PLANAR R. F. LOAD RESISTOR FOR MICROSTRIP OR STRIPLINE

A planar film RF load resistor useful, in some instances, from dc up into the microwave frequency range and, in other instances, particularly useful through broadband ranges in the microwave frequency spectrum range. It is a planar thin (or thick) film RF load resistor having a smaller radius edge in conductive contact with a like shaped radius edge of an RF signal thin (or thick) film conductor, and a larger radius outer edge in conductive contact with a highly conductive film plate. The radius centers are substantially the same for the planar film RF load resistors with both microstrip and stripline units.

10 Claims, 8 Drawing Figures
FIG. 6

FIG. 7

FIG. 8
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1. PLANAR R. F. LOAD RESISTOR FOR MICROSTRIP OR STRIPLINE

This invention relates in general to load resistors and, in particular, to a planar RF load resistor particularly useful in the microwave frequency range.

Reflection loss absorption of RF energy can be difficult to attain with, in transmission lines, many different methods being used to terminate a line in its characteristic impedance depending on the type of line. In waveguide, for example, a wedge shaped lossy material similar to that used in anechoic walls is commonly used. With coaxial transmission line an intervening disc of resistive material is in common usage, and with open wire lines, used at lower frequencies, a single cylindrical resistor is generally adequate. In stripline a balanced double sided "pall" load is used but, heretofore, there have been few if any broadband, effective microwave load resistors for microstrip available. One approach when a broadband load was needed has been to construct a microstrip-to-coaxial line transition used with a coaxial line load. Expense is a factor with such transmission line terminations particularly with configurations having a low VSWR through their operational range of frequencies.

Microstrip ungrounded tapered resistors have been found to be somewhat restricted in useful frequency range while grounded tapered resistors have higher VSWR than desired and also, an inherent hot spot. Simple grounded square resistors have too high a VSWR. Further, with tapered resistors one-quarter wavelength long at a pre-chosen center frequency, the VSWR quickly goes up to unusable values with frequency variation to any material degree from the design center.

It is, therefore, a principal object of this invention to provide planar RF load resistors having low VSWR through a broad range in the microwave frequency range.

Another object is to provide planar transmission line planar RF load resistor terminations of even power distribution.

A further object is to provide such planar RF load resistor transmission line terminations that while highly reliable are relatively low cost units.

Features of the invention useful in accomplishing the above objects include, in planar RF load resistors for microstrip and stripline, a planar transmission line having a substantially semicircular termination end and a planar resist material section in conductive contact with substantially the entire peripheral edge of the transmission line semicircular termination end. The planar resist material section has an outer substantially semicircular edge having a radius center substantially common to the radius center of the transmission line semicircular end and with the resist material section outer semicircular edge in conductive contact with a planar conductive material plate that may be electrically connected to a ground plane plate.

Specific embodiments representing what are presently regarded as the best modes of carrying out the invention are illustrated in the accompanying drawings.

In the drawings:

FIG. 1 represents a portion of microstrip circuitry with a conductive film transmission line terminated by a planar RF load resistor in outer peripheral contact with a conductive plate;

FIG. 2, a partial side elevation view of the microstrip transmission line end termination of FIG. 1;

FIG. 3, a microstrip transmission line end termination quite similar to that of FIG. 1 with, however, additional resist material added for greater transmission line to load resistor contact;

FIG. 4, a differential element of a film resistor such as that of FIG. 1 useful in determining the resistance value for a film resistor of that geometry and with an included angle θ greater or lesser than the 180° angle shown;

FIG. 5, a perspective view of such a transmission line resistor termination in stripline;

FIG. 6, a cutaway and sectioned side elevation view of the transmission line terminating resistor assembly of FIG. 7;

FIG. 7, a top plan view of a 50 watt load transmission line terminating resistor mounted in a case with the top removed; and

FIG. 8, a VSWR to frequency in GHz diagram for the transmission line terminating resistor configuration of FIGS. 6 and 7.

Referring to the drawings:

The microstrip section 10 of FIGS. 1 and 2 is shown to include a thin film RF conductor 11 positioned on a relatively high dielectric constant ceramic material substrate 12. The thin film RF conductor 11 is shown to have a semicircular terminal end 13 with a radius r1 that is in conductive contact with a resistive film 14 having an interior radius peripheral edge with a radius r2 the same as the radius of the end 13 of the RF conductor 11 and an outer radius r2 peripheral edge 15 that is in conductive contact with a metal plate 16. Although the conductive metal plate 16 deposited on substrate 12 is shown to have an extension 17 around the edge of substrate 12 to conductive contact with conductive material ground plane plate 18 on the bottom of the substrate 12, as shown in FIG. 2, the conductive metal plate 16 could in some installations be a plate of a capacitor to in effect give an RF path to ground or other circuitry as may be required. Further, while the planar film RF load resistor 14 is shown as being semicircular with a θ included angle of 180° this included angle may be varied either to a greater θ included angle or lesser angle in meeting various design objectives.

FIG. 3 is another embodiment very similar to the embodiment of FIG. 1 that includes a substantially semicircular resistor 14' with additional resistive material film added at each end to provide additional conductor 11' to resistor 14' conductive contact along sides of RF conductor 11' for a short distance from the semicircular end 13'. It should be noted that any one of the elements, shown with any of the various transmission line end RF load resistor termination embodiments, or all of the planar components supported by a substrate may be constructed using either thin or thick film techniques.

With reference to the differential element showing of FIG. 4 and the resistance of a film resistor, consistent with geometry such as shown in FIG. 1, would be substantially in accord with the following:

The parameters of the problem are:

r1 radius of conductor end
r2 radius of film resistor edge
θ included angle of resistor
ρ (sheet) resistivity of resistor
r radius variable in polar coordinates
θ angle variable in polar coordinates
R resistance to be found

Define a differential resistance element as in FIG. 4.

Remembering the formula for resistance of a square element:

\[ R = \rho (dr \times d\theta) \]

The resistance of the differential element is found to be:

\[ \rho (dr \times d\theta) \]

Integrating over θ from r1 to r2, we have the resistance of a differential wedge:

\[ dr = \int_{r1}^{r2} \frac{dr}{\rho r \times d\theta} \]

These differential wedges combine in parallel to form the resistance R.

Integrating conductance one obtains

\[ \frac{1}{R} = \frac{1}{\int_{r1}^{r2} \rho d\theta} \]

Now ρ is uniform over the deposited area and therefore not a function of r or θ. Likewise, r and θ are independent variables.
So:
\[ \frac{1}{\rho} = \frac{1}{R} \theta_i \int \frac{d\theta}{r_i} \]
\[ r_1 \int \frac{dr}{r} \]
\[ \frac{1}{\theta_i - \theta_1} = \frac{1}{\rho \ln r_i - \ln r_i} \]
Since \( \theta_i - \theta_1 \neq 0 \),
\[ \frac{1}{\theta_i} = In \frac{r_i}{r_i} \]
\[ R = \frac{\rho}{\ln r_i - \theta_i} \]
\[ \text{in our particular case, } R = 50 \Omega, \theta_1 = 100 \text{ m}, r_1 = 12.5 \text{ mls} \]

These mathematical relationships are substantially the same with the embodiment of FIG. 3 with only slight variation in view of the extra planar resist material extension at both ends of the resistor 14'. Obviously, variations induced with the extra resistive film material of the FIG. 3 embodiment from that of FIG. 1 would be of less consequence where the circuitry film elements are deposited on a high dielectric constant substrate such as a dense ceramic having a dielectric constant falling in the range of from, for example, 9 through 11 as opposed to a substrate like polyethylene having a much lower dielectric constant falling in the range of approximately 2.

Such planar RF load resistors are also quite applicable to stripline circuitry such as illustrated by FIG. 5. This includes a planar conductor 11" positioned between dielectric volumes 19 and 20 that in some instances would be air but generally speaking would be of like dielectric solid material chosen to meet particular design objective requirements. This is with planar semiconductor resistor 14" interconnected the semicircular end 13" and the semicircular 21 radius edge 21 of ground plane conductive plate 16" that is shown to be connected with outside ground plane conductive plates 22 and 23 by through interconnecting electrically conductive material pins 24.

Referring now to the microstrip embodiment of FIGS. 6 and 7 a rectangular section of microstrip 10' similar in many respects to the microstrip section 10 of FIGS. 1 and 2 and has the same \( r_1 \) and \( r_2 \) and \( \theta \) included angle relationships as with the embodiment of FIGS. 1 and 2. With this embodiment the thin film transmission line 11 extends from one edge of the rectangular ceramic substrate section 12 to the semicircle edge 13 end in conductive contact with the resistive film 14.

The microstrip section 10' enclosed within a hermetically sealed conductive material connector box 25 having a lid 26 fastened to the top of the connector box 25 by conventional means, not shown, to enclose an internal rectangular opening and the microstrip section 10' positioned therein with the ground plane plate 18 side thereof in contact with opening bottom surface 27. A hermetically sealed coaxial threaded connector element 28 of conventional construction is threaded 29 into the connector case 25 with a center coaxial conductive rod 30 projecting through case opening 31 to RF signal conductive contact with thin film transmission line 11. After the connector 28 is completely threaded into position in the box housing 25 the coaxial rod lead 30 is soldered or brazed to the thin (or thick) film transmission line 11 to insure a good RF connection between the rod 30 and the transmission line 11 before lid 26 is fastened in place on the box housing 25.

With a load resistor unit such as shown in FIGS. 6 and 7 designed for operation up through 1.1 GHz,
tion from the exterior to the interior of said box with a coaxial connector center conductor RF signal path connected to said planar RF signal line.

9. The RF load resistor circuit unit of claim 1, wherein said unit is a stripline unit.

10. The RF load resistor circuit unit of claim 9, wherein two opposite outside ground plane plates are provided on the outside of two dielectric material sheets sandwich enclosing said coplanar circuit elements in stripline relation; and conductive interconnect means interconnecting said planar conductive material plate and the two opposite outside ground plane plates.

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