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(12) # EUROPEAN PATENT APPLICATION

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(54) **Radio frequency load resistor.**

(57) Radio frequency load resistor for terminating a coaxial cable without reflection comprising a center conductor (28) of uniform radius and an outer conductor (32) having a radius which gradually decreases from the input (12) to the same radius as the center conductor (28); the outer conductor (32) has a resistance provided by a thin film (50) of resistive material thereon; the radius of the outer conductor (32) and the resistance as a function of distance along the axis are correlated so that this load resistor produces minimal reflected energy, the RF energy being absorbed by the resistive film on the outer conductor (32) with the heat produced thereby being readily dissipated into the surrounding medium.

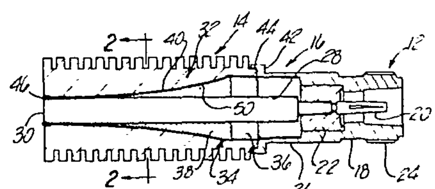

Fig-1

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Radio frequency load resistor

This invention relates to a radio frequency load resistor for terminating a radio frequency transmission line, this load resistor comprising an input adapted to be connected with a coaxial cable, a center conductor extending from this input and terminating in a free end, and an outer conductor extending from the input to a juncture with the center conductor, the ratio of the radius of the outer conductor to the radius of the center conductor varying inversely with the distance from the input.

Radio frequency (RF) load resistors are commonly used to absorb the power output of a transmission line. Such a device is used to replace the transmitting antenna in circumstances where radiated power would be undesirable, for example during a tuning operation. Such loads may be required to absorb power ranging from a few watts to several hundred watts. Further, radio frequency load resistors are sometimes required to have a voltage standing wave ratio of relatively low value of about 1.10 or less.

In the prior art, RF load resistors have been used which include a resistive center conductor for dissipating the RF energy. An outer conductor of conical shape provides the desired impedance characteristic and also serves as a medium through which the heat energy is dissipated. A heat sink comprising an oil filled can with external fins is disposed over the conical outer conductor. This arrangement relies upon heat transfer from the resistive center conductor by convection and conduction through an air or oil dielectric to the heat sink. This imposes a limit on the cooling capacity for the load resistor. This device is of relatively complex structure which requires numerous parts.

The present invention overcomes the disadvantages and limitations of the prior art radio frequency load resistors by providing a radio frequency load resistor, for terminating a radio frequency transmission line, which comprises: an input adapted to be connected with a coaxial cable; a center conductor extending from this input and terminating in a free end; and an outer conductor extending from the input to a juncture with the center conductor, the ratio of the radius of the outer conductor to the radius of the center conductor varying inversely with the distance from the input, the outer conductor having a higher resistance than the center conductor, and the value of this ratio and the value of this resistance being correlated so that the impedance of this load resistor is matched to the impedance of the coaxial cable.

In accordance with the invention, an RF load resistor is provided which exhibits a wide bandwidth with a low voltage standing wave ratio and is capable of absorbing high power. It is also of simple construction with few parts.

The manner of carrying out the invention is described in detail below with reference to the accompanying drawings which illustrate two specific embodiments, in which:

FIGURE 1 shows one embodiment of the RF load resistor of this invention in a cross-sectional view;

FIGURE 2 is a view taken on lines 2-2 of FIGURE 1; and

FIGURE 3 shows another embodiment of the RF load resistor of this invention.

Referring now to the drawings, there is shown illustrative embodiments of an RF load resistor for a coaxial cable according to the invention.

A termination for a non-resonant line which will absorb transmitted power without reflection requires a resistive load having an input impedance equal to the characteristic impedance of the line. A coaxial cable having a characteristic impedance of 50 ohms, for example, may be terminated with a 50 ohm resistor connected across its output end and the transmitted power will be dissipated in the resistor with a minimum of reflection. In order to provide such a termination it is necessary to couple the load resistor to the coaxial cable in such a way that the load resistor itself has an input impedance equal to the characteristic impedance of the cable.

Before proceeding with a detailed description of the device of this invention, it will be helpful to consider certain relationships regarding transmission line impedance. A concentric line or coaxial cable has a characteristic impedance which may be expressed as follows:

$$Z_o = \frac{\sqrt{\mu / \epsilon_o}}{2\pi} \ln \frac{r_2}{r_1} \qquad (1)$$

Where:

μ = permeability of free space
ϵ_o = permittivity of free space
r_2 = inner radius of outer conductor, and
r_1 = radius of center conductor .

For convenience, the constant terms may be combined and represented by k so that the characteristic impedance may be expressed as:

$$Z_o = k \ln \frac{r_2}{r_1} \qquad (2)$$

The impedance of a coaxial line is, of course, significantly increased by inserting a resistor in the line. This can be done by inserting a section of line which has the outer conductor made up of a dielectric substrate having a layer of resistive material thereon to provide a "lumped" resistance. A conductor comprising a resistive film on the surface of a dielectric substrate will have a resistance value:

$$R = \frac{\rho d}{A} \qquad (3)$$

Where:

ρ = resistivity of the film material
d = length along the axis, and
A = cross-sectional area of the film.

A load resistor may be constructed so that it will have an input impedance equal to the characteristic impedance of a coaxial line by correlating the change of lumped resistance along the line with the change of distributed impedance along the line. For this purpose, at every increment of distance along the line, the cumulative lumped resistance should be offset by the cumulative reduction of distributed impedance of the line. This can be realized by making:

$$\frac{dZ}{dx} = -\frac{dR}{dx} \qquad (4)$$

Where:

$Z = k \ln\frac{r_2}{r_1}$ = distributed impedance

$R = \frac{\rho d}{A}$ = lumped resistance, and

x = distance along the axis of the resistor from the input end.

In general, according to this invention, a load resistor has a distributed impedance which is decreased gradually along the line while the cumulative lumped resistance is increased gradually along the line. Accordingly, the ratio of the inner radius of the outer conductor to the radius of the center conductor decreases along the line according to a predetermined function and the cumulative lumped resistance increases according to a predetermined function, the functions being correlated in such a manner that reflection of energy by the resistor is minimized.

In a first embodiment of this invention, the radius of the center conductor is uniform along the line and the radius of the outer conductor decreases according to an exponential function of distance along the line. The particular function is derived from equation (2) and (4) to obtain:

$$Z = k \ln\frac{r_2}{r_1} \qquad (2)$$

and, $$r_2 = r_1 e^{\frac{Z(d-k)}{dk}} \qquad (5)$$

Where:

e = base of natural logarithms

Z = characteristic impedance of the line being terminated

d = length of resistive element, and

k = a constant of proportionality.

With a radius r_2 for the outer conductor, as given in equation (5), the cumulative value of lumped resistance must increase linearly with distance along the line. From inspection of equation (3) it will be seen that:

$$\frac{R}{d} = \frac{\rho}{A} \qquad (6)$$

which shows that resistance per unit length is constant if the cross-sectional area A is constant. For a thin film on the inner surface of a cylinder, the cross-sectional area of the film on a cylinder of radius r is approximately:

$$A = 2\pi\ rt \qquad (7)$$

Thus the area A will be constant along the line if the product of the radius r and film thickness t is constant. This relationship of film thickness and radius is obtained by depositing the thin film by sputtering the film material from a wire coaxially disposed within an outer conductor having a radius which varies according to equation (5). From equation (7), it will be seen that the thickness of the film is given by:

$$t = \frac{A}{2\pi r} \qquad (8)$$

Thus, where the cross-sectional area A is held constant, the thickness of the film varies inversely with the inner radius of the outer conductor.

In a second embodiment of the invention, the radius of the center conductor is uniform along the line and the radius of the outer conductor decreases according to a linear function of distance along the line. With the radius increasing linearly, the cumulative value of lumped resistance must increase according to a predetermined function. That function is satisfied by a uniform thickness of the resistive material. This can be provided by a tumbling operation to coat the outer conductor with a resistive material such as carbon particles.

Referring now to FIGURE 1, a first preferred embodiment of the RF load resistor is shown. The load resistor comprises, in general, a coaxial input 12 and a load resistor 14. The input 12 is adapted to be connected with the output end of the coaxial cable (not shown) which is fed from an RF generator. The power supplied by the coaxial cable to the input 12 is to be dissipated in the load resistor 14.

The input 12 includes a conventional coaxial cable connector member comprising an outer metal sleeve or terminal 18 and a center metal pin or terminal 20. The sleeve 18 contains a dielectric body 22, such as Teflon, which supports the center pin 20 coaxially of the sleeve 18. Additionally, the sleeve 18 is provided with a screw thread 24 for mating engagement with the associated connector member on the end of a coaxial cable.

The input 12 also includes a transition section or adapter 16 for the purpose of adapting the coaxial cable to the input of the load resistor 14. The adapter 16 increases the sizes of the conductors with a minimum of discontinuity in the impedance of the line. The adapter 16 comprises an outer conductor or sleeve 26 which is an integral extension of the sleeve 18, with an increased inside diameter. A center conductor 28, which is larger than the pin 20, extends from an integral connection with the pin and terminates in a free end 30. The conductor 28 is the center conductor for both the transition section or adapter 16 and the load resistor 14. The center conductor 28 is a cylindrical metal rod of uniform diameter.

The load resistor comprises a portion of the center conductor 28 and an outer member 32 of dielectric material which is preferably a ceramic material such as alumina or berylia. The outer member 32 defines an axial bore 34 with an input section 36 of uniform diameter which is equal to that of sleeve 26. The axial bore 34 of the member 32 also includes an elongated horn-shaped load section 38. The load section 38 of the bore is of tapered diameter which gradually diminishes from the diameter of the input section 36 to the diameter of the center conductor 28 at the free end 30 thereof. The bore 34 is defined by an inner wall surface 40 which is a surface of revolution and hence has a circular transverse cross-section at all locations. As described subsequently, the wall surface 40 serves as a substrate for a thin layer of film 50 of resistive material.

The outer member 32 is mounted on the adapter 16 by a flange 42 which is secured to the member 32 by a solder ring 44. The free end 30 of the center conductor 28 is conductively connected with the outer member 32 by a solder ring 46.

A thin film 50 of resistive material is deposited on the inner surface of the load section 38 of the outer member 32. The inner surface 40 of the outer member 32 has a radius which is an exponential function of distance along the axis of the inner conductor 28. In particular, the radius of the inner surface 40 is given by equation (5) above. The film is suitably a metallic film, preferably gold, and has a thickness which gradually increases with decreasing diameter of the surface 40. The thickness of the film 50 is such that the resistance is a linear function of distance along the line in order to prevent reflection of energy from the load resistor. In particular, the thickness of the film is inversely proportional to the radius of the inner surface. As described above with reference to this first embodiment, this variation of film thickness may be obtained by sputtering of the metal onto the inner surface 40. For example, the thin film is suitably sputtered onto the inner surface from an axially disposed wire extending the length of the outer member 32.

The outer member 32, as shown in FIGURES 1 and 2, is generally cylindrical in its outline configuration. It is preferably a monolithic structure of ceramic material having good heat transfer properties. The outer member 32 includes a plurality of radially extending heat dissipating fins 52.

In operation of the load resistor shown in FIGURES 1 and 2, the radio frequency energy fed to the resistor is converted to heat energy in the resistive film 50.

The heat is transferred from the resistive film by conduction through the outer member 32 and is dissipated to the surrounding atmosphere or other medium through the fins 52. It is to be noted that in this embodiment of the invention the heat energy is uniformly distributed along the axis of the load section 38 of the resistor. This is obtained because the resistance is a linear function of distance along the axis and hence the power loss is uniformly distributed along the axis. This distribution of power loss is highly advantageous in heat transfer from the resistive film to the surrounding atmosphere.

A second embodiment of the invention is disclosed in FIGURE 3; in this embodiment all of the parts are the same as those in the embodiment of FIGURES 1 and 2 except for the ceramic member 32. Accordingly, the same parts in the embodiment of FIGURE 3 are designated with the same reference characters as used in FIGURE 1. The description given above with reference to FIGURES 1 and 2 is applicable to FIGURE 3 except for the outer member 32'. The difference between member 32' and member 32 is in the shape of the axial bore 34' in the load section 38' and the thickness of the resistive film 50'. As described above with reference to the second embodiment, the inner radius of the outer conductor, i.e. the surface 40' increases as a linear function of distance along the line. In this embodiment the film 50' of resistive material is of uniform thickness over the surface 40'. The film 50' of resistive material is suitably a layer of carbon particles which have been applied with uniform thickness. The operation of the embodiment of FIGURE 3 is the same as described above except that it does not have the advantage of uniform distribution of power loss along the axis of the load resistor.

Claims:

1. Radio frequency load resistor for terminating a radio frequency transmission line, said load resistor (14) comprising: an input (12) adapted to be connected with a coaxial cable; a center conductor (28) extending from said input (12) and terminating in a free end (30); and an outer conductor (32;32') extending from said input (12) to a juncture (46) with the center conductor (28), the ratio of the radius of the outer conductor (32;32') to the radius of the center conductor (28) varying inversely with the distance from said input (12); characterized in that the outer conductor (32;32') has a higher resistance than the center conductor (28), and the value of said ratio and the value of said resistance are correlated so that the impedance of said load resistor (14) is matched to the impedance of the coaxial cable.

2. Radio frequency load resistor as claimed in claim 1, characterized in that the center conductor (28) has a uniform radius from said input (12) to said juncture (46) and the outer conductor (32;32') has a radius which gradually decreases from said input (12) to said juncture (46).

3. Radio frequency load resistor as claimed in claim 2, characterized in that the outer conductor (32;32') comprises a dielectric substrate (32;32') with a film (50; 50') of resistive material on the inner surface thereof.

4. Radio frequency load resistor as claimed in claim 3, characterized in that the radius of the inner surface of the dielectric substrate (32) is an exponential function of the distance from said input (12).

5. Radio frequency load resistor as claimed in claim 4, characterized in that the resistive film (50) has a constant value of resistance per unit distance along the axis of the dielectric substrate (32).

6. Radio frequency load resistor as claimed in claim 5, characterized in that the resistive film (50) has a thickness which varies inversely as the radius of the inner surface of the dielectric substrate (32).

7. Radio frequency load resistor as claimed in

claim 3, characterized in that the radius of the inner surface of the dielectric substrate (32') is a linear function of the distance along the axis thereof from said input (12).

8. Radio frequency load resistor as claimed in claim 7, characterized in that the resistive film has an increasing value of resistance per unit distance along the axis of the dielectric substrate (32').

9. Radio frequency load resistor as claimed in claim 8, characterized in that the resistive film has a uniform thickness.

10. Radio frequency load resistor as claimed in claim 3, characterized in that the dielectric substrate (32; 32') is a body of ceramic material.

11. Radio frequency load resistor as claimed in claim 10, characterized in that said body of ceramic material includes heat dissipating fins (52) thereon.

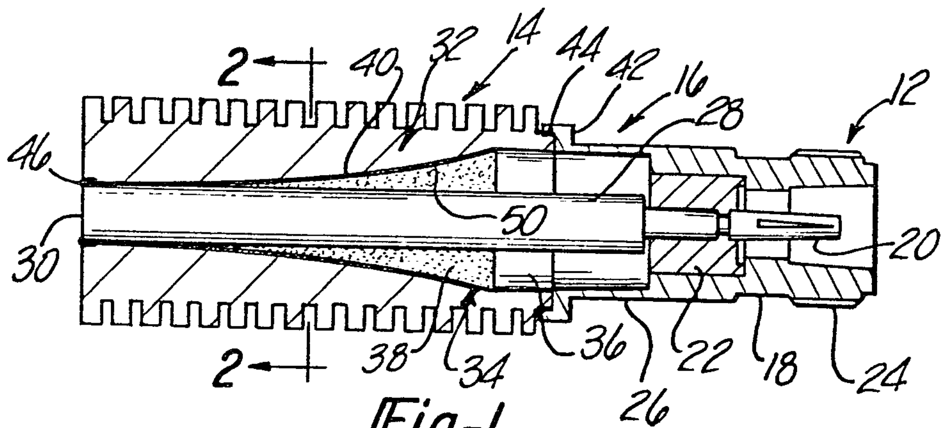

Fig-1

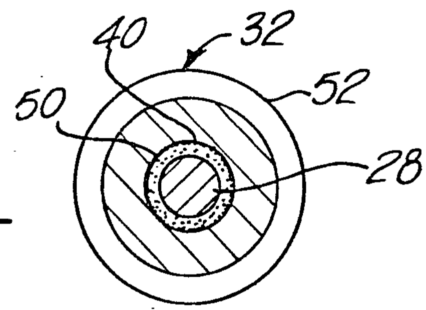

Fig-2

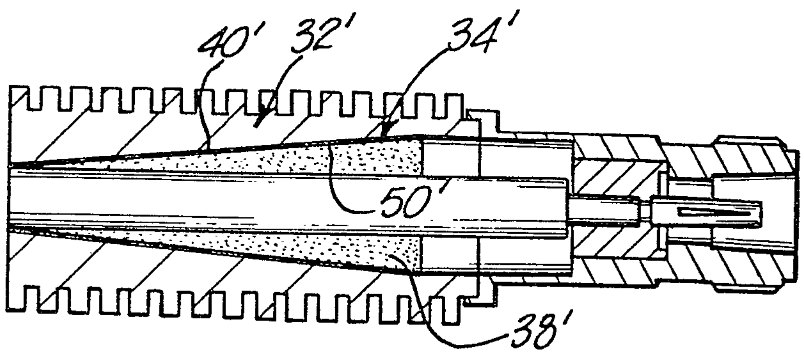

Fig-3

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EUROPEAN SEARCH REPORT

Application number
EP 80 40 073[illegible]

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim
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X	US - A - 3 309 634 (H.A. WHEELER et al.) * The whole document *	1,5,9, 11
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A	US - A - 3 296 559 (R.Q. MAINES) * The whole document *	1,3, 10,11

CLASSIFICATION OF THE APPLICATION (Int Cl.[3])

H 01 P 1/26

TECHNICAL FIELDS SEARCHED (Int. Cl.[3])

H 01 P 1/26

CATEGORY OF CITED DOCUMENTS

- X: particularly relevant
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- E: conflicting application
- D: document cited in the application
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X The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	07-11-1980	LAUGEL

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EUROPEAN SEARCH REPORT

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DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim
A	FR - A - 1 199 085 (ETABLISSEMENTS GEFFROY & CIE "FERISOL") * The whole document * --	1,2, 4,7
A	FR - A - 2 360 184 (WILHELM SIHN Jr. KG) * The whole document * ----	1,2,4, 10,11

CLASSIFICATION OF THE APPLICATION (Int. Cl. 3)

TECHNICAL FIELDS SEARCHED (Int. Cl. 3)