# United States Patent [19]

**Meier**

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[54] **MICROWAVE TRANSMISSION LINE**


[75] Inventor: **Paul J. Meier,** Westbury, N.Y.

[73] Assignee: **Cutler-Hammer, Inc.,** Milwaukee, Wis.



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[52] **U.S. Cl.** ..... **333/95 R,** 333/98 R, 329/161

[51] **Int. Cl.** ..... **H01p 3/12,** H01p 1/00

[58] **Field of Search** .... 333/95 R, 98 R, 31 A, 84 R, 333/84 M; 329/161



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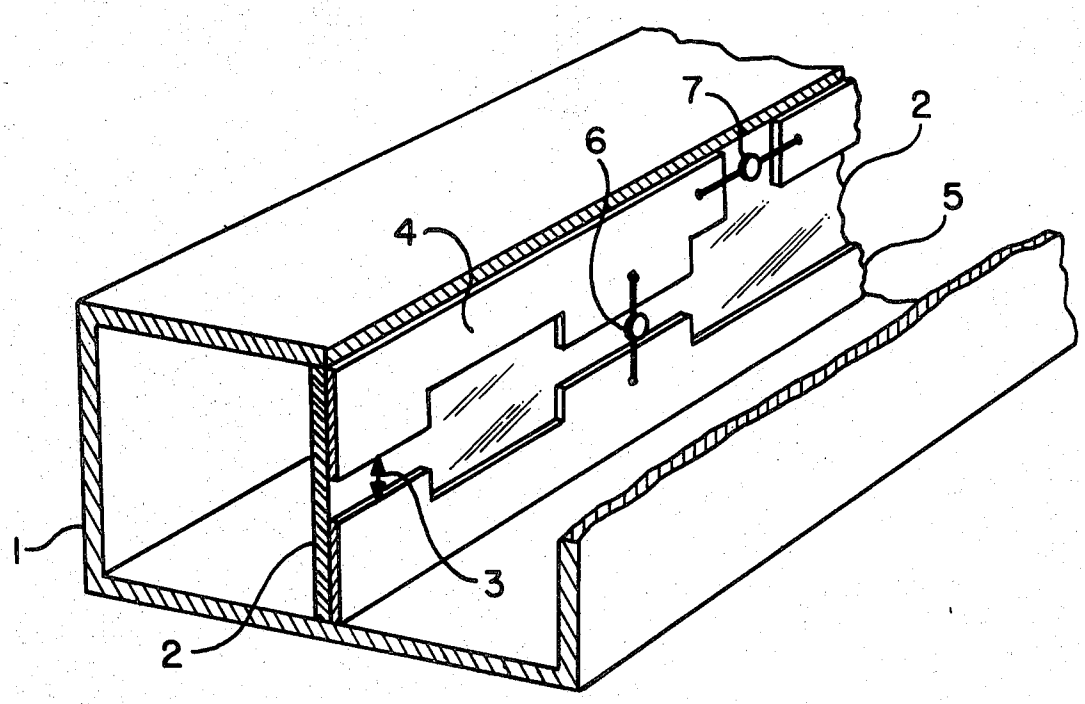
*Primary Examiner*—Archie R. Borchelt
*Assistant Examiner*—Wm. H. Punter
*Attorney, Agent, or Firm*—Henry Huff; Kevin Redmond



[57] **ABSTRACT**

A microwave transmission structure consisting of a hollow conductive waveguide with at least one film conductor supported on a dielectric substrate within the guide to provide a conductive surface projecting inwardly from the guide wall in the manner of a ridge in ridgeguide.


**7 Claims, 5 Drawing Figures**



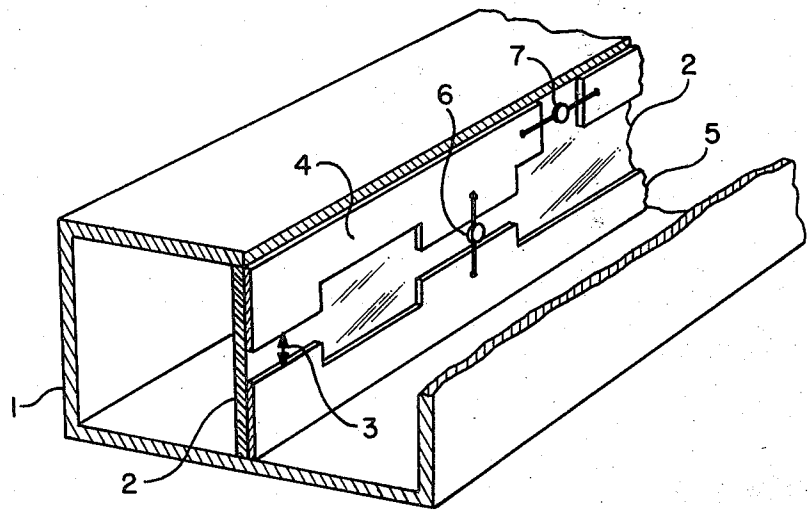



FIGURE 1

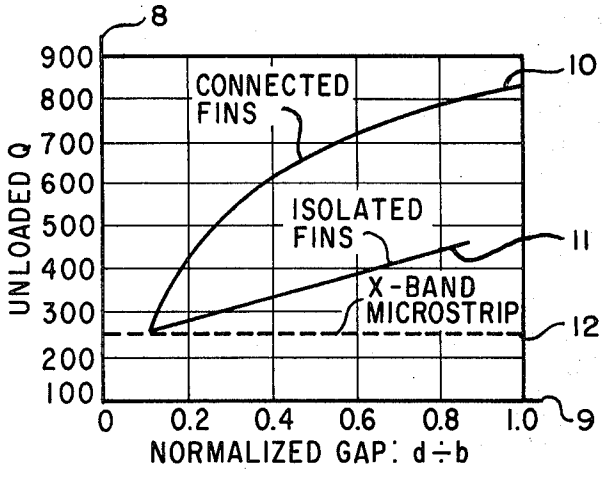



FIGURE 2

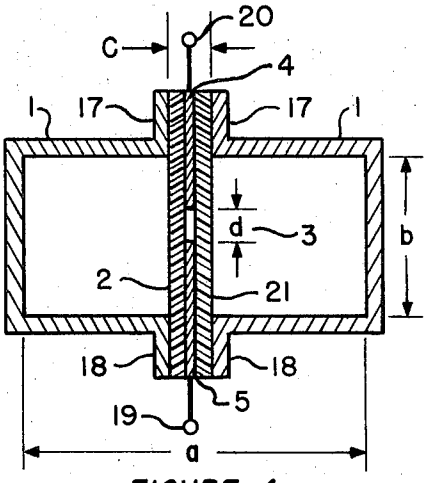



FIGURE 4

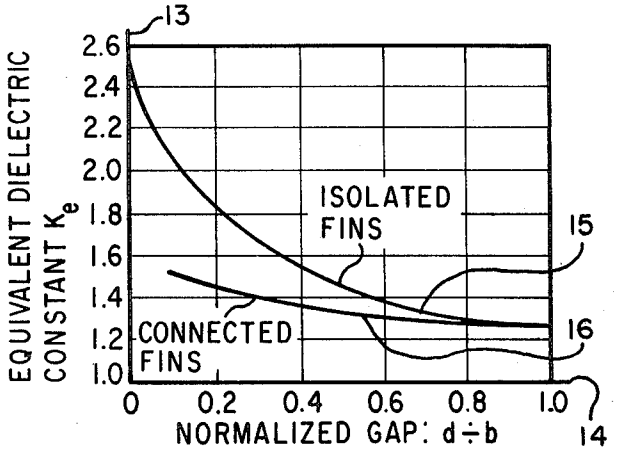



FIGURE 3

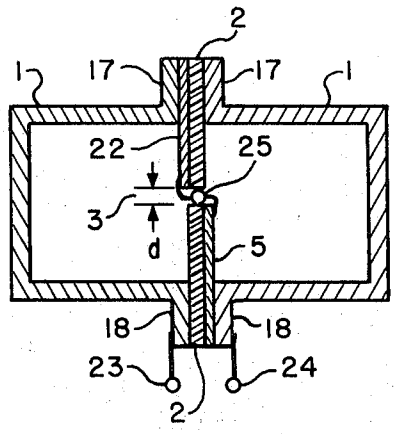



FIGURE 5

# MICROWAVE TRANSMISSION LINE

## BACKGROUND

1. Field of the Invention

The invention pertains to microwave transmission lines comprising a dielectric substrate clad with a film conductor enclosed by and cooperating with a waveguide.

2. Description of the Prior Art

Many known arrangements of film conductors on dielectric substrates are used as microwave transmission lines. These lines, referred to herein as printed transmission lines, include slot-line, dielectric sandwich line, inverted microstrip, suspended strip line and coplanar line. The foregoing types of transmission lines can be used to produce low cost, intricate microwave circuits, compatible with discrete components at low microwave frequencies; however, they are not entirely satisfactory at high microwave frequencies for various reasons including high fabrication costs, high loss, critical tolerance requirement, fragile substrates, thin conductor strips, difficulty in mounting discrete components, and in obtaining a simple transition to conventional waveguide. The principal object of this invention is to provide an improved type of transmission line having the desirable characteristics of printed transmission lines without the above mentioned inadequacies.

## SUMMARY

According to this invention, a printed transmission line analog of ridgeguide, called fin-line, is formed by providing conductive fins within a hollow waveguide. The fins are comprised of conductive film on a dielectric substrate and cooperate with the waveguide in a manner similar to that of the ridges in ridgeguide, increasing the separation between the first and second modes of propagation, and thereby providing a wider useful bandwidth than conventional waveguide. The similarity of this structure to standard waveguide facilitates the design and fabrication of simple transition devices for interconnecting the two.

The film clad dielectric structure of the fins permits the techniques and hardware developed for conventional printed lines to be used to advantage. In particular, the impedance level can be changed along the line by changing the gap width. Different gaps are readily produced at low cost by a number of well known techniques including photoetching, and discrete components developed for hybrid printed circuits can be applied with little difficulty.

The fin gap is generally larger than a corresponding microstrip line width, easing the printing tolerances and facilitating the installation of discrete components. Since there is no ground plane, the critical spacing from line to ground plane occurring in most printed transmission lines is eliminated permitting the use of a thicker and therefore stronger dielectric substrate.

Due to the elimination of the ground plane and the use of a waveguide enclosure, the E-field need not be concentrated within the dielectric substrate, permitting a reduction of the dielectric loss. Radiation loss is eliminated by confining the E-field within the guide walls. These reductions in line loss permits the fabrication of high Q circuit elements not previously achievable with conventional printed transmission lines. Further performance details may be found in P. J. Meier, "Two New Integrated-Circuit Media with Special Advantages at Millimeter Wavelengths," IEEE 1972 G-MTT Symposium Digest, p. 221–223, May 22, 1972.



## DRAWINGS

FIG. 1 is a perspective view of an embodiment of the invention showing the relative location of the waveguide, dielectric substrate, film conductors, matching sections and discrete components.

FIG. 2 is a graph of the unloaded Q as a function of the normalized gap for the embodiments of FIG. 1 and FIG. 4.

FIG. 3 is a graph of the variation in equivalent dielectric constant as a function of the normalized gap for the embodiments of FIG. 1 and FIG. 4.

FIG. 4 is a cross section of an embodiment of the invention showing useful design dimensions and a first method of introducing bias on the film conductors.

FIG. 5 is a cross section of an embodiment of the invention showing a second method of introducing bias on the film conductors.

## DESCRIPTION

Referring to FIG. 1, a dielectric substrate 2, clad with film conductors 4 and 5 and supporting discrete circuit elements 6 and 7, is mounted within waveguide 1. Gap 3, normally located midway of the waveguide, separates film conductors 4 and 5. Substrate 2 is preferably mounted in the center of the guide causing the maximum field strength to exist across gap 3. The edges of conductors 4 and 5 remote from the gap 3 are electrically connected to the waveguide wall. In more complicated configurations, the fin conductors may be dc isolated from the walls while still being connected at RF to permit the introduction of bias.

Referring to FIG. 2, the higher Q achievable with either waveguide connected or waveguide isolated fins as compared to microstrip is shown. In this figure, ordinate axis 8 represents unloaded Q. Abscissa 9 represents a normalized gap defined as the ratio of the gap width ($d$) to guide height ($b$). The Q of X-band microstrip is shown to be 250 by dotted line 12. Graph 10 shows the variation in Q when the fin conductors are directly connected to the waveguide wall. Graph 11 shows the variation in Q when the fin conductors are dc isolated from the waveguide walls. The data shown in FIGS. 2 and 3 was measured at X-band using a teflon-fibreglass substrate with a dielectric constant of 2.5 in a fin-line whose aspect ratio (b/a) was 0.45, and whose c/a ratio was 0.07, where a is the internal guide width and c is the dielectric thickness.

Referring to FIG. 3, the equivalent dielectric constant, $K_e$ of the waveguide is plotted as a function of normalized gap width. In this figure, ordinate 13 is $K_e$ while abscissa 14 is the normalized gap width (d/b). Graph 15 shows the variation in $K_e$ for dc isolated fins while graph 16 shows the variation for fin conductors connected to the waveguide wall. It can be seen that a high value of $K_e$ approaches that of the substrate material for isolated fins with narrow normalized gap widths. The value of $K_e$ drops to 1.25 for both connected and isolated fins when the normalized gap width is 1.0. The value of $K_e$ at this point is only slightly above that of air, and represents the relatively small effect a dielectric substrate alone can have on the effective dielectric constant of the guide.

Data available in S. Hopfer, "The Design of Ridged Waveguides," IRE Trans., Vol. MTT-3, p. 20–29, Oct.

1955 can be used to facilitate the design of various practical configurations of the subject invention. Thin, moderate dielectric constant substrates have little effect on the field distributions, and therefore the single mode bandwidth and attenuation can be estimated directly from ridgeguide data such as found in the above reference.

Lines constructed in accordance with the present invention possess a number of the more desirable characteristics of printed transmission lines and ridgeguide including large dimensions at higher microwave frequencies, low loss, and ease of pattern variation. Line dimensions significantly larger than those of printed transmission lines aid in easing the fabrication process, facilitating the addition of discrete components, and reducing the copper loss.

To produce a 50 ohm transmission line at 60 GHz in microstrip, the printed line width must be less than 0.005 inches and the substrate thickness must be less than 0.002 inches in order to prevent excessive radiation with common substrate material. If an alumina substrate is used at the same frequency, both the printed line width and the dielectric substrate thickness must be less than 0.004 inches.

In either case, the printed line widths are sufficiently narrow to make line fabrication and lead attachment difficult. The thin substrates are weak and costly to produce. On the other hand, a gap width of 0.01 inches and a dielectric thickness of 0.02 inches can be used for fin-line at 60 GHz, significantly alleviating the dimensional problems encountered with printed transmission lines noted above.

The use of a film conductor clad substrate facilitates the fabrication of a variety of patterns to produce various line impedances, matching sections and filter elements. Complicated patterns can be produced uniformly and in large volume by processes such as photoetching while the production of similar patterns in ridgeguide would require expensive machining.

As noted previously, embodiments of the present invention are adaptable to hybrid integrated circuit components including active devices requiring bias. Although the film conductors can be directly connected to the waveguide walls for passive devices, isolation of the film conductors from each other at dc is necessary to permit bias to be supplied through the conductors to active devices. At the same time, the conductors must have continuity with the waveguide wall at RF frequencies.

A way in which this may be accomplished is shown in FIG. **4.** Waveguide **1** is divided in two along the longitudinal axis at the center of the broadwalls and a dc isolated fin-line structure is inserted into the guide. This structure is comprised of a first dielectric sheet **2,** two film conductors **4** and **5,** and second dielectric sheet **21.** The film conductors are located between the two dielectric sheets and therefore are isolated from the waveguide walls at dc. Film conductors **4** and **5** are separated by gap **3** of width *d.* Bias is placed on film conductor **4** through lead **20** and on film conductor **5** through lead **19.** RF continuity between the fins and the waveguide wall and between the two segments of the wall is obtained by using an RF choke formed by choosing the internal length of upper flange **17** and lower flange **18** to be a quarter-wavelength in the dielectric medium.

A second method of introducing bias on the film conductors is shown in FIG. **5.** In this configuration, the waveguide **1** is divided into two halves along the longitudinal axis at the center of the broadwalls and a fin-line structure is inserted between the two halves. This fin-line structure is comprised of a single dielectric substrate, clad on the upper left-hand side with film conductor **22** and on the lower right-hand side with film conductor **5.** Gap **3** is located between the conductors and one-quarter wavelength flanges **17** and **18** are used for mounting and RF continuity.

Each half of the waveguide is dc isolated from the other by the dielectric **2,** and each of the film conductor makes contact with only one half of the waveguide. Bias can be introduced by connection to each film conductor directly or through each half of the waveguide. The latter arrangement is shown in FIG. **5,** where the bias is supplied to the film conductors through the waveguide from leads **23** and **24.** An active device **25** is located in a hole drilled through the dielectric substrate adjacent gap **3.** This device receives bias through its connections to film conductors **5** and **22.**

I claim:

**1.** A microwave transmission line comprising:

a. a hollow conductive waveguide adapted to operate in a mode having a transverse electric component,

a dielectric substrate in the form of a sheet of such thickness and dielectric constant that the electric field is distributed principally in the space within the guide surrounding the dielectric, said substrate sheet having an edge secured to the inside of the waveguide wall with a surface extending inwardly of the guide away from the wall in a transverse direction across the guide and in the longitudinal direction of the guide over a distance substantially greater than the width of the guide in said transverse direction,

c. a first conductor formed of film material supported on said substrate surface extending inwardly of the guide and terminating in an edge away from the waveguide wall, said first conductor being RF connected to the waveguide wall, and

d. a second conductor RF connected to the waveguide wall within the guide and separated from said edge of the first conductor by a nonconductive gap.

**2.** A microwave transmission line as recited in claim **1,** wherein the gap width is different at different regions along the line to provide respective different impedance levels in said regions.

**3.** A transmission line as recited in claim **2,** wherein said substrate is a planar sheet and said second conductor is a second film conductor supported on said dielectric substrate surface.

**4.** A microwave transmission line as recited in claim **3,** further comprising:

a. an RF choke including outwardly extending flanges to mount the dielectric substrate and maintain RF connection of the conductors to the waveguide wall and RF continuity of the waveguide wall, said flanges being located along a longitudinal division in the waveguide wall,

b. a second dielectric substrate located between said film conductors and said flanges to provide dc isolation of the film conductors from each other and

from the flanges, whereby said film conductors can be used as bias conductors.

**5.** A microwave transmission line as recited in claim **2,** wherein said substrate is a planar sheet, said second conductor is a second film conductor supported on the opposite side of said substrate from the first film conductor.

**6.** A transmission line as recited in claim **5,** further comprising an RF choke including outwardly extending flanges used to mount the dielectric and provide RF connection of the film conductors to the waveguide wall and RF continuity of the waveguide wall, said flange being located along two longitudinal divisions made in opposite walls of the guide which divide the guide in two segments, direct connection being made by each film conductor to a separate segment of the waveguide wall, whereby said film conductors can be used as bias conductors.

**7.** A microwave transmission line as claimed in claim **1,** wherein said waveguide is rectangular and said dielectric substrate is perpendicular to a broad wall near the center of the guide.

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