April 15, 1969 T. M. BUCKLEY 3,439,296

MICROWAVE WINDOW EMPLOYING A HALF-WAVE WINDOW STRUCTURE WITH INTERNAL INDUCTIVE MATCHING STRUCTURE

Filed April 20, 1967

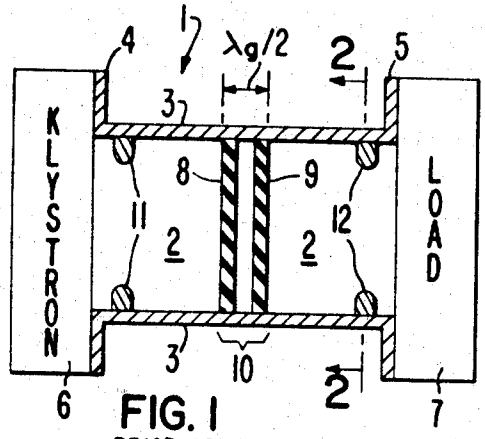

FIG. 1
PRIOR ART

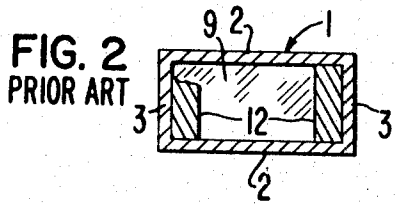

FIG. 2
PRIOR ART

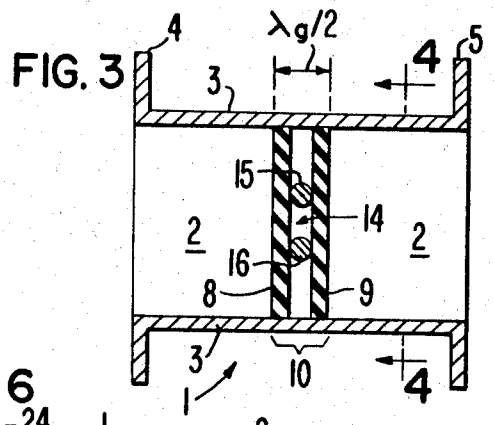

FIG. 3

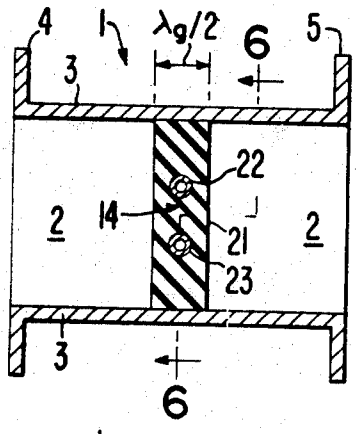

FIG. 5

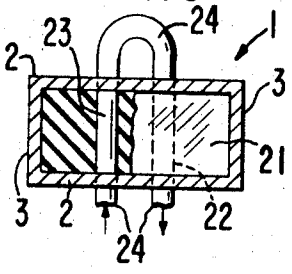

FIG. 6

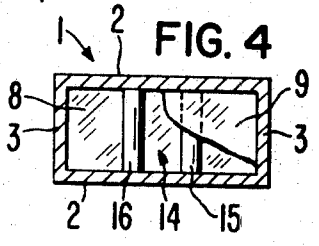

FIG. 4

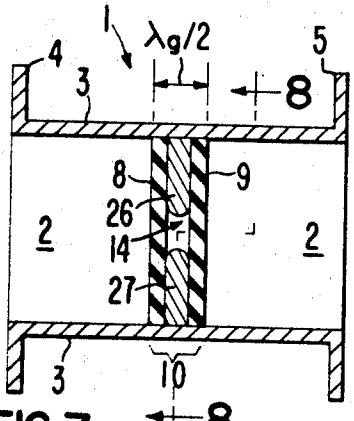

FIG. 7

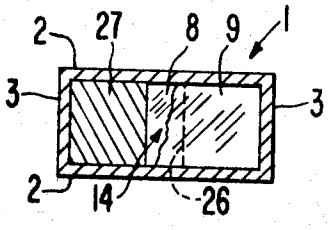

FIG. 8

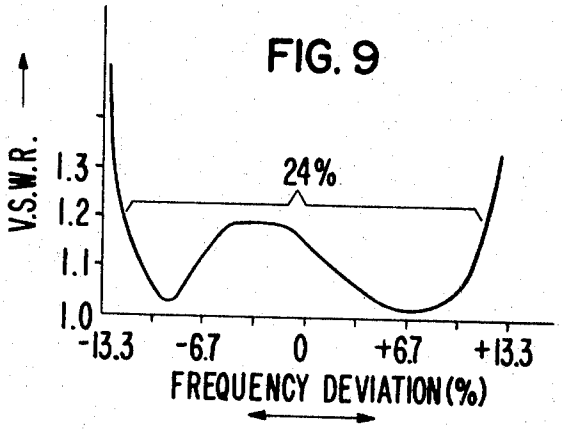

FIG. 9

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MICROWAVE WINDOW EMPLOYING A HALF-WAVE WINDOW STRUCTURE WITH INTERNAL INDUCTIVE MATCHING STRUCTURE

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11 Claims

ABSTRACT OF THE DISCLOSURE

A microwave window is disclosed for use with microwave tubes and other broadband high power radio frequency devices. The window comprises a gas tight wave permeable dielectric structure sealed across a waveguide such that a pressure differential can be maintained across the window while permitting high power microwave energy to be passed therethrough without substantial reflection over a relatively broad band of frequencies. An inductive structure, such as an inductive iris or pair of inductive iris defining rods, is disposed in the midplane of the dielectric structure for broadbanding the window and for suppressing certain undesired resonant ghost modes associated with the window. The composite window structure, including the inductive and dielectric structures, is one half an electrical wavelength thick in the waveguide.

In one embodiment, the dielectric structure is formed by a pair of axially spaced dielectric plates with an inductive iris defining structure sandwiched between the dielectric plates.

In another embodiment, the dielectric structure is unitary with the inductive iris defining structure embedded in the dielectric structure. Fluid coolant may be passed through coolant passageways in the inductive structure or through the spaces between the spaced dielectric plates.

The window has exceptionally broad bandwidth and high power capacity and is surprisingly free of ghost modes.

Description of the prior art

Heretofore, one half wavelength microwave windows have been built. One example of such a window is disclosed in copending U.S. patent application Ser. No. 389,250, filed Aug. 13, 1964, now abandoned, and assigned to the same assignee as the present invention. In this prior art window, a pair of dielectric plates are sealed across a rectangular waveguide in spaced relation. The composite spaced structure is one half an electrical wavelength thick. Inductive iris structures were placed in the waveguide on opposite sides of the dielectric structure for broad-banding the window. The irises were spaced from the nearest face of the window by 0.36 to 0.44 of an electrical wavelength in the waveguide. While such a window provides substantial bandwidth and high power capacity it is desired to improve upon the performance of that window by increasing its bandwidth and suppressing certain resonant ghost modes within its operating band.

Other prior art microwave windows have employed conductive structure embedded in or painted on the dielectric window sturcture for suppressing certain ghost modes and to enhance cooling of the window structure. For example, U.S. Patent No. 2,990,526, issued June 27, 1962 shows conductive rods embedded in a half wavelength dielectric window member for cooling. Likewise, U.S. Patent No. 3,183,459 shows a dielectric slab window member with a hollow conductive septum embedded therein for cooling and for suppression of ghost modes.

However, in these latter windows, the conductive members were arranged to be perpendicular to the electric field of the desired mode of propagation through the window member such as not to perturb the desired mode. Thus, to the extent they produced a lumped reactance, this reactance was capacitive.

Summary of the present invention

The principal object of the present invention is the provision of an improved microwave window.

One feature of the present invention is the provision of a microwave window structure including a dielectric wave permeable structure sealed across a waveguide and having a lumped inductive structure disposed inside the dielectric structure for broad-banding the window and for suppressing undesired ghost modes.

Another feature of the present invention is the same as the preceding feature wherein the inductive structure is disposed in the midplane of the dielectric window structure.

Another feature of the present invention is the same as any one or more of the preceding features wherein the inductive structure is an inductive iris.

Another feature of the present invention is the same as the preceding feature wherein the inductive iris is defined by a pair of conductive members extending across the waveguide parallel to the electric field lines of the dominant excited transmission waveguide mode.

Another feature of the present invention is the same as any one or more of the preceding features wherein the dielectric window structure includes a pair of spaced dielectric plates having the inductive structure sandwiched therebetween.

Another feature of the present invention is the same as any one or more of the preceding features wherein the composite window structure, including the dielectric and lumped inductive structure, is approximately one half an electrical wavelength long in the waveguide in which it is disposed at the center frequency of its operating passband.

Other features and advantages of the present invention will become apparent upon a perusal of the following specification taken in connection with the accompanying drawings wherein:

Brief description of the drawings

FIG. 1 is a sectional view, partly in schematic block diagram form, of a microwave circuit incorporating the prior art window;

FIG. 2 is a sectional view of the structure of FIG. 1 taken along line 2—2 in the direction of the arrows and rotated 90°;

FIG. 3 is a sectional view similar to that of FIG. 1 depicting the microwave window of the present invention;

FIG. 4 is a sectional view, partly broken away, of the structure of FIG. 3 taken along line 4—4 in the direction of the arrows, and rotated 90°;

FIG. 5 is a sectional view, similar to that of FIG. 3, depicting an alternative embodiment of the present invention;

FIG. 6 is a sectional view, partly broken away, of the structure of FIG. 5 taken along line 6—6 in the direction of the arrows and rotated 90°;

FIG. 7 is a sectional view, similar to that of FIG. 3, depicting an alternative embodiment of the present invention;

FIG. 8 is a sectional view, partly broken away, of the structure of FIG. 7 taken along line 8—8 in the direction of the arrows and rotated 90°; and

FIG. 9 is a plot of voltage standing wave ratio (VSWR) versus precent frequency deviation from the

center of the passband for widows of the present invention.

Description of the preferred embodiments

Referring now to FIGS. 1 and 2, there is shown a microwave circuit employing the prior art microwave window. The circuit includes a length of hollow rectangular waveguide **1** having a pair of broad walls **2** and a pair of narrow walls **3**. The waveguide **1** is flanged at its ends **4** and **5** and connected to a klystron tube **6** and load **7**, respectively. A pair of wave permeable dielectric plates **8** and **9**, forming a window structure **10**, are sealed, as by metal brazes, at their margins to the inside walls of the waveguide **1** to form gas tight seals therebetween. Suitable dielectric materials for the plates **8** and **9** include alumina ceramic, sapphire, and beryllia.

The window members **8** and **9** are spaced apart along the waveguide **1** and the total electrical length, taken along the direction of microwave power flow in the waveguide, between the two outer faces of members **8** and **9** is approximately one half a wavelength at the center frequency of the passband of the window. In other words, there is a 180° phase shift in wave energy propagating along the waveguide between the outer faces of members **8** and **9** at the frequency of the center of the passband of the window.

A pair of inductive matching irises **11** and **12** are positioned on opposite sides of the dielectric window structure **10** forming lumped inductances for broad-banding the composite waveguide window assembly. Such a window has a bandwidth between 1.2 VSWR points of about 20% and a substantial amount of this bandwidth, as of 15% can be made free of ghost modes, i.e., interfering modes of resonance associated with the local R.F. fields in and around the window structure **10**.

Referring now to FIGS. 3 and 4, there is shown a microwave window assembly of the present invention. The apparatus is essentially the same as that of FIGS. 1 and 2 except that the outside matching irises **11** and **12** are replaced by an inductive iris **14** located inside the window structure **10**, thereby forming the lumped inductance inside the window structure **10**. By placing the broad banding iris **14** inside the window **10**, the bandwidth of the microwave window assembly is substantially increased from about 3% to between 25 and 30% and, furthermore, the ghost modes are much better suppressed. In fact, the ghost modes were completely suppressed within the passband of the window assembly and outside of the passband for a total suppressed band of 33%. As shown in FIG. 9, the passband extended over a range of 24% between 1.2 points of VSWR. In addition, the window assembly of FIGS. 2 and 3 can be much shorter and, thus, more compact than the prior art window.

In the embodiment of FIGS. 3 and 4, the inductive iris **14** is defined by the space between a pair of conductive rods **15** and **16** which extend across the waveguide **1** from one broad wall **2** to the opposed broad wall **2** and, thus, parallel to the electric field lines of the dominant $TE_{1,0}$ waveguide transmission mode within the waveguide **1** and window **10**. The $TE_{1,0}$ mode is excited for transmitting microwave power through the window assembly.

As in the window of FIGS. 1 and 2, the dielectric plates **8** and **9** and rods **15** and **16** are dimensioned such that the composite window structure **10** is approximately one half an electrical wavelength long at the center frequency of the passband of the window assembly. In a typical example of an S-band window, having a center passband frequency of 3.03 GHz., the window had the following dimensions: inside waveguide width 2.840", inside waveguide height—1.340", thickness of alumina ceramic plates **8** and **9**—0.220" each, spacing between plates **8** and **9**—0.250", diameter of rods **15** and **16**—0.250", spacing between centers of rods **15** and **16**—0.790" with each rod spaced 1.025" from its closest side wall **3**.

Referring now to FIGS. 5 and 6, there is shown an alternative embodiment of the present invention. This embodiment is essentially the same as that of FIGS. 3 and 4 except that the window structure **10** is formed by a unitary block **21** of dielectric with conductive iris defining tubes **22** and **23** embedded therein. A fluid coolant is passed through the tubes **22** and **23** for cooling the window structure **10** in use. Coolant pipes **24** are connected to the tubes **22** and **23** for directing the coolant through the window **10**. The composite window structure **10** is dimensioned for the same one half an electrical wavelength, as previously described.

Referring now to FIGS. 7 and 8, there is shown an alternative embodiment of the present invention. This embodiment is essentially the same as that of FIGS. 3 and 4 except that the iris defining rods **15** and **16** have been replaced by a pair of iris defining conductive plates **26** and **27**. The plates **26** and **27** as of copper project toward the center of the waveguide **1** from the side walls **3** and extend from one broad wall **2** to the opposed broad wall **2** across the waveguide **1**. Coolant may be passed through the plates **26** and **27** for cooling of the window structure **10**.

Although the window assembly of the present invention has been described using a rectangular waveguide **1** it may also be used with cylindrical waveguide. However, mode separation and, thus, mode suppression and bandwidth will be superior when using rectangular waveguide as compared to cylindrical waveguide.

Since many changes could be made in the above construction and many apparently widely different embodiments of this invention can be made without departing from the scope thereof it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. A microwave window apparatus including, means forming a hollow waveguide structure for transmitting microwave energy therethrough in a certain dominant waveguide transmission mode, means forming a dielectric wave permeable window structure disposed within and sealed across said waveguide to form a gas tight partition thereacross, the improvement comprising, means forming a lumped inductance to the microwave energy of the certain dominant mode disposed inside said dielectric wave permeable window structure for increasing the bandwidth of the passband of the window apparatus.

2. The apparatus of claim **1** wherein said lumped inductance means disposed inside said window structure is an inductive iris.

3. The apparatus of claim **1** wherein said lumped inductance means disposed inside said window structure includes a conductive rod extending across said waveguide with a substantial component of its length directed parallel to the electric field lines of the certain dominant transmission waveguide mode within said window structure.

4. The apparatus of claim **1** wherein said window structure, including said lumped inductance means, is dimensioned to have an electrical length taken along the direction of power flow through the window of approximately one half a wavelength at the center frequency of the passband of the window apparatus.

5. The apparatus of claim **1** wherein said lumped inductance means inside said window structure includes a conductive plate which projects from a side wall of said waveguide toward the center of said waveguide along a direction perpendicular to the electric field lines of the certain dominant waveguide mode within said window structure.

6. The apparatus of claim **1** wherein said lumped inductance means disposed inside said window structure

includes a pair of conductive rods extending across said waveguide from one side wall to an opposed side wall with a substantial component of their lengths being directed parallel to the electric field lines of the certain dominant waveguide mode within said window structure.

7. The apparatus of claim **1** wherein said dielectric window structure is a unitary dielectric member with said lumped inductance means being embedded therein.

8. The apparatus of claim **1** wherein said dielectric window structure includes a pair of spaced dielectric plates with said lumped inductance means sandwiched therebetween.

9. The apparatus of claim **8** wherein said lumped inductance means includes means defining an inductive iris.

10. The apparatus of claim **9** including in combination, a microwave tube coupled to the microwave window apparatus for feeding microwave power through said waveguide and said wave permeable window structure.

11. The apparatus of claim **9** wherein said waveguide is a rectangular waveguide.

References Cited

UNITED STATES PATENTS

3,034,079 5/1962 Uhler.

HERMAN KARL SAALBACH, *Primary Examiner.*

L. ALLAHUT, *Assistant Examiner.*

U.S. Cl. X.R.

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