United States Patent [19]

Quirk

[11] **3,842,361**

[45] **Oct. 15, 1974**

[54] **MICROWAVE AMPLIFIER**

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[73] Assignee: **General Electric Company**, Owensboro, Ky.

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[52] **U.S. Cl.** **330/56**, 331/96, 333/83

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

[58] **Field of Search** 330/53, 56; 331/96–98; 333/83

[56] **References Cited**

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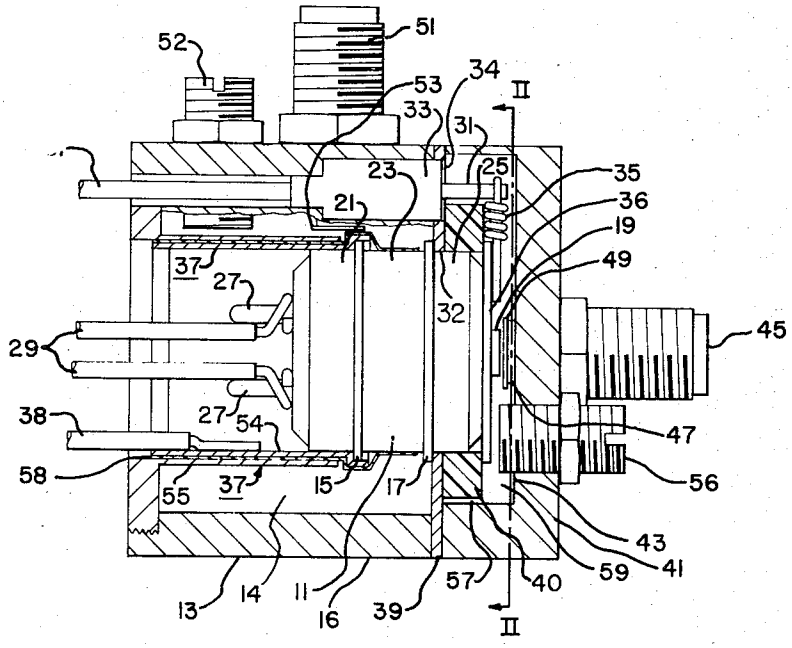
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Primary Examiner—Stanley D. Miller, Jr.
Attorney, Agent, or Firm—N. J. Cornfeld; D. A. Dearing; F. L. Neuhauser

[57] **ABSTRACT**

A double-tuned microwave amplifier comprising an outer conductive shell, a controlled charge carrier device disposed within said shell, and means operatively dividing the shell into two radial transmission mode, double-tuned cavities upon energization thereof by said device.

10 Claims, 4 Drawing Figures



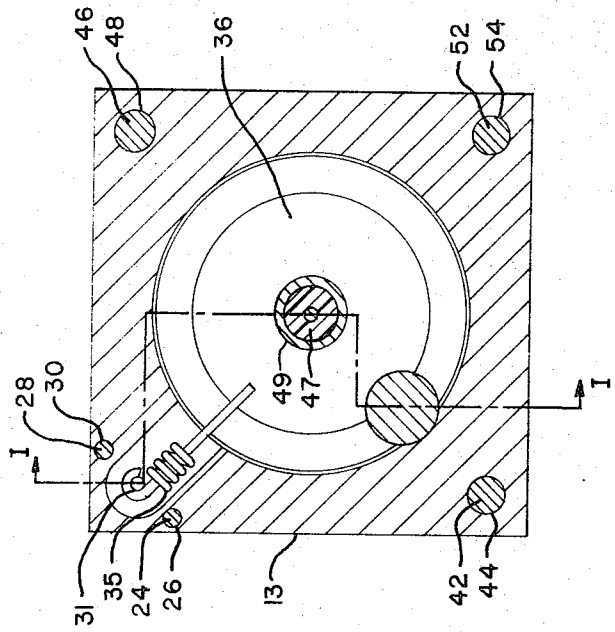

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I
I
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FIG. 2

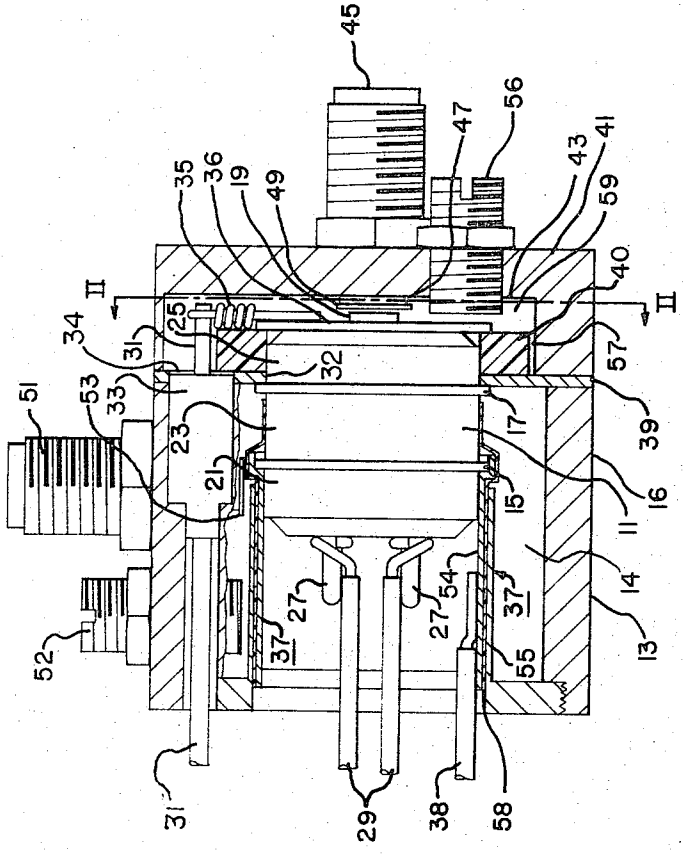

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II
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FIG. 1

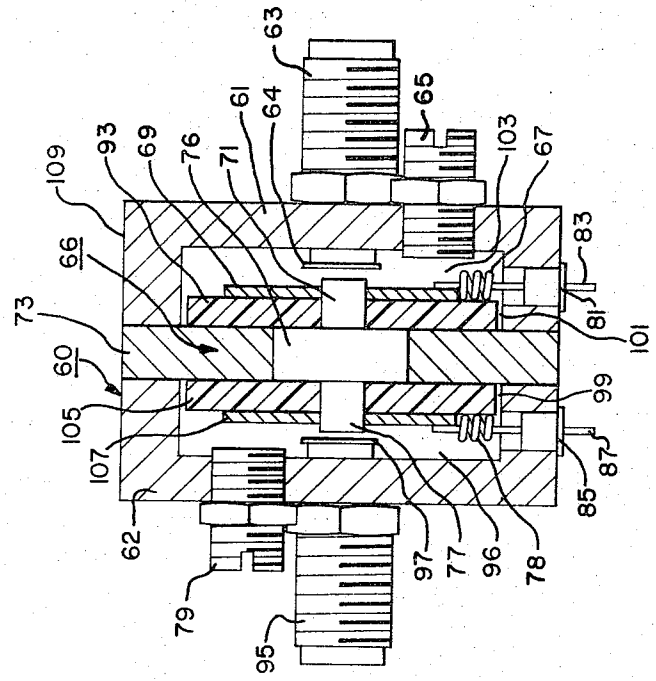

63
65
64
61
93
69
76
71
109
103
67
66
83
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81
101
60
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87
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77
96
78
79
95

FIG. 4

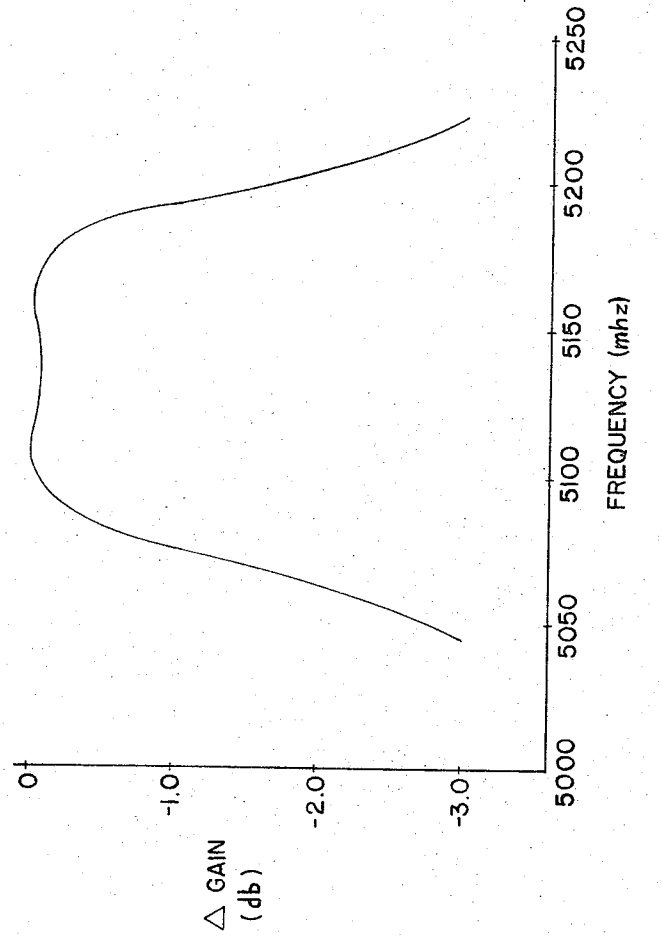

0
-1.0
-2.0
-3.0
Δ GAIN (db)
5000
5050
5100
5150
5200
5250
FREQUENCY (mhz)

FIG. 3

MICROWAVE AMPLIFIER

BACKGROUND OF THE INVENTION

This invention relates to the art including microwave amplifiers, and more specifically, to such amplifiers having double-tuned radial cavity characteristics.

A well known type of microwave circuit is comprised of a triode tube designed for operation at microwave frequencies and an associated circuitry in the form of distributed constant transmission line sections. One common form which has been utilized to amplify and/or generate energy in the microwave energy band comprised so-called "coaxial" transmission line sections. More recently, in order to provide amplification and/or generation of microwave energy with substantially reduced overall size and with more compact configuration, it has been proposed to utilize radial modes of propagation in place of the earlier developed coaxial modes. An example of such device for generation of microwave energy but not amplification thereof is found in U.S. Pat. No. 3,718,869 to H. W. A. Gerlach and assigned to the United States of America as represented by the Secretary of the Army. While the device disclosed and claimed therein may be operative to effect a foreshortening of its overall dimensions, this device, because it discloses only a single-tuned cavity oscillator, is devoid of any suggestion of the double-tuned radial cavity amplifier of this invention.

SUMMARY OF THE INVENTION

It is, accordingly, a principal object of this invention to provide a microwave amplifier characterized by a circuit having a radial transmission mode wherein a double-tuned response characteristic is provided, thereby to achieve substantially increased gain-bandwidth product for such amplifier.

In accordance with the invention, a double-tuned microwave amplifier is provided having means defining a first radial mode resonant cavity between two terminals of a controlled charge carrier device and a second radial mode resonant cavity defined by one of said terminal and an inner wall of a conductive enclosure for said amplifier.

These and other objects of this invention will be better understood from the following description taken in connection with the accompanying drawings.

BRIEF DESCRIPTION OF DRAWING

FIG. 1 is an axial section of one embodiment of the invention with parts broken away for clarity.

FIG. 2 is a cross section of the device of FIG. 1 taken along the line II—II of FIG. 1.

FIG. 3 is a graph of the power gain of the double-tuned amplifier of the embodiment of FIG. 1.

FIG. 4 is an axial section of another embodiment of this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIGS. 1 and 2, a controlled charge carrier device 11 is shown mounted within a conductive shell 13 which is constructed in accordance with the features of my invention in order to provide the double-tuned response characteristic. The shell 13 is here shown as having an exterior square cross section. It will be understood that this configuration is merely

exemplary, the shape being related for convenience only. The interior cross-sectional configuration is shown to be circular; however, it will be understood that other configurations such as elliptic, rectangular or other configuration well known in the art may be used within the scope of this invention.

The view shown in FIG. 1 is substantially taken along line I—I of FIG. 2. Some elements, which, strictly speaking, would not be visible when viewed along line I—I, have been added to the view of FIG. 1 to show their relationship therein.

The shell 13 is formed with a main body portion 16 and is provided with a closure cap 41 having a centrally provided recess 43 and having a central aperture through which the RF output coupling 45 is passed for purposes explained hereinbelow. The closure cap is secured to the main body portion of shell 13 by securing means 24, 28, 42, 46, and 52 inserted through closure cap apertures 26, 30, 44, 48, and 54, respectively, and through aligned openings in a conductive plate 39 and ultimately fixedly secured in the main body portion 16.

The controlled charge carrier device 11, as shown in FIG. 1, may be a triode, which may be of any conventional variety of high frequency planar electrode ceramic-metal construction. As is well known, such a triode is provided with cathode, grid and plate electrodes (not shown) with a cathode terminal 15, grid terminal 17, and anode terminal or stud 19, respectively, conductively connected to the associated electrode. The electrodes, as is well known, are separated by ceramic insulators 21, 23, and 25. The cathode is indirectly heated by current supplied from a source of heater current (not shown) connected in any conventional manner to pins 27 through heater wires 29.

DC bias on the anode of the triode is provided, in any conventional manner, from a DC source (not shown) such as through, in order, lead wire 31, conventional quarter wavelength choke 33, lumped constant choke 35, and lastly, a conductive disc 36 which is conductively connected to the anode stud 19. The choke 33 is preferably formed as a distributed constant choke which in this instance would be a quarter wavelength at the desired operating frequency of the device to minimize leakage of RF energy through the line to the source of DC. The conductive disc 36 is provided with a central aperture through which the anode stud 19 passes in a tight fit, the disc 36 being spaced from the plate 39 by means of an insulating disc 40. The disc 40 may be constructed of beryllia or other heat conductive material and thus provides a heat conductive path to the shell 13. The use of the disc 40 is optional and may be omitted if not required.

Inasmuch as the shell 13 of the device is normally maintained at ground potential, the cathode terminal 15 of the device is supported by means of a distributed constant quarter wavelength cathode choke 37 formed by a cathode line 55 and an inner coaxial wall 54, thereby isolating the cathode terminal from ground potential in the manner well known to those skilled in the art. Direct current connection to the cathode of the triode is provided in any conventional manner such as by lead wire 38 secured to the inner coaxial wall 54 of choke 37, the inner wall 54 being conductively connected to the cathode terminal 15. The inner wall 54 is surrounded by a layer of insulation 58 to electrically

insulate it from the cathode line **55** which is electrically connected to shell **13.**

The conductive plate member **39,** which as disclosed above is fixedly secured to the shell **13,** is also conductively connected to the grid terminal **17.** Apertures **34, 32** are provided in said plate to permit the passage therethrough of the connection **31** from the quarter wave anode choke **33** and the ceramic anode insulator **25,** respectively.

The RF output coupling **45** may be of any conventional type such as that used in the coaxial designs. The inner terminal **47** thereof may be provided with a disc-like probe **49** which, as shown, is positioned in spaced relation to the anode stud **19** of the tube.

RF input is supplied through a conventional terminal **51** having a probe **53** located in the cathode cavity **14** formed by the cathode line **55** in capacitive relation with the interior wall of the main body portion **16** of shell **13.**

In operation, and assuming that the tube has been supplied with the conventional DC potential, heater current, and an RF input, a first anode cavity **57** operating in a radial transmission mode is formed in accordance with the invention between the plate **39** and the surface of disc **36** that is in juxtaposition with the adjacent surface of the anode ceramic **25.** A second radial mode anode cavity **59** is formed between the remote or free surface of the disc **36** and the inner wall of the recess **43.**

Coupling between the first and second anode cavities **57, 59** is achieved through a transfer of electromagnetic wave energy from the conductive enclosure for first anode cavity **57** represented by conductive plate **39,** the inner wall of the recess **43** and the surface of disc **36** adjacent the anode ceramic **25** to the conductive enclosure for the second anode cavity **59** represented by the inner wall of closure cap **41** and the surface of conductive plate **36** opposite anode ceramic **25** in accordance with principles well known in the art.

An input tuning screw **52** mounted in shell **13** is provided in cathode cavity **14.** Adjustment of the tuning screw **52** adjusts the electrical characteristics of the cathode cavity in a well known manner. Similarly, an output tuning screw **56,** mounted in closure cap **41,** is provided in the second anode cavity **59** for adjustment of the electrical characteristics thereof. Also, the insulator **40** provides dielectric loading of the resonant cavity **57.** However, it may be omitted and the loading effect thereof be replaced by other conventional tuning means.

To illustrate the response characteristics of a double-tuned radial cavity amplifier constructed in data taken from this amplifier, with this invention, an amplifier was made substantially as shown in FIGS. **1** and **2** using a conventional high-frequency triode tube type as the controlled charge carrier device. The amplifier so constructed was operated with a DC voltage source in the anode circuit of 700 volts with a power output of 150 watts. FIG. **3** shows a graphical representation of data taken from this amplifier, the ordinate being calibrated for the change in power gain from a reference level of 10.8 db. (corresponding to the "0" ordinate value) and the abscissa being calibrated to indicate frequencies in megahertz between 5,000 and 5,250. As can be seen, the graphical representation of this data shows the characteristic form of a conventional double-tuned amplifier. It is significant to note that as shown in FIG. **3** the power gain achieved over this bandwidth was approximately 10.8 db. as denoted by the flattened portion of the curve approximately between 5,100 and 5,175 mhz. To recognize the significance of the 10.8 db. gain achieved by this amplifier, it may be compared to the gain achievable with prior art coaxial single-tuned amplifiers which can achieve a gain of approximately 8 db. over 15 to 25 mhz. bandwidth. From this, it is clear that the gain bandwidth product of this embodiment of the invention is a great improvement over that achieved with prior art amplifiers.

Referring to FIG. **4,** a second embodiment constructed in accordance with the invention herein is shown wherein transistor **66** is used as the controlled charge carrier device. The transistor **66** is supported with a shell **60** to provide a doubletuned response similar to that achieved with the embodiment shown in FIGS. **1** and **3.** The transistor **66,** which may be of a conventional three-terminal construction, has a collector, base, and emitter (not shown) with collector, base, and emitter terminals **71, 76,** and **77,** respectively, attached thereto. The transistor may be of any conventional construction and further may be either a P-N-P or N-P-N type.

The shell **60** is provided with end walls **61** and **62** and a main body portion **109.** The RF output coupling **63** and input coupling **95** are supported in end walls **61** and **62,** respectively. A conductive plate **73** is coupled between the base terminal **76** and the walls of the main body portion **109** of shell **60** and divides the shell **60** into two conductive chambers. A heat conductive insulator **93** is positioned around collector terminal **71** to insulate plate **73** from a conductive plate **69** which is DC connected to the end of collector terminal **71.** The insulator also aids in supporting the disc **69.** Similarly, a heat conductive insulator **105** is positioned around emitter terminal **77** to insulate conductive plate **73** from a conductive plate **107,** which is DC connected to the emitter terminal **77.** The insulators **105, 107** function in a similar manner to the insulator **40** (FIG. **1**) and, likewise, may be omitted if desired.

The RF output coupling **63** may be in accordance with that shown in FIG. **1.** The disc-like probe **64** of coupling **63** is spaced from the collector **71** and the conductive plate **69** to provide RF coupling therebetween in accordance with well known principles.

Similarly, the RF input coupling **95** in end wall **62** has a disc-like probe **97** spaced from emitter terminal **77** and conductive plate **107** to provide an RF input to the transistor **66.** The RF input is preferably transmitted as shown in FIG. **4** through double-tuned radial transmission mode cavities **96, 99.** The first input cavity **96** is formed by the inner surface of end wall **62** and the surface of plate **107** remote from spacer **105.** The second emitter cavity **99** is formed by the surface of plate **107** interfaced with spacer **105** and the surface of plate **73.** Coupling between cavities **96, 99** is in accordance with the principles discussed in regard to the cavities **57, 59** of the embodiment of FIG. **1** except that the energy is coupled from the outermost cavity **96** to the innermost cavity **99** rather than from the innermost cavity **57** to the outermost cavity **59.**

It will be apparent to those skilled in the art that a single-tuned resonant emitter cavity may be substituted for the double-tuned emitter cavity shown in FIG. **4.**

DC bias to the emitter terminal **77** is provided, in any conventional manner, such a current path through, in

order, lead wire **87**, passing through a feed-through capacitor **85** in the shell **60**, a conventional lumped constant choke **78** and conductive plate **107** which is electrically connected to emitter terminal **77**.

DC bias to the collector may be provided in any conventional manner such as along the circuit path through, in order, lead wire **83**, passing through a feed-through capacitor **81** in shell **60**; a conventional lump constant choke **67** and the conductive plate **69** which is electrically connected to collector terminal **71**.

The operation of the embodiment of FIG. **4** is essentially the same as that of the embodiment of FIGS. **1** and **2**. With proper DC biases placed on the emitter and collector terminals **77, 71** and with an RF input supplied to terminal **95**, a first collector cavity **101** operating in the radial transmission mode is formed by the plate **73**, and the surface of plate **69** juxtaposed the adjacent surface of the insulator **93**. A second radial mode anode cavity **103** is formed by inner surface of end wall **61**, the surface of plate **69** opposite the insulator **93**.

Coupling between the radial cavities **101, 103** is in accordance with that discussed in regard to the embodiment of FIGS. **1** and **2**.

Tuning screws **65** and **79** are provided in end walls **61, 62**, respectively, and enable fine tuning of the cathode cavity **96** and second radial cavity **103**, respectively, according to principles well known in the art.

It will be apparent to those skilled in the art that an amplifier constructed in accordance with the invention herein may be operated with the anode cavities either "double-tuned" (i.e., tuned to the same frequency) or "stagger-tuned" (i.e., tuned, respectively, to complementary frequencies on each side of a center frequency) in accordance with well known principles such as set forth in Electronic and Radio Engineering, McGraw-Hill Electrical and Electronic Engineering Series, Chapter 12, pp. 400–442 (**4**th Ed., 1955).

The invention thus described provides a new and improved microwave amplifier having a compact design and, more particularly, having a double-tuned radial transmission mode resonator yielding an improved power gain bandwidth product.

While the invention has been shown and described with respect to specific embodiments thereof, it is not intended to be limited to the particular forms shown and described. Accordingly, the appended claims are intended to cover all modifications within the spirit and scope of the invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A microwave frequency amplifier comprising:

a. a conductive shell having a main body and at least one end wall, said main body having a longitudinal axis of symmetry intersecting said at least one end wall;

b. a controlled charge carrier device for operation at microwave frequencies supported within said shell, said device having first, second, and third terminals;

c. an RF input terminal supported in said shell electrically coupled to said first terminal;

d. means in said shell defining a first resonant cavity between the second and third terminals of said device radially of said axis and a second resonant cavity between said third terminal and said at least one end wall radially of said axis;

e. coupling means for transmitting electromagnetic energy from said first to said second cavity; and

f. a double-tuned radial resonant circuit being provided by the electromagnetic coupling of said cavities upon RF energy being supplied to the RF input, thereby energizing said device and said cavities to operate at microwave frequencies.

2. The amplifier of claim **1** wherein said cavity defining means comprises a first conductive plate electrically connected to the second terminal of said device and to the main body portion.

3. The amplifier of claim **2** wherein said cavity defining means further comprises a second conductive plate electrically coupled to the third terminal, said first cavity being formed between said first and second plates and said second cavity being formed between said at least one end wall and said second plate; and wherein an RF output coupling is mounted in said at least one end wall for coupling microwave energy out of said shell.

4. The amplifier of claim **1** further comprising a first input means in said shell defining a first input cavity radially of said axis for transmitting electromagnetic energy from said RF input to said first terminal.

5. The amplifier of claim **1** further comprising a second input means defining a second input resonant cavity radially of said axis, said second input cavity being electromagnetically coupled between said first input cavity and said first terminal to transmit electromagnetic energy therebetween.

6. Microwave frequency amplifier comprising:

a. a conductive enclosure;

b. a controlled charge carrier device having at least two terminals, said device being supported within said conductive enclosure;

c. means in said enclosure defining a first radial mode resonator circuit between two of said at least two terminals and a second radial mode resonator circuit between one of said two terminals and said enclosure, said first and second resonator circuits being energized by operation of said controlled charge carrier device at microwave frequencies; and

d. means coupling said first and second resonator circuits to provide a double-tuned resonator arrangement, thereby to provide increased gain-bandwidth for said amplifier.

7. The amplifier of claim **6** wherein said circuit defining means comprises a first conductive plate electrically connected to the other of said two terminals of said device and to said enclosure.

8. The amplifier of claim **7** wherein said conductive enclosure comprises a main body portion and at least one end wall and wherein said circuit defining means further comprises a second conductive plate electrically coupled to said one terminal, said first cavity being formed between said first and second plates and said second cavity being formed between said second plate and said at least one end wall.

9. The amplifier of claim **6** wherein said device is a triode, said one terminal being an anode terminal, said other terminal being a grid terminal.

10. The amplifier of claim **6** wherein said device is a transistor, said one terminal being a collector terminal, said other terminal being a base terminal.

* * * * *