

[54] MEANS AND METHOD FOR SUPPRESSING
MICROWAVE RESONANCE IN
ELLIPTICAL CAVITIES

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[51] **Int. Cl.** **H03f 3/60**

[58] **Field of Search** 330/34, 56; 331/96,
331/97, 117 D; 333/83 R, 83 A

[56]

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[57]

ABSTRACT

Means and method for suppressing resonant modes in a substantially right cylindrical elliptical cavity by suppressing the transmission of microwave energy perpendicular to the major axis of the cavity.

14 Claims, 8 Drawing Figures

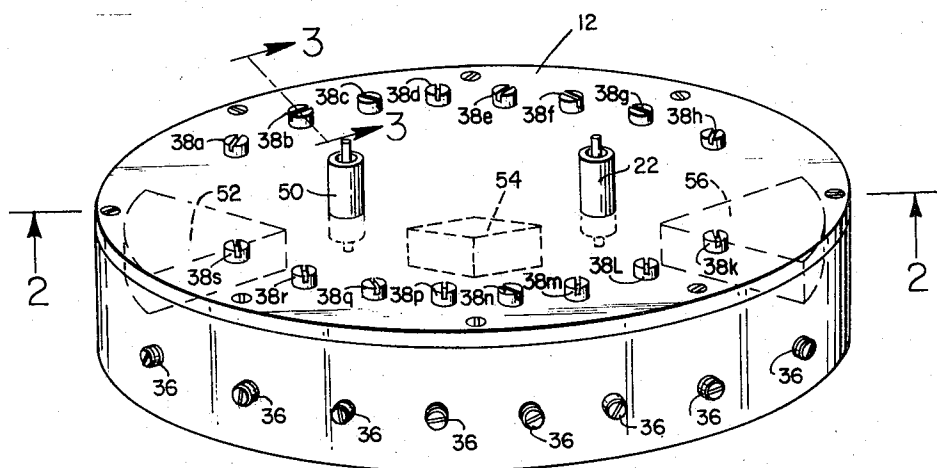


Fig.1.

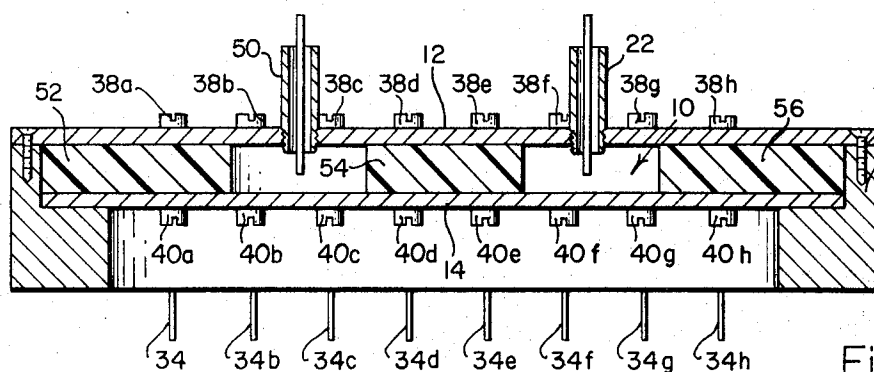
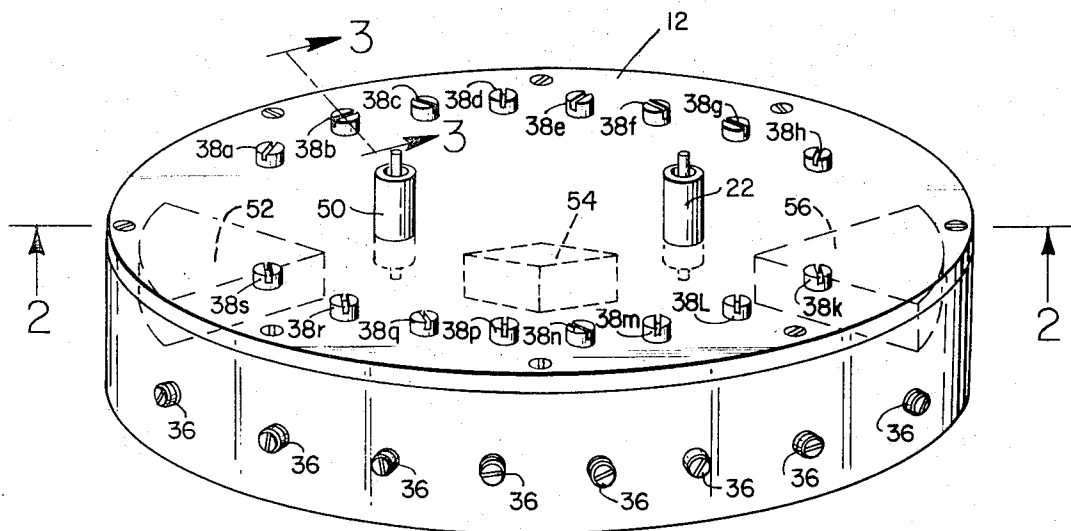


Fig.2.

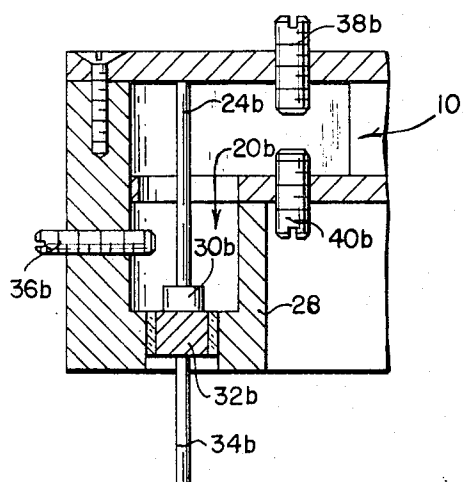


Fig.3.

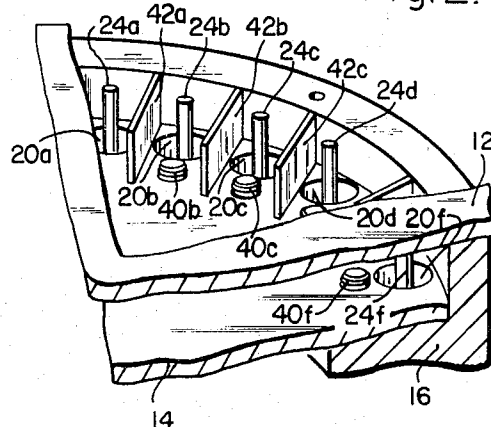


Fig.4.

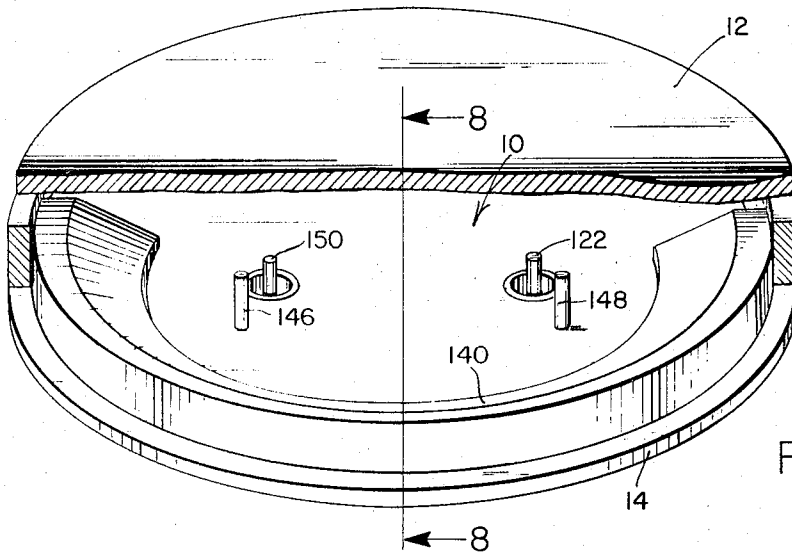


Fig. 7.

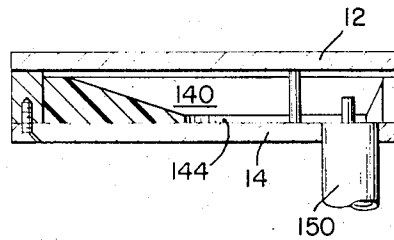


Fig. 8.

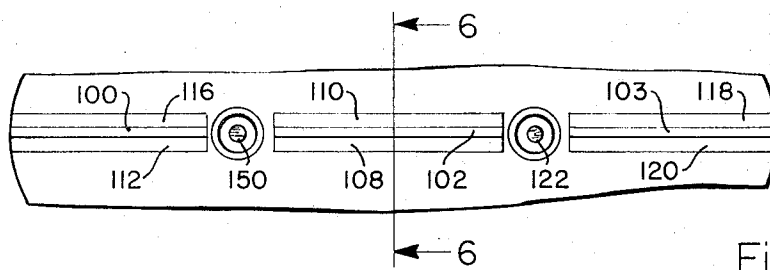


Fig. 5.

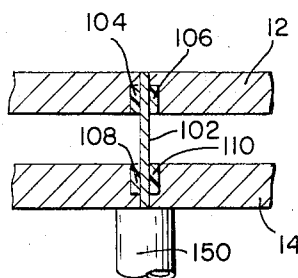


Fig. 6.

MEANS AND METHOD FOR SUPPRESSING MICROWAVE RESONANCE IN ELLIPTICAL CAVITIES

BACKGROUND OF THE INVENTION

This is one of two patent applications which are filed concurrently and which are assigned to Hughes Aircraft Company, the assignee of this application. The other patent application is, "Elliptical Structure for Combining the Power of Many Microwave Sources" by Henry G. Oltman, Jr. and Hans A. Maurer.

Prior means for combining the microwave output of many diode amplifiers include arrangements of diodes along and coupled to a transmission line, either used as oscillators phase-locked to an independent source, as described by W. O. Schlosser and A. L. Stillwell in the Proceedings of the IEEE, September 1968, at page 1588; or used as amplifiers in a two-port structure, as described by M. E. Hines, in the 1968 Digest of G-MTT International Microwave Symposium, Detroit, Michigan, May 1968 on pages 46-53.

Another means for combining the power output of many diode amplifiers includes an array of sources feeding antenna radiating elements with the power combined in free space as described in D. Staiman, M. Breese, and W. T. Patton, in a Digest of Papers of the International Solid State Circuits Conference, Feb. 15, 1968, at pages 88 and 89.

Still another means for combining the microwave power output of many diode amplifiers includes the use of a series of diodes in a coaxial cavity as described by F. M. Magalhaes and W. D. Schlosser, Digest of Technical Papers, International Solid State Circuits Conference, Feb. 16, 1968, at pages 150 and 151.

It has also been suggested to use hybrid junctions to collect the powers of many diodes. A conventional waveguide resonator or a quasi-optical focused Fabry-Perot resonator may be used to intercouple and extract power from the diodes. An arrangement of either several diodes on one silicon chip or several diode chips on one heat sink may be used. Each of the techniques listed may have certain advantages over others, but the device disclosed and claimed herein has one or more advantages over each of those listed.

BRIEF DESCRIPTION OF THE INVENTION

The apparatus of this invention is adapted to attenuate or suppress the transmission of microwave energy substantially perpendicular to the major axis of a substantially right, substantially elliptical, substantially cylindrical cavity having two terminals, each being located at a different focus of the cavity. The cavity will be referred to herein as an elliptical cavity.

A signal injected at either focus radiates along radial paths from that focus to the side walls of the elliptical cavity, and there is reflected to the other focus. All paths from one focus to the other via the boundary of the elliptical cavity are equal in length, whereby all the signals at the second focus are in phase and can be removed from the cavity. By locating a plurality of amplifier modules or signal sources at the periphery of the elliptical cavity, the incident signal introduced at one focus can either be amplified by the amplifiers or used to injection phase-lock the sources (which effectively results in amplification). The amplified signal is then collected at the output terminal at the other focus of the cavity. The plurality of amplifiers or source mod-

ules are electromagnetically coupled to the microwave field within the cavity. The incident fields are amplified and retransmitted by the amplifiers in a manner analogous to reflections in a conventional reflection amplifier in other waveguide media, e.g., a tunnel diode amplifier.

The amplifier modules or phase-locked generators and coupling means can take many forms. For example, they could be coaxial cavities, each containing a diode amplifier or generator, coupled to the cavity through an iris or through a magnetic loop or probe.

The injected signals, in general, are not at resonant frequencies of the cavity. It is desirable to suppress resonant modes. That is, resonant frequency signals are unwanted signals which are unrelated to the signals being amplified. Production of unwanted signal means that part of the amplification capability of the amplifiers may be used to amplify the unwanted signals. Further, amplification of resonant signals may cause the resonant signals to reach unmanageable amplitudes, interfering with the desired operation of the apparatus.

It has been discovered that all resonant modes of the elliptical cavity have a component of travel in a direction perpendicular to the major axis of the elliptical cavity. It is therefore contemplated by this invention to suppress the modes of travel which are perpendicular to the major axis of the ellipse. It should be noted that the desired signals originating at one focus of the elliptical cavity and delivered to the other focus of the elliptical cavity never cross the major axis of the elliptical cavity.

To attenuate the resonant modes, which tend to travel across the major axis of the elliptical cavity, absorbing material or other suitable loads may be placed along the major axis of the elliptical cavity to extract power, selectively, from the resonance modes and, hence, suppress them.

The absorber may take several forms. The simplest is lossy plastic material placed along the major axis of the cavity. The plastic material may be shaped into wedges. The use of such wedges is not completely effective because not all of the desired resonant power which propagates across the major axis is absorbed by the material. Some is reflected at the interface and some propagates through because the material thickness is not sufficient completely to attenuate the wave.

A second means for suppressing resonant modes is to place a terminating wall along the major axis of the cavity. Waves of the undesired resonance modes propagate toward the terminating wall from either side. To absorb the waves completely, each half of each termination should have a termination impedance equal to one-half of the wave impedance. The impedance may be adjusted by using bulk absorbers into which the terminating wall is imbedded, or thin film resistors may be used. With proper termination, no signal will be reflected from the wall.

When the entire periphery of the cavity is not used for amplification, an absorber may be formed around the unused portion of the periphery of the elliptical cavity. The absorber preferably has a wedge-shaped cross-section. The resonant fields are propagated into the absorber and completely attenuated. Unfortunately, a signal insertion loss for the useful signal is also observed. The loss can be reduced by placing reflector antennas near the foci of the elliptical cavity to reflect

most of the energy toward the side of the cavity containing the amplifiers.

It is therefore an object of this invention to suppress resonant modes of propagation in elliptical cavities.

It is a more specific object of this invention to suppress such resonant modes wherein the elliptical cavity is a substantially right, substantially cylindrical, substantially elliptical cavity.

It is still a more specific object of this invention to suppress such resonant modes of operation by attenuating microwave energy which has a component perpendicular to the major axis of the elliptical cavity.

It is also a still more specific object of the invention to eliminate such resonant modes by terminating the propagation perpendicular to the major axis with lossy terminals along the major axis of the elliptical cavity.

It is yet a more specific object of this invention to provide means and methods for achieving the above enumerated objects.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects will become apparent from the following description, taken in connection with the accompanying drawings, in which:

FIG. 1 is an outside view of a typical substantially right elliptical cylindrical cavity, showing in dashed lines the positioning of a first embodiment of a microwave absorber which is adapted to suppress resonance modes of operation.

FIG. 2 is a sectional view, taken at 2—2 in FIG. 1.

FIG. 3 is a sectional view, taken at 3—3 in FIG. 1.

FIG. 4 is a fragmentary view, partly in section, of a portion of the apparatus of FIG. 1 with the top cover partly removed to show a typical embodiment of the coupling mechanism for coupling diode cavities to the main cavity of the apparatus.

FIG. 5 is a top view of a typical substantially right elliptical cylindrical cavity, with the top cover partly removed to show a second embodiment of a means for suppressing microwave resonance in elliptical cavities;

FIG. 6 is a sectional view taken at 6—6 in FIG. 5;

FIG. 7 is a top view of a typical substantially right elliptical cylindrical cavity, with part of the top broken away to show a third embodiment of a means for suppressing resonance modes in an elliptical cavity; and

FIG. 8 is a sectional view taken at 8—8 in FIG. 7.

DETAILED DESCRIPTION OF THE INVENTION

In FIGS. 1—4, a substantially right, substantially elliptical, substantially cylindrical microwave cavity 10 is defined by a pair of substantially elliptical top and bottom plates 12, 14 and an up-standing side wall 16 electrically contacting the top and bottom walls 12 and 14. Around the periphery of the cavity 12 are formed a plurality of smaller cavities 20A, B, C . . . , as shown particularly in FIG. 4, for receiving microwave energy from the coaxial cable 22 which is positioned substantially at one focus of the elliptical cavity. In the embodiments shown in the figures, only eight such cavities are indicated on each side of the major axis of the elliptical cavity. In practice, the cavities may be more closely spaced and a larger number of cavities, as desired, may be used. The cavity 10 is mentioned hereinafter as an "elliptical cavity."

Referring to FIG. 3, probes 24A, B, C . . . extend upward from the cavities 20A, B, C . . . into the elliptical cavity 10. The cavities 20A, B, C . . . are shown, typi-

cally, bored out of a ring 28 which depends from the side wall 16. Within each cavity 20A, B, C . . . is an amplifying diode 30A, B, C . . . , each being connected through a radio frequency choke 32A, B, C . . . to a pigtail 34A, B, C . . . to which a source of DC bias voltage (not shown) may be attached to cause the diode 30A, B, C . . . to operate in the proper range.

Within each of the cavities 20A, B, C . . . is a tuning screw 36A, B, C . . . for adjusting the cavity 20A, B, C . . . to the frequency band of the incoming and transmitted radiation. The coupling of the cavities 20A, B, C . . . to the elliptical cavity 10 is adjusted by adjusting the position of the screws 38A, B, C . . . and 40A, B, C . . . between the up-standing probes 24A, B, C . . . Between the cavities 20A, B, C . . . , septums 42A, B, C . . . may, optionally, be structured to minimize cross talk between the cavities 20A, B, C The septums 42A, B, C . . . are preferably conductive plates extending outward from the wall 16 into the cavity 10 far enough that the tuning screws 38A, B, C . . . and 40A, B, C . . . control the amount of coupling or energy delivered to and received from each of the cavities 20A, B, C

Incoming microwave energy is amplified by the diodes 30A, B, C . . . and retransmitted into the cavity 10 to the focus of the elliptical cavity where a coaxial cable 50 removes the power. It is understood that the coaxial cables 22 and 50 are representative only and that other known means for coupling microwave power into and out of the cavity 10 may be used.

When the cavities 20A, B, C . . . are operated as generators or oscillators, the incoming microwave energy phase-locks the generators so that the cumulative signal at the terminal 50, from each of the generators, arrives in phase.

Microwave power is introduced through coaxial cable 22 into the cavity 10. The power radiates radially from the axis of the coaxial cable 22 toward the cavities 20A, B, C The incident fields are amplified by the diodes 30A, B, C . . . and transmitted back to the coaxial cable 50 at the other focus of the elliptical cavity 10. All signals travel from the focus associated with the coaxial cable 22 to the focus associated with the coaxial cable 50 via the elliptical boundary of the cavity 10 along equal length paths, whereby all signals received at the coaxial cable 50 are in phase and can be removed by the coaxial cable 50.

Alternatively, the diodes 30A, B, C may be operated in an oscillatory mode, that is in an unstable condition to produce signals which, in general, would be out of phase. A small amplitude incident signal from the coaxial cable 22 injection phase-locks the sources causing them to deliver in phase signals to the coaxial 50.

It is important that resonance within the cavity 10 is suppressed. Studies indicate that all resonant modes within the elliptical cavity 10 have a component of propagation transverse to the major axis of the ellipse.

The major axis of the elliptical cavity 10 is defined as a plane normal to the top and bottom plates 12, 14, and including the major axis of the ellipse defining the cavity 10.

One means for absorbing or suppressing the resonant modes is to place an absorbing material 52, 54 and 56 along the major axis of the elliptical cavity, as shown in FIGS. 1 and 2. The absorbers 52 and 56 blank off a portion of the periphery of the cavity 10 adjacent the major axis of the cavity. The absorbers 52 and 56 taper

toward the major axis of the cavity 10 as the foci of the elliptical cavity are approached, whereby microwave signals introduced into one focus from the coaxial cable 22 are unblocked in their travel from that focus to the periphery of the cavity in the regions of the amplifying or oscillating diodes 30A, B, C The absorber 54 is positioned between the foci of the cavity, and it also tapers toward the major axis of the cavity as the foci are approached so that all regions of the periphery having amplifying or oscillating diodes 30a, b, c . . . have an unimpeded path to both the coaxial cable 22 and the coaxial cable 50.

The region of the major axis of the cavity 10 adjacent the coaxial cables 22 and 50 has no absorbing material. To place absorbing material in that region would cause portions of the desired signal to be absorbed. The question of how close to bring the absorbing material to the foci of the cavity involves an engineering trade-off. The closer the absorbing material is brought to the foci, the greater the absorption of the resonant modes, but this is traded off with greater absorption of the desired signals.

In the embodiment of FIGS. 5 and 6, a portion of the top wall 12 of the cavity 10 is broken away in the region of the major axis of the cavity. The coaxial cables 122 and 150 are inserted in the bottom 14 of the cavity at the foci of the elliptical cavity 10. Upstanding metallic or highly conductive walls 100, 102 and 104 are embedded in the metallic walls 12 and 14, as shown in FIG. 6, and extend along the major axis of cavity 10 to intercept microwaves propagating perpendicular to the major axis of the elliptical cavity. Channels of lossy material, such as that shown at 104, 106, 108 and 110, are imbedded in the walls 12 and 14 adjacent the upstanding wall 102. Similar channels of lossy material, such as that shown at 112, 116, 118 and 120 are embedded in the walls 12 and 14 adjacent the upstanding conductive walls 100 and 104. In the region of the coaxial cables 122 and 150 no barrier exists, but the walls 100, 102 and 103 suppress most of the propagation perpendicular to the major axis of the cavity 10 and therefore suppress the resonant modes of the cavity 10. In a preferred embodiment of the apparatus of FIGS. 5 and 6, the terminating impedance experienced by microwaves incident upon the upstanding walls 100, 102 and 103 should be equal to the wave impedance. This may be accomplished by making the lossy material 104, 106, 108, 110, 112, 116, 118, 120 of a bulk absorber. Alternatively a thin-film resistor could, for example, be used. With a termination equal to the wave impedance, no signals are reflected from the upstanding walls 100, 102, and 103.

It is within the contemplation of this invention that other known terminations having a terminating impedance equal to the wave impedance can be positioned along the major axis of the elliptical cavity, thereby to suppress the resonant modes.

A third embodiment of the means for suppressing resonant modes in an elliptical cavity is shown in FIGS. 7 and 8. Amplifying modules are placed around half of the perimeter of the elliptical cavity. A wedge-shaped absorber 140 is placed around the periphery of the other half of the elliptical cavity. All microwaves have a resonant modes propagate fields into the absorber and are attenuated. However, this technique introduces a signal insertion loss because useful signal is also radiated directly into the absorber from the foci of the cavity.

ity. The absorber 140 is preferably tapered toward the inner periphery in the region of the major axis of the cavity as shown at 144. To reduce the signal insertion loss, reflector elements such as the reflector elements 146 and 148 are placed near the foci to reflect most of the energy toward the amplifier side of the cavity 10.

Thus, the method of this invention is to suppress modes of propagation perpendicular to the major axis of the elliptical cavity. Several means for suppressing such modes have been described as shown herein. With the resonant modes suppressed, the entire capacity of the various amplifiers and phase-locked oscillators used in the apparatus is available to amplify the desired signal.

Although the invention has been described in detail above, it is not intended that the invention should be limited by that description, but only in accordance with that description in combination with the appended claims.

What is claimed is:

1. In combination:

a microwave cavity shaped substantially in the form of a right elliptical cylinder;

means for introducing microwave energy into said

cavity at one focus thereof;

means on the periphery of said cavity for producing signals of greater amplitude than signals received at said periphery from said focus;

means, positioned at the second focus of said cavity for removing microwave energy therefrom; and

means for suppressing propagation of microwave energy across the major axis of said cavity.

2. Apparatus as recited in claim 1 in which said means for suppressing propagation of microwave energy across the major axis of said cavity comprises:

microwave absorbing material positioned within said cavity in the region of said major axis.

3. Apparatus as recited in claim 1 in which said means for suppressing propagation perpendicular to said major axis comprises:

a microwave terminal along a substantial portion of said major axis for preventing propagation across said major axis, and termination means, electrically connected to said terminal to absorb microwave energy incident upon said terminal.

4. Apparatus as recited in claim 3 in which said termination has an impedance substantially equal to the wave impedance of said microwave energy.

5. Apparatus as recited in claim 3 in which said terminal comprises a highly conductive wall blocking said cavity along a portion of said major axis.

6. Apparatus as recited in claim 5 in which said wall is metallic.

7. Apparatus as recited in claim 5 in which the impedance of said absorbing material is equal to substantially the wave impedance of said microwave energy.

8. In a substantially right cylindrical elliptical microwave cavity, including two planar walls thereof, means for introducing microwave energy into said cavity at one focus thereof, means disposed on the periphery of said cavity for amplifying microwave energy received at said periphery, means disposed at the other focus of said elliptical cavity for removing microwave energy from said cavity, and means for suppressing resonant modes comprising:

means for inhibiting propagation of microwave energy across the major axis of said cavity.

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9. Apparatus as recited in claim 8 in which said means for inhibiting comprises means for terminating microwave energy at the major axis of said cavity.

10. In a substantially right cylindrical elliptical microwave cavity, including two planar walls thereof, means for suppressing resonant modes comprising:
means for inhibiting propagation of microwave energy across the major axis of said cavity; with said means for inhibiting including means for terminating microwave energy at the major axis of said cavity, and with said means for terminating including a highly conductive wall positioned along the major axis of said cavity, and resistive material electrically connected to said wall.

11. Apparatus as recited in claim 10 in which said wall is metallic.

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12. Apparatus as recited in claim 10 in which said resistive material is embedded in contact with said barrier and the two planar walls of said cavity.

13. Apparatus as recited in claim 12 in which the impedance of said means for terminating is equal to substantially the wave impedance of propagating microwave signals in said cavity.

14. In a substantially right cylindrical elliptical microwave cavity, including two planar walls thereof, means for suppressing resonant modes comprising:

means for inhibiting propagation of microwave energy across the major axis of said cavity; with said means for inhibiting including microwave absorbing material positioned within said cavity along at least a portion of the major axis of said cavity.

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