

### [54] TERMINATIONS

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### Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 189,913, Oct. 18, 1971, abandoned.

[52] U.S. Cl. .... **333/22 F, 333/22 R, 333/81 B**

[51] Int. Cl. .... **H01p 1/26**

[58] Field of Search .... **333/22 R, 22 F, 81**

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pages 312-314

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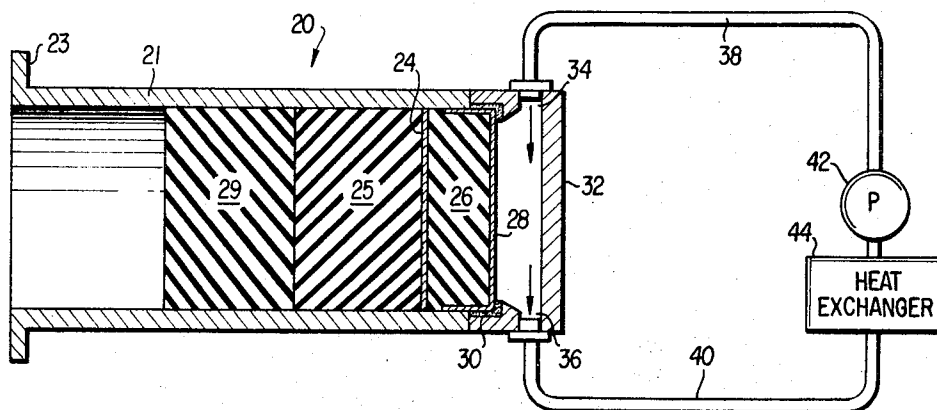
*Attorney, Agent, or Firm*—J. B. Hinson

[57]

### ABSTRACT

A termination for terminating or absorbing a signal transmitted through a transmission line is disclosed as comprising a transmission line having a short circuit thereacross and a thin film of a resistive material disposed within the transmission line approximately one-fourth of a wavelength of the transmitted signal from the short circuit to thereby absorb the signal energy. More specifically, the ratio of the bulk resistivity of the thin film to the thickness of the thin film is selected to be substantially equal to the characteristic impedance of the transmission line thereby ensuring substantially complete energy absorption of the transmitted signal. The thin film is disposed upon a thermally conductive member made of an illustrative material such as beryllium oxide and which not only exhibits a high conductivity but also presents low losses to signals transmitted therethrough. In order to more efficiently dissipate the generated thermal energy, a suitable fluid coolant such as air or water may be directed past the short circuit.

**3 Claims, 2 Drawing Figures**



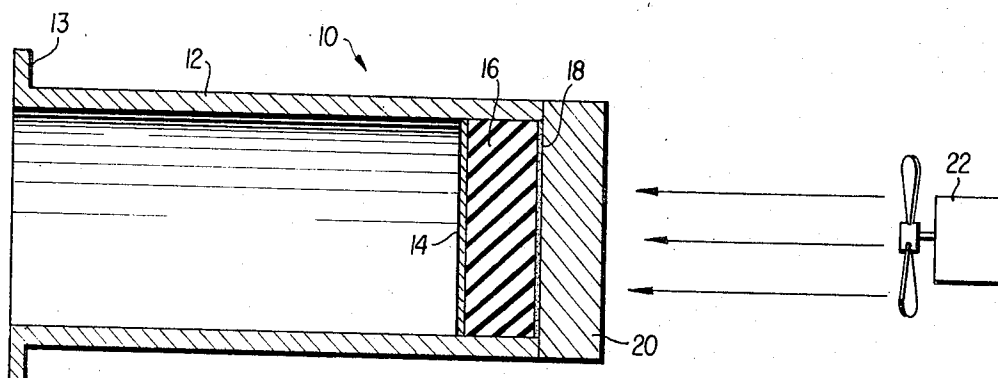


FIG. 1

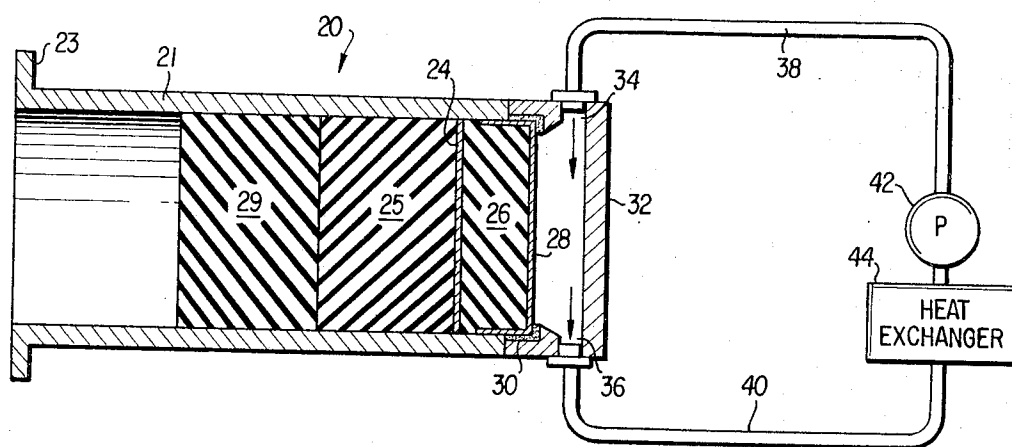


FIG. 2

## TERMINATIONS

This Application is a Continuation-in-Part Application Ser. No. 189,913, filed Oct. 18, 1971, now abandoned.

## BACKGROUND OF THE INVENTION

## 1. Field of the Invention

This invention relates to terminations for transmission lines and in particular to such terminations of reduced size and weight.

## 2. Description of the Prior Art

In radar and transmission systems, there arises the need to terminate transmission lines to prevent reflected or standing waves to be established therein. Microwave terminations or dummy loads of the prior art typically employ the use of lossy materials presenting distributed loads along the transmission line for gradual power absorption and impedance matching. Such devices are typically employed for terminating transmission lines carrying rf average power in the range of 10 to 1,000 watts. Materials such as graphite and iron loaded epoxies are used in termination loads adapted for the 10 to 100 watt range dependent upon the frequency and transmission line size desired. For termination loads adapted for higher power dissipation, silicon carbide-type ceramic materials are often employed.

As will be emphasized later, the size and the weight of such dummy loads or terminations are critical design criteria where such terminations are to be incorporated into airborne radar systems. As the average power and the frequency of the transmitted wave increase and decrease, respectively, the size and the weight of the terminations become larger. For terminations capable of handling lower frequencies and higher average power signals, it may be necessary to further cool the load as by air or liquid coolants. Typical size and weights of presently available terminations are set forth as follows:

| Transmission line | Average Power (watts) | Length (inches) | Weight (pounds) | Cooling |
|-------------------|-----------------------|-----------------|-----------------|---------|
| S band—WR 284     | 5                     | 12              | 5               | air     |
|                   | 750                   | 14              | 10              | air     |
|                   | 7500                  | 17              | 15              | liquid  |
| X band—WR 90      | 1                     | 4¼              | ½               | air     |
|                   | 150                   | 5½              | 1½              | air     |
|                   | 2000                  | 6¾              | 1¾              | liquid  |

As indicated above, the size and weight of these terminations may present undue design problems if the standard techniques of the prior art are used for applications where weight and size are critical factors such as in airborne radar systems.

## SUMMARY OF THE INVENTION

It is therefore an object of this invention to provide new and improved terminations whose weight and size have been reduced by an order of 10 and yet still capable of achieving a VSWR in the order of 1.05 to 1.20 over 10–20 percent frequency bands.

The present invention achieves above-mentioned and additional objects and advantages by providing new and improved terminations comprising a transmission line terminated in a short circuit, a thin film of a resistive material disposed approximately  $N/4$  of a wavelength of the transmitted signal from the short circuit where  $N$  is an odd integer, and a member disposed in intimate thermal contact with the thin film and having the property of efficiently conducting thermal energy from the thin film. The resistance of the thin film as de-

termined by the ratio of its bulk resistivity to its thickness, is made substantially equal to the characteristic impedance of the transmission line. In an illustrative embodiment, a suitable thermal cooling fluid such as air or water may be directed across the short circuit to dissipate heat therefrom.

In another illustrative embodiment of this invention, the bandwidth of the termination may be increased by inserting a transformer within the transmission line in front of the thin film. In this manner, the impedance of the transmission line is reduced by the transformer so that the resistivity of the thin film may be reduced significantly and the bandwidth characteristics of the termination improved.

## BRIEF DESCRIPTION OF THE DRAWINGS

These and other objects and advantages of the present invention will become more apparent by referring to the following detailed description and accompanying drawings, in which:

FIG. 1 is a sectioned, side view of a termination or load in accordance with the teachings of this invention; and

FIG. 2 is a sectioned, side view of an alternative embodiment of this invention.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Wave energy absorption has been discussed in Fields and Waves in Modern Radio, by S. Ramo and J. Whinnery, at page 313 (J. Wiley, 1944), wherein it is stated that a planar wave transmitted in space may be completely absorbed by directing the planar wave normally onto a thin conducting film placed one-quarter wavelength in front of a perfect conductor. To achieve efficient absorption, the sheet resistance of the thin film as determined by the ratio of the bulk resistivity ( $\rho$ ) of the film material to the thickness of the film is set equal to the wave impedance. The ratio of bulk resistivity to thickness ( $\rho/T$ ) defines the sheet resistance of the thin film in ohms per square. In contrast to the distributed loads of the prior art, the thin film 14 of the present invention is placed in a plane at the point where the voltage of the transmitted and reflected waves sum to a maximum to achieve the desired energy absorption. The use of the thin film 14 as opposed to a distributed load, achieves a significant reduction in size and weight of this invention. It is understood that such a thin film requires support and additionally would be destroyed by the absorbed energy if not dissipated.

In accordance with the teachings of this invention, the energy transmitted to the thin film 14 is dissipated to prevent the destruction of the thin film and to thereby provide a practical embodiment of the concept, to be illustrated in FIGS. 1 and 2 of the drawings. With regard to FIG. 1, there is shown a termination 10 comprising a transmission line or a wave guide 12 illustratively having a rectangular configuration and being connectable as by a flange 13 to the transmission line to be terminated. In accordance with the teachings of this invention, the transmission line is terminated in a short circuit formed by a member 20 secured to the wave guide 12 as by brazing and made of a suitable electrically conductive material such as aluminum. Typically, the member 20 would be made of the same metal as the wave guide 12. The thin film or layer 14 is disposed within the wave guide 12 across its substan-

tially entire cross-section at a position approximately  $N/4$  wavelength ( $\lambda$ ) from the electrically conductive member 20 to substantially absorb the wave transmitted therealong, where  $N$  is an odd integer. The thickness ( $T$ ) of the film 14 is made sufficiently thin with regard to the wavelength ( $\lambda$ ) of the transmitted signal to ensure that the absorbing effect of the film 14 is concentrated at the point within the guide 14 of maximum voltage. This condition is met where:

$$2\pi/\lambda \times T < < 1$$

Further, the thickness  $T$  determines the sheet resistance of the film 14 to equal substantially the characteristic impedance of the transmission line 12.

Thus, in a manner analogous to where a planar wave is transmitted into space, a transmission line is adapted in accordance with the teachings of this invention to effectively absorb the energy of the wave transmitted along the transmission line by inserting the thin film 14 and determining its resistivity or impedance to be equal to that of the characteristic impedance of the transmission line. The characteristic impedance of a transmission line is an inherent characteristic of that transmission line dependent upon the configuration and materials of the transmission and is not influenced by impediments disposed within the transmission line. The characteristic impedance of a transmission line is defined as the impedance of an infinite length of that transmission line having no variation in impedance along its entire length. More specifically, the sheet resistance of the film 14 is determined by the ratio of the bulk resistivity  $\rho$  to the film thickness  $T$ . In an illustrative embodiment of this invention, the film 14 was made of Nichrome to a thickness of approximately 100A to provide a resistivity 108 ohms per square ( $\rho$  of Nichrome being 108 microohms-cm). Significantly, the thin film 14 is disposed upon a member 16 made of a high thermally conductive material such as beryllium oxide BeO to not only provide a support for the heat generated by absorption of the wave energy in the thin film 14 but also to transmit efficiently to prevent the destruction of the film 14.

To facilitate heat dissipation, the conductive member 20 may be disposed in intimate thermal contact with the thermally conductive member 16 to serve as a primary heat sink. In one illustrative embodiment of this invention, a thin layer in the order of 0.001 to 0.003 inches of a suitable thermally conductive adhesive 18 such as the thermal epoxy 418H made by Epoxy Technology of Watertown, Massachusetts, may be disposed between the thermally conductive member 16 and the electrically conductive member 20 to insure an efficient thermal transfer therebetween. Dependent upon the power of the wave to be absorbed, suitable additional cooling means such as a fan 22 may be used for directing a cooling fluid such as air past the surface of the member 20. In a further embodiment of this invention, fins (not shown) may be connected to the member 20 to achieve additional cooling.

With reference to the article "Thermal Resistivity Table Simplifies Temperature Calculations," by the inventor of this invention, Microwave Magazine, Feb. 1970, BeO (beryllia ceramic) provides an efficient thermally conductive medium for the transfer of the heat from the thin film 16. In actual tests, thin films as utilized in FIG. 1 may be operated at temperatures in the order of 180° C without degradation and power

densities in the order of 500 to 1,000 watts per square inch can be accommodated. It is understood that an additional temperature difference would exist between this surface of the thermally conductive member 16, and the exposed surface of member 20. The power capability of the entire system would be dependent upon the effectiveness of the additional heat sinking which may be used. As explained above with regard to FIG. 1, the exposed surface of the member 20 may be further cooled by the flow of air provided by a fan 22. Thus, the power handling capability would not only be dependent upon the thermal conductivity of the member 16 but also the type of additional cooling used.

As shown in FIG. 1, the space between the thin film 14 and the electrically conductive member 20 is filled with the thermally conductive member 16, which causes the wavelength of the signal transmitted to the member 20 to be reduced according to the following equation:

$$\lambda g \epsilon = \lambda g \alpha / \sqrt{\epsilon}$$

where  $\lambda g \alpha$  is the guide wavelength of the signal as transmitted in air through the transmission line 10,  $\epsilon$  is the dielectric constant of the material of the member 16 and  $\lambda g \epsilon$  is the guide wavelength of the signal transmitted through member 16. In the illustrative example where the member 16 is made of BeO, the guide wavelength of the transmitted signal is reduced by a factor of 2.6 where the  $\epsilon$  of BeO is 6.6. As a result, the distance between the thin film 14 and the member 20, i.e.,  $\lambda g \epsilon / 4$  of the transmitted signal, is shortened by a similar amount, thus decreasing the overall dimensions of the termination 10.

The choice of material for the member 16 is primarily dependent upon its thermal conductivity, but is also dependent upon its structural stability at higher temperatures, its dielectric content as discussed above and also its wave loss characteristics. BeO meets all of these requirements to a great degree and is a preferred material for the manufacture of member 16. In other embodiments, alumina ceramic and boron nitride may be used as the thermally conductive material.

Illustratively, the thin film 14 could be formed by vacuum depositing a layer of Nichrome upon the member 16. The film 14 could be made of other resistive materials such as the cermet resistive inks which are compositions of metals, oxide powders and glass suspended in a suitable vehicle and which may be screen printed and fired in air at high temperature to form the thin film onto the member 16, or carbon which could be vacuum or pyrolytically deposited upon the member 16.

In a further embodiment of this invention as shown in FIG. 2, the termination may include a transmission line 21 connectible to a transmission line by a flange 23. A thin film 24 is disposed within the wave guide 22, a distance of one-fourth wavelength from the electrically conductive member 28 forming the short circuit across the transmission line 21. In a manner similar to that described above, a member 26 made of a highly thermally conductive material such as BeO is provided for efficiently conducting thermal energy from the thin film 24 to the member 28. Further, provision is made for directing a suitable coolant such as water across the member 28 to dissipate the thermal energy therefrom. In the particular embodiment shown in FIG. 2, the electrically conductive member 28 may be disposed upon

the member 26 as by vacuum depositing a thin layer of film of metal followed by electro-plating or electroless plating of the remaining portion of layer 28. The liquid coolant is then directed across the metallic layer 28 through a cooling chamber 32. A cooling chamber 32 is water sealed to the electrically conductive member 28 by a suitable seal 30. The liquid coolant is pumped through the chamber 32 by a coolant pump 42 which is connected by conduit 38 to an entrance port 34 and by a conduit 40 connected to the exit port 36. It is noted that the embodiment of FIG. 1 could be modified to liquid cool the metal member 20 to achieve an intermediate level of heat dissipation.

The termination load 10 of FIG. 1 achieves illustratively a VSWR of 1.1 or less over a bandwidth of 1 to 2 percent of the design frequency. The bandwidth of the termination may be broadened to 10 percent by lowering the sheet resistivity of the thin film by a factor of four and by providing a transformer in front of the thin film to match the impedance of the film to that of the transmission line as transformed by the transformer. As shown in FIG. 2, first and second matching members are inserted in front of the thin film 24 to provide a multiple transformer function thus permitting the film resistivity required for matching the transformed impedance to be reduced. In effect, the first and second matching members 25 and 29 serve as a transformer for reducing the impedance seen by a wave propagated along the transmission line. If a single matching member such as a dielectric block having a characteristic impedance  $Z_e$  and a length  $\lambda g_e/4$  is inserted within an air-filled transmission line whose characteristic impedance is  $Z_A$ , the transformed impedance  $Z_T$  upon the other side of the transformer is given by the following equation:

$$Z_T = Z_e^2/Z_A$$

Thus, the resistivity or impedance  $Z_R$  of the film is made substantially equal to that of the transformed impedance  $Z_T$  as defined by the equation above. As a result, the resistivity of the film is significantly decreased and the bandwidth characteristics of the termination improved. The introduction of a single matching transformer resulted in a load termination operable in S band with a measured VSWR under 1.20 from 3.0 to 3.5 GHz. By using an additional transforming stage as shown in FIG. 2, a VSWR of 1.03 may be achieved over a 10 percent frequency bandwidth.

In the illustrative embodiment of FIG. 2, the first matching member 25 is made of BeO and the second matching member 29 is made of polyphenylene oxide. Other materials such as Boron Nitride, and Teflon with low microwave loss characteristics and high softening points may be used to make members 25 and 29.

Thus, there has been shown a termination whose dimensions and weight have been reduced in accordance with the teachings of this invention significantly from

that achieved by the prior art. From the following chart, it may be seen that a significant reduction of size and weight may be achieved in accordance with the teachings of this invention for various terminations capable of operating under various load and frequency and conditions:

| Transmission Line | Watts | Length (Inches) | Weight (pounds) | Cooling |
|-------------------|-------|-----------------|-----------------|---------|
| S band—WR 284     | 150   | 1 1/4           | 1/2             | air     |
|                   | 1000  | 2               | 2               | liquid  |
|                   | 7500  | 3               | 3               | liquid  |
| X band—WR 90      | 50    | 1/2             | 1/6             | air     |
|                   | 150   | 1 1/4           | 1/2             | air     |
|                   | 2000  | 1               | 1/4             | liquid  |

Numerous changes may be made in the above-described apparatus and different embodiments of the invention may be made without departing from the spirit thereof. For example, this invention may be equally adapted to circular wave guides, coaxial lines and strip lines. Though the invention has been described as including a transmission line, the thin film, the short circuit, the thermally conductive member and the matching transformer may be assembled and employed as an insertable termination into existing transmission lines. Therefore, it is intended that all matter contained in the foregoing description and shown in the accompanying drawings, shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. Apparatus for absorbing energy from a signal transmitted along a transmission line having a characteristic impedance, said apparatus comprising:

a short circuit means disposed across said transmission line;

b a film disposed across substantially the entire cross-section of said transmission line;

c thermal conduction means disposed in intimate thermal relation with said film for efficiently conducting the thermal energy absorbed by said film from said film to said short circuit means;

d said film being disposed a distance  $N\lambda/4$  from said short circuit means where N is an odd integer and  $\lambda$  is the wavelength of the signal transmitted in said thermal conduction means; and

e matching transformer means disposed within said transmission line in front of said film, said film having an impedance substantially equal to the reduced impedance of said transmission line as transformed by said matching transformer means.

2. Apparatus as claimed in claim 1, wherein said film is vacuum deposited upon said thermal conduction means to provide an intimate thermal relation therebetween.

3. Apparatus as claimed in claim 1, wherein said film comprises a resistive ink intimately bonded to said thermal conduction means.

\* \* \* \* \*

**UNITED STATES PATENT OFFICE**  
**CERTIFICATE OF CORRECTION**

Patent No. 3,796,973 Dated March 12, 1974

Inventor(s) Gerald I. Klein

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Add The Following Claims:

-- 4. Apparatus for absorbing energy from a signal transmitted along a transmission line, said apparatus comprising:

a) short circuit means disposed across said transmission line;

b) a film disposed within said transmission line and having a sheet resistance equal to the characteristic impedance of said transmission line;

c) thermal conduction means comprising a berillium oxide member disposed in intimate thermal relation with said film for efficiently conducting thermal energy from said film to said short circuit means, said film being disposed a

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**UNITED STATES PATENT OFFICE**  
**CERTIFICATE OF CORRECTION**

Patent No. 3,796,973 Dated March 12, 1974  
Inventor(s) Gerald I. Klein

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

distance  $N \frac{\lambda}{4}$  from said short circuit means where N is an odd integer and  $\lambda$  is the wavelength of the signal transmitted in said thermal conduction means.

5. Apparatus for absorbing energy from a signal transmitted along a transmission line, said apparatus comprising:

- a) short circuit means disposed across said transmission line;
- b) a film disposed within said transmission line;
- c) matching transformer means disposed within said transmission line for matching the characteristic impedance of said transmission line to said sheet resistance of the film;

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**UNITED STATES PATENT OFFICE**  
**CERTIFICATE OF CORRECTION**

Patent No. 3,796,973 Dated March 12, 1974

Inventor<sup>(s)</sup> Gerald I. Klein

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

d) thermal conduction means disposed in intimate thermal relation with said film for efficiently conducting the thermal energy absorbed by said film from said film to said short circuit means, said film being disposed a distance  $\frac{N \lambda}{4}$  from said short circuit means where N is an odd integer and  $\lambda$  is the wavelength of the signal transmitted in said thermal conduction means.

6. Apparatus as claimed in claim 5, wherein said transformer means comprises a polyphenolene oxide.

7. Apparatus for absorbing energy from a signal transmitted along a transmission line, said apparatus comprising:

a) short circuit means disposed across said transmission line;

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**UNITED STATES PATENT OFFICE  
CERTIFICATE OF CORRECTION**

Patent No. 3,796,973 Dated March 12, 1974

Inventor(s) Gerald I. Klein - 4 -

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

b) a film disposed within said transmission line;  
said film having a sheet resistance lower than the characteristic impedance of said transmission line;

c) matching transformer means disposed within said transmission line for matching the sheet resistance of said film to the characteristic impedance of said transmission line;

d) thermal conduction means disposed in intimate thermal relation with said film for efficiently conducting the thermal energy absorbed by said film from said film to said short circuit means, said film being disposed a distance  $\frac{N\lambda}{4}$  from said short circuit means where N is an odd integer and  $\lambda$  is the wavelength of the signal transmitted in said thermal conduction means. --.

Signed and sealed this 26th day of November 1974.

(SEAL)  
Attest:

McCOY M. GIBSON JR.  
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