

- [54] **ELLIPTICAL STRUCTURE FOR
COMBINING THE POWER OF MANY
MICROWAVE SOURCES**
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City, Calif.
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333/83 R, 333/83 A
- [51] Int. Cl. **H03f 3/10, H03f 3/60**
- [58] Field of Search 330/34, 56; 331/96,
331/97, 117 D; 333/83 R, 83 A

[56] **References Cited**

UNITED STATES PATENTS

2,428,780 10/1947 Bowen 333/83 R

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[57] **ABSTRACT**

A non-resonant microwave cavity shaped substantially in the form of a right elliptical cylinder, means for introducing microwave energy at one focus of the elliptical cavity and removing microwave energy at the other focus of the elliptical cavity; and means on the periphery of the elliptical cylindrical cavity for amplifying incident microwave energy and for retransmitting it; whereby microwave energy introduced into the cavity at one focus of the ellipse is amplified by a plurality of microwave amplifiers, and the amplified energy is delivered to the other focus in phase. Because the total distance from the input focus to the periphery of the cavity and back to the output focus is the same for all points on the periphery of the elliptical cavity. Alternatively microwave signals may be generated by a plurality of microwave generators at the periphery of the cavity, the generators being phased by microwave signals from the input focus of the cavity to cause high energy microwave signals from the generators to be in phase at the output focus of the cavity.

9 Claims, 4 Drawing Figures

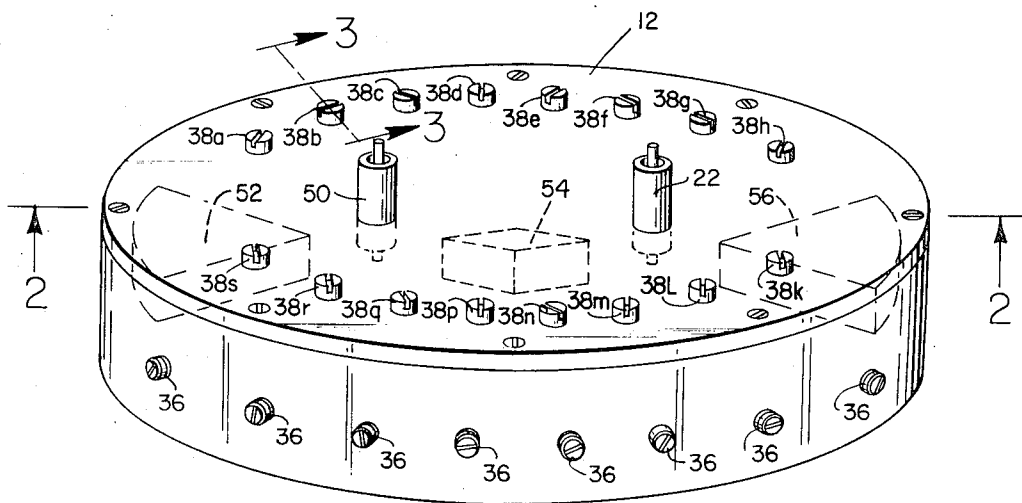


Fig.1.

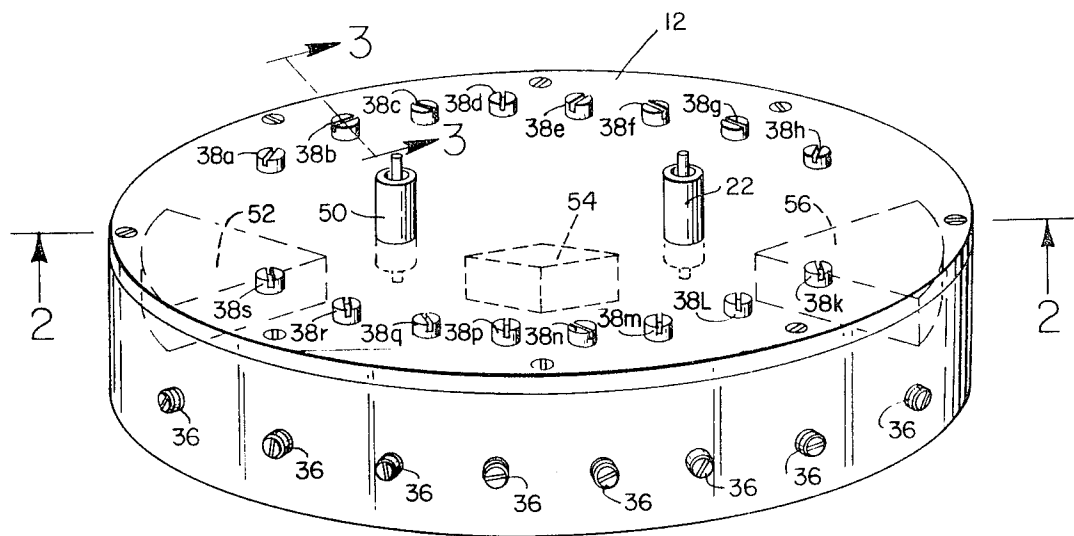
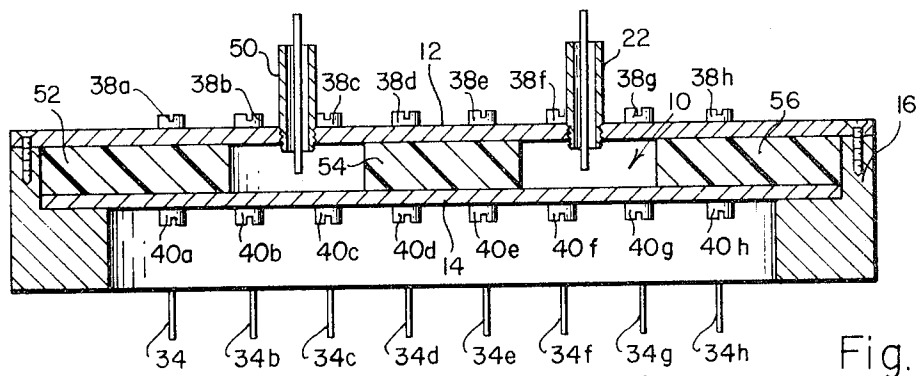


Fig.2.

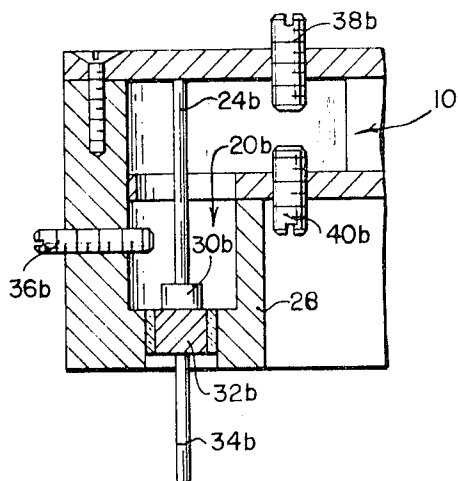


Fig.3.

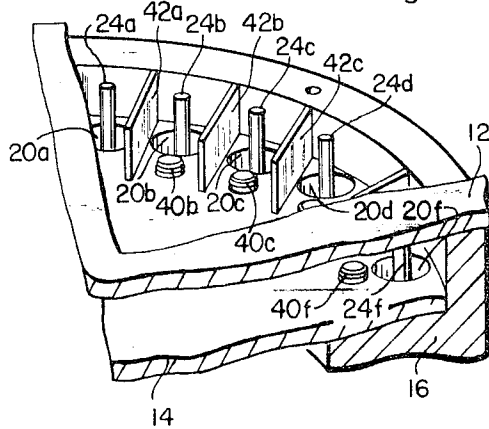


Fig.4.

ELLIPTICAL STRUCTURE FOR COMBINING THE POWER OF MANY MICROWAVE SOURCES

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, "Means and Method for Suppressing Microwave Resonance in Elliptical Cavities" by Henry G. Oltman, Jr.

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, Sept. 1968, at page 1588; or used as amplifiers in a two-part 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 by D. Staiman, M. Breese, and W. T. Patton, in a Digest of Papers of the International Solid State Circuits Conference, 15 Feb. 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, 16 Feb. 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 intercoupled 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 advantages of the device disclosed are:

1. It is broadband. Its only band-limiting feature may be in the feed structure which can be made very broad band.
2. The structure feeds all of the periphery sources or amplifiers in parallel, whereby the failure of any one or a small fraction of the sources does not significantly affect the power output. Considered as an amplifier, each diode interacts only with its fractional share of the input signal, and at most, can cause the loss of only that fraction. This is contrasted with serial arrangements in which each diode interacts with all of its incident signal.
3. A large number of diode sources can be used to produce a large output signal.
4. The form of the device offers the advantage of easy accessibility to each diode source for application of operating power and removal of heat dissipated in each source.

5. The form of the device offers the advantage of combining several structures in series and/or parallel for increased gain of output power.

6. As an amplifier or as an injection phase-locked oscillator, the device permits the excitation of all the diode sources with approximately equal input power. This permits the manufacture of diode sources which are substantially identical and have equal the electromagnetic coupling to the device.

7. The device is a large closed cavity in which spurious resonances could occur. This structure has the advantage over other related structures in that resonance suppressing absorbers can be located to suppress the resonance modes while still having a negligible effect on the desired propagation of microwave energy therein.

The apparatus of this invention uses 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 modules 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.

There are no frequency dependent characteristics of the elliptical structure of the cavity. The terminal transducers and the amplifier modules introduce whatever frequency dependence the apparatus may have. Each of these auxiliary parts can be made very broadband.

It is therefore an object of this invention to amplify microwave signals.

It is a more specific object of this invention to provide apparatus and method for producing high powered microwave signals.

It is a still more specific object of this invention to use a microwave cavity which is shaped substantially as a right elliptical cylinder adapted to receive microwave energy from a terminal at one focus thereof and to deliver microwave energy from a terminal at the other focus thereof.

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 cavity which is constructed in accordance with this invention, showing in dashed lines the positioning of a typical microwave absorber which is adapted to suppress resonance modes of operation. The diode modules or generators for amplifying signals introduced at one of the foci and for delivering energy to the output connection at the other focus are not shown in this figure.

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.

DETAILED DESCRIPTION OF THE INVENTION

FIGS. 1-4 teach and show the basic concept of the invention. Referring to those figures, 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 10 are formed a plurality of smaller cavities 20A, B, C 111, 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 show, typically, 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 pig-tail 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. Another mode of operation is to use a pulsed D.C. voltage to provide energy to the diodes.

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.

It is important that resonances within the cavity 10 is suppressed. 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.

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 cable 50.

Although the apparatus operates without absorbers 52, 54 and 56, it operates better with the resonant modes suppressed. The absorbers 52, 54 and 56 are merely representative of the resonance suppressors which are described and claimed in a copending patent application filed concurrently herewith by Henry G. Oltman, Jr. for "Means and Method for Suppressing Microwave Resonance in Elliptical Cavities" which is assigned to Hughes Aircraft Company, the Assignee of this invention.

The apparatus described and claimed herein is an efficient broadband means for combining microwave power which is separately amplified or produced, to deliver a large microwave 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 by that description taken in combination with the accompanying claims.

We claim:

1. In combination:
a cavity shaped substantially in the form of a right elliptical cylinder;
means for introducing 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; and
means, positioned at the second focus of said cavity for removing energy therefrom.
2. Apparatus as recited in claim 1 in which said energy is microwave energy.
3. In combination:
a conductive cavity, adapted to contain microwave signals, shaped substantially in the form of a right elliptical cylinder;
a plurality of amplifying means, positioned on the periphery of said cavity;

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means for introducing microwave energy into said cavity at a first focus thereof; and
means for extracting microwave energy at the other focus thereof.

4. Apparatus as recited in claim 3 in which said amplifying means comprises a plurality of amplifiers, positioned on the periphery of said cavity to receive energy from said first focus of said cavity and to deliver amplified energy to said second focus of said cavity.

5. Apparatus as recited in claim 4 in which said amplifiers are diode amplifiers.

6. Apparatus as recited in claim 3 in which said amplifying means comprises a plurality of microwave oscillators positioned on the periphery of said cavity, phase locked with signals received from said first focus and adapted to deliver signals to said second focus,

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whereby signals from said plurality of oscillators arrive at said second focus in phase and large amounts of microwave power may be extracted from said cavity at said second focus.

7. Apparatus as recited in claim 6 in which said oscillators are diode oscillators.

8. Apparatus as recited in claim 3 in which said means for introducing microwave energy at said first focus and means for removing microwave energy at said second focus of said elliptical cavity are coaxial cables.

9. Apparatus as recited in claim 3 in which said elliptical cavity is non-resonant at the microwave frequencies introduced into said cavity.

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