of said second cavity portion in electrically conductive relation with said conductive body, means for connecting the other end of said second flat resistor in electrically conducting relation with the center of said first resistor, a

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 wave length 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 wave length in the operating frequency range of said device.

**References Cited**

UNITED STATES PATENTS

| | | | |
|---|---|---|---|
| 3,174,123 | 3/1965 | Frederico | 333—22 X |
| 3,213,392 | 10/1965 | Hedberg | 333—22 |

ELI LIEBERMAN, *Primary Examiner.*

HERMAN KARL SAALBACH, *Examiner.*

P.L. GENSLER, *Assistant Examiner.*