

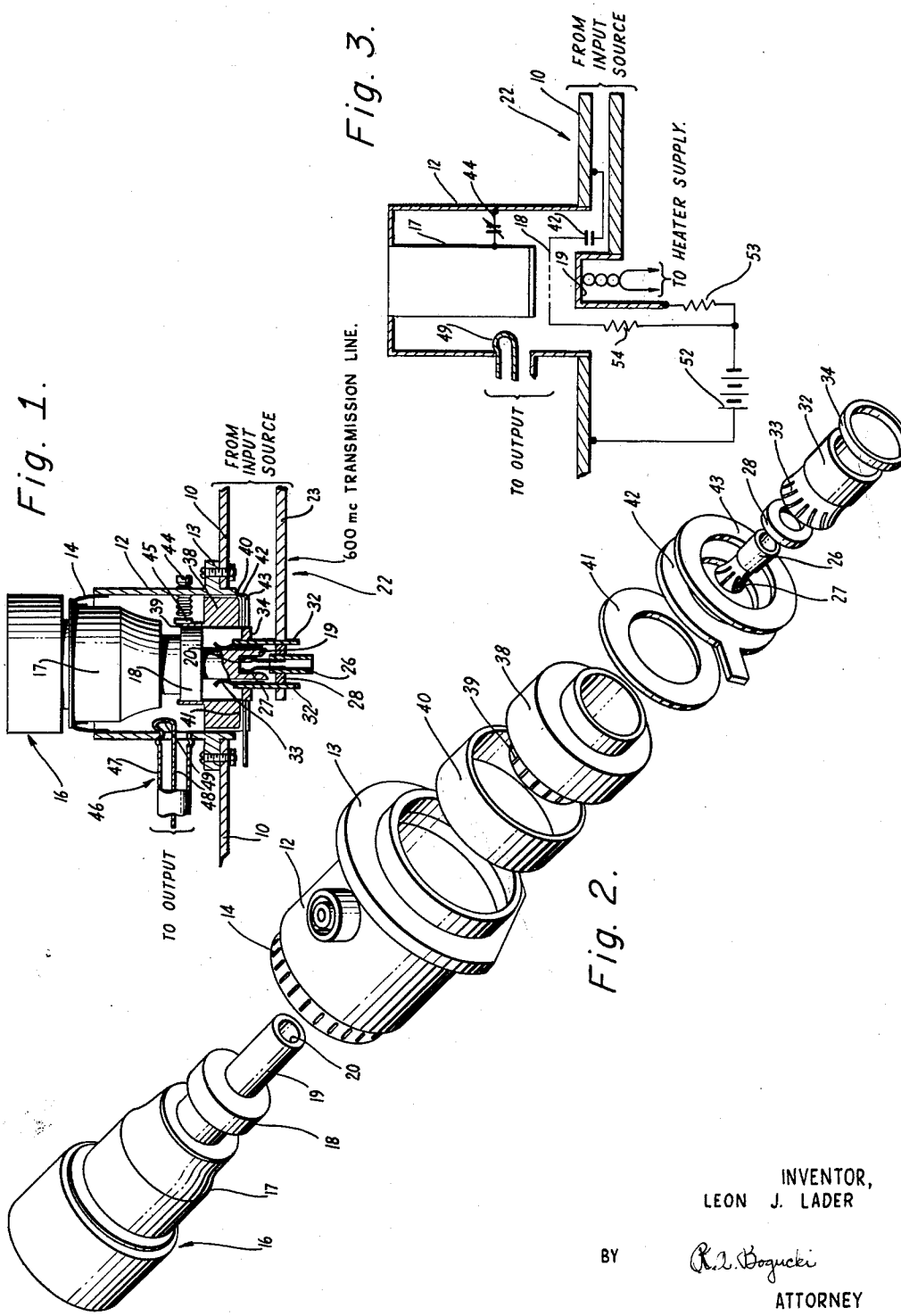
May 12, 1964

L. J. LADER

3,133,253

MICROWAVE AMPLIFIER WITH HEAT DISSIPATING MEANS

Filed May 1, 1959



INVENTOR,
LEON J. LADER

BY

R. A. Bogucki

ATTORNEY

1

3,133,253

MICROWAVE AMPLIFIER WITH HEAT DISSIPATING MEANS

Leon J. Lader, Los Angeles, Calif., assignor to Hughes Aircraft Company, Culver City, Calif., a corporation of Delaware

Filed May 1, 1959, Ser. No. 810,502

3 Claims. (Cl. 328—19)

This invention relates to electron tube amplifiers, and particularly to amplifiers which operate at very high and ultra high frequencies and which provide frequency multiplication along with amplification.

There is often a need for amplification and concurrent multiplication of signals from one frequency to another. Often, for example, input signals in the band which includes 500 mc. (in the very high frequency and ultra high frequency range) are to be utilized later at frequencies in the band which includes 1800 mc. When it has been desired to perform this combination of functions in the past it has usually been necessary to utilize one of a number of somewhat unsatisfactory expedients. Some structures, for example, have utilized tubes in which the anodes are maintained at high D.C. potentials above ground. These arrangements are often bulky, but particularly also require protection from accidental shorts and special cooling arrangements to provide stable operation.

Another expedient which has been employed is to utilize a frequency doubler and thus to operate from 900 mc. to 1800 mc., for example. With this arrangement, cavities have heretofore been used at both input and output, which increases the size even more. These and other arrangements additionally have not had suitable RF operating characteristics. Some devices have not been capable of frequency adjustments, and many have required high input impedances in order to operate stably. When desired RF characteristics have been obtained the devices have usually been difficult to fabricate and assemble, and, once assembled, cannot be modified and the tube cannot be replaced.

It is therefore an object of the present invention to provide an improved high frequency amplifier.

Yet another object of this invention is to provide a compact amplifier which is stable and which can concurrently provide a frequency multiplication function.

A further object of this invention is to provide a device for amplifying and tripling signals in the very high and ultra high frequency region.

A further object of this invention is to provide an improved tripling amplifier which is capable of operating over a range of frequencies with demountable electron tubes and which achieves high power and stable operation without a need for additional tuning and control circuitry.

These and other objects of the present invention are achieved, in one example, by an arrangement which can operate to amplify and to triple the frequency of input energy provided in the frequency band which includes 600 mc. A cylindrical housing mounted on a ground plane member is arranged to receive a demountable electron tube of the type having external contact surfaces for its electrodes. The housing structure and the ground plane member are arranged to provide both a thermal heat sink and a D.C. electrical reference for the anode. A coaxial output cavity is defined principally by the anode of the tube and by the cylindrical housing, and is tuned to the output frequency. Inputs are provided to this arrangement through an input transmission line which includes the ground plane member and which feeds energy into the control grid contact surface. The input conductor is coupled to the cathode, and each of the

2

operative elements of the tubes are isolated from the remainder, so that the arrangement is stable and simply adjusted. The device thus constructed provides high power outputs in the frequency region of 1800 mc., and triple the input frequency, without overheating or endangering the anode, because of the large cooling surface provided by the continuous metallic path from anode to ground plane.

The novel features of this invention, as well as the invention itself, both as to its organization and method of operation, may best be understood when considered in the light of the following description, when taken in connection with the accompanying drawings, in which like reference numerals refer to like parts, and in which:

FIG. 1 is a side elevation, partly in section, of one form of amplifier in accordance with the invention;

FIG. 2 is a perspective exploded view of the arrangement of FIG. 1; and

FIG. 3 is a schematic representation of the arrangement of the elements of the amplifier of FIG. 1.

An arrangement in accordance with the invention, referring now to FIGS. 1 and 2, may operate to amplify input energy provided at 600 mc., more or less, and to provide an output which is tripled in frequency and which is thus at 1800 mc. Such signals are usually considered to occupy a part of the very high or ultra high region of the frequency spectrum. The structure is mounted upon a ground plane member 10 which serves as the common RF connection and as a heat sink for the dissipation of thermal energy generated in operation of the device. A tube housing structure 12 is mounted on the ground plane member 10. This housing structure 12 has the general form of a hollow cylinder which is concentric with a central axis extending normal to the ground plane member 10. A flange 13 extending radially outwardly from the housing structure 12 permits it to be attached both mechanically (and thus thermally) and electrically to the ground plane member 10. At what will be termed the entry end of the housing structure 12 is provided a resilient RF contact structure 14 defining an entry aperture into which a tube may be inserted.

The type of electron discharge device which is employed in practicing this invention is a tube 16 of the disc seal type. By way of example, the present form utilizes a disc seal triode 16 which is mounted concentric with the central axis and partially within the tube housing structure 12. Disc seal electron discharge devices utilize electrodes which are generally circular in shape and which are spaced apart but parallel to a common plane. Such tubes do not utilize conventional lead-in components, but instead have peripheral contact surfaces to which RF connection may be made. These tubes are particularly useful for the amplification of high frequency signals. The portion of the tube 16 which is within the housing structure 12 includes, in the present instance, a cylindrical anode contact surface 17 which is in contact with the resilient structure 14 of the housing structure 12, and which thus is uppermost (as seen in the figures) in the arrangement. The control grid contact surface or RF connection 18 is intermediate the ends of the tube 16 and encompassed by the housing structure 12, and the cathode connection 19 is at the outside and at the base of the tube 16. Electrical connection is made to the tube 16 heater at an inner connection surface 20 which is recessed into the tube 16 base.

An input circuit 22 for this arrangement is provided by a conductor 23 which may be a flat strip type of conductor and which forms a transmission line at 600 mc. with the ground plane member 10. The input conductor 23 is coupled to the cathode connection 19 in a manner to be described below. Coupling is made directly from the in-

put circuit 22 to the grid contact surface 18 by the diversion of input energy into the coaxial line defined by the lower portion of the tube 16 and the housing structure 12. Energy is provided to the input circuit 22 from an input source (not shown) which may be a preceding driver stage.

The elements which couple the external circuitry to the contact surfaces of the tube 16 are arranged to provide a demountable support structure and also to provide a number of features which improve RF stability and operation. Heater connections are made from an elongated cylindrical tube 26 at the base of the tube 16 and extending into the recessed heater connection 20. Contact fingers 27 at the heater connection 20 provide the desired electrical contact but permit the tube 16 to be moved axially for insertion or removal. The cylindrical tube 26 is maintained in position by a dielectric insulator ring 28 which is coupled to a conductive cylinder 32 (which may be perforated for air circulation) which is in turn connected to the input conductor 23.

The conductive cylinder 32 at the base of the housing structure 12 is a portion of the connection made to the cathode contact surface 19 from the input conductor 23 and includes resilient contact fingers 33 outside the base of the tube 16 and in contact with the cathode contact surface 19. This structure is isolated from the control grid connections by a dielectric insulator ring 34 which encompasses the cylinder 32.

Electrical coupling to the grid contact surface 18 of the tube 16 is also made by a conductive cylinder or hub 38 which has an axially protruding portion with resilient fingers 39 in contact with the grid contact surface 18. An insulator ring 40 outside the conductive hub 39 and between the hub 39 and the housing structure 12 provides a bypass path between the grid surface 18 and the anode surface 17 and a coupling to the ground plane member 10. An RF bypass is also provided between the grid 18 and cathode contact surfaces 19 by a pair of insulator discs 41, 43 and an intermediate capacitive disc 42. The capacitive disc 42 may be a ceramic or other type of capacitor dielectric.

The output coaxial cavity is defined by the outer surface of the upper portion of the tube 16, including the anode structure of the tube 16 and the inner surface of the housing structure 12. The cavity is so dimensioned and situated as to be resonant, in the present example, in the region about 1800 mc. A tuning screw 44 threaded or otherwise movably mounted in the wall of the housing structure 12 adjacent a tab 45 within the cavity provides for adjustment of the center of the output frequency. Energy is extracted from the coaxial cavity by an output circuit including a coaxial line 46 which is coupled to the housing structure 12. The outer conductor 47 and the inner conductor 48 of the coaxial line 46 are joined by a pick-up loop 49 within the cavity.

In operation, devices in accordance with the present invention provide amplification of input energy and may additionally provide frequency multiplication. In the present device, for example, input energy at 600 mc. is tripled to 1800 mc. concurrently with the signal amplification. When reference is made to 600 mc., it will be understood that this is the nominal or center frequency, and that input signals may vary over a considerable band. It is important to note the inherent reliability of the anode structure in the present arrangement. The direct coupling which exists between the anode contact surface 17, the housing structure 12 and the ground plane member 10 establishes that in the operation of the device the anode of the tube 16 is coupled to a thermal heat sink, and thus does not overheat, and is also electrically coupled to a reference. The direct heat conduction path is between the anode contact surface 17, the housing structure 12 and the ground plane member 10 and provides ready dissipation of thermal energy generated in the anode. The anode has a large and exposed cooling surface and for this reason also is less apt to become overheated. Addi-

tionally, the D.C. connection to the reference plane 10 eliminates many potential difficulties due to the possibility of accidental contact or short to ground.

Input signals are applied to the grid contact surface 18 of the tube 16 from the input transmission line circuit 22 formed by the ground plane member 10 and the input conductor 23. An input signal at 600 mc. propagated along the transmission line formed by these two parallel members 10 and 23 is diverted into the coaxial transmission line formed by the exterior of the base of the tube 16 and the inner surface of the lower portion of the tube housing structure 12 which rests in the opening in the ground plane 10. The input energy may therefore be considered to be launched into the coaxial line formed by the tube 16 and the housing 12 in this region, and to generate RF currents in the conductive cylinder 38 which is coupled to the control grid contact surface 18. The input currents are thus applied to the control grid of the tube 16 through the conductive path formed by the resilient fingers 39 on the conductive cylinder 38 and the grid contact surface 18. Note that the insulator ring 40 outside the conductive cylinder 38 provides electric separation of the cylinder 38 from the housing structure 12, and thus provides a bypass between the anode and grid of the tube 16. The presence of the capacitive disc 42 in the transmission path between the input circuit 22 and the conductive cylinder 38 provides a built-in capacitance which provides a bypass between the cathode and grid of the tube 16. Additionally, the capacitive disc 42 provides D.C. isolation of the cathode.

The functional relationships of some of the elements may be more clearly understood by reference to the schematic diagram of FIG. 3. FIG. 3 also shows some additional elements, such as a source of D.C. potential 52 which is coupled at its positive terminal to the ground plane member 10. Negative bias may be applied to the cathode 19 by a coupling to the potential source 52 through a cathode bias resistor 53. A grid leak resistor 54 may also be employed. Such features provide material advantages. It may be seen, for example, that the coupling between the grid of the tube 16 and the ground plane member 10 because of the conductive cylinder 32 causes the tube to be operated as an RF grounded structure because the grid is maintained at RF ground between the input and output circuits. This establishes a common reference for input and output which tends to prevent feedback and self-oscillation of the system at the respective input and output circuits.

Referring now to all of FIGS. 1, 2 and 3, amplification of signals applied to the tube 16 is accomplished in the usual manner by density modulation of the electron stream. Amplified outputs are derived at the multiple frequency because the coaxial cavity defined by the anode of the tube 16 and the housing structure 12 may be considered to present a high impedance at the desired output frequency. Thus energy at that frequency may efficiently be extracted by the coupling loop 49 coupled to the output circuit coaxial line 46. The tuning screw 44 provides an adjustment of the frequency of the coaxial cavity, and constitutes, as may be seen in FIG. 3, a variation in the capacitance loading of the cavity. Therefore, signals which are derived at the anode of the tube 16 excite the coaxial cavity and in turn excite the desired output signal at 1800 mc. in the output circuit.

It should be noted that a number of alternatives may be utilized in the construction and utilization of this arrangement. The device may be utilized as an amplifier alone, without frequency multiplication, although the frequency multiplication capability is an extremely useful factor. The device could be operated instead as a frequency doubler, for example, by the use of a smaller input circuit transmission line to carry signals at 900 mc. Adjustments could be made in the tuning of the output coaxial cavity by the use of different tuning means, such as a ring of high dielectric or high permeability material.

Similarly, the coupling of energy from the input circuit and to the output circuit may be accomplished by any one of a number of energy transducers available in the frequency region involved.

A number of further advantages from this arrangement should also be evident. Structurally, the design is extremely compact and simple to assemble. As may be seen particularly in the exploded view of FIG. 2, each of the elements may be simply fabricated and each is substantially symmetrical and of a simple geometric form. Thus the structure may be readily assembled in laminated fashion without the need for alignment devices. Especially important is the fact that the tube is demountable with respect to the housing structure and the resilient contact members. The tube may be removed or replaced without the need for breaking electrical circuit connections or without requiring the normal breaking open of a cavity.

In summary, the anode structure is not only thermally coupled to a heat sink, but also has a large exposed portion for superior cooling and is maintained at a D.C. reference potential, which improves the RF continuity of the device. This arrangement in turn is made possible by the manner in which the other contact surfaces are isolated and bypassed, these features in themselves providing additional advantages. The arrangement also permits the cathode to be biased, and the input to be driven by a low impedance source. Devices heretofore available have often encountered difficulty because of loading effects introduced when the source is of low impedance.

I claim:

1. An amplifier for operation at high frequencies and for providing an output of triple frequency, said amplifier comprising: an electron discharge device positioned along a central axis and having an anode structure of cylindrical outer configuration, and also having external control grid and cathode contact surfaces; a thermally conductive member encompassing the electron discharge device and lying in a plane substantially normal to the central axis; and having at least a portion of the surface thereof in intimate heat exchanging relation with heat dissipating means, a hollow cylindrical housing member encompassing at least a portion of the electron discharge device and being substantially concentric with the anode structure about the central axis, the housing forming therewith a coaxial cavity at least approximately tuned to the output frequency, the housing structure being thermally and electrically connected to both the anode structure and said thermally conductive member whereby the heat generated in said anode may be conducted to said means; and an input conductor coupled to the external contact surface of the cathode and forming a transmission line with said thermally conductive member, the transmission line being coupled to the external contact surface of the control grid of the electron discharge device.

2. An ultra high frequency amplifier for providing concurrent frequency multiplication of input signals comprising: a conductive member having an opening to receive

a tube; a cylindrical hollow tube housing structure registering with and mounted about the opening in said conductive member and having its opposite end open to receive a tube, the housing structure being thermally and electrically connected to said conductive member; a disc seal triode structure mounted within the housing structure, the triode including a cylindrical anode contact surface registering with and in electrical and thermal contact with the housing structure, and control electrode and cathode contact surfaces disposed therealong successively further in the direction toward said conductive member, the housing structure and the control electrode contact surface defining a coaxial line for input energy, and the housing structure and the anode structure defining a coaxial cavity for output energy; output means coupled to the coaxial cavity; an input conductor coupled to the cathode contact surface and spaced apart from and parallel to said conductive member for forming therewith an input energy transmission line for feeding energy into the coaxial line for input energy; a conductive cylinder between the control electrode contact surface and the housing structure for coupling input energy to the control electrode contact surface; dielectric means between the conductive cylinder and the housing structure for providing a bypass between the control electrode and the anode of the tube; and means coupled between the conductive cylinder and the cathode contact structure for providing a capacitive bypass between the control electrode and the cathode of the tube.

3. An amplifier comprising: an electron discharge device having a central axis, an anode with a cylindrical exterior configuration, and external grid and cathode contact surfaces; a thermally conductive member encompassing said electron discharge device and lying in a plane substantially normal to said axis; a hollow cylindrical member having an electrically and thermally conductive connection to said anode and to said thermally conductive member and concentrically encompassing said anode to form therewith a coaxial cavity tuned to the operating frequency of the amplifier, at least a portion of said thermally conductive member being adapted to dissipate heat generated by said anode; output means coupled to said coaxial cavity; and an input conductor coupled to said external cathode contact surface and forming a transmission line with said thermally conductive member.

References Cited in the file of this patent

UNITED STATES PATENTS

50	2,847,518 2,895,076	Lavoo et al. ----- Aug. 12, 1958 Stocker ----- July 14, 1959
----	------------------------	---

FOREIGN PATENTS

55	70,815	France ----- Feb. 23, 1959
----	--------	----------------------------

OTHER REFERENCES

Principles of Radar (M.I.T. Radar School Staff), 2nd edition, published by McGraw-Hill, 1946, pages 4—47 to 4—49 relied on.