June 15, 1954 W. C. BROWN ET AL 2,681,427

MICROWAVE AMPLIFIER

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FIG. 1

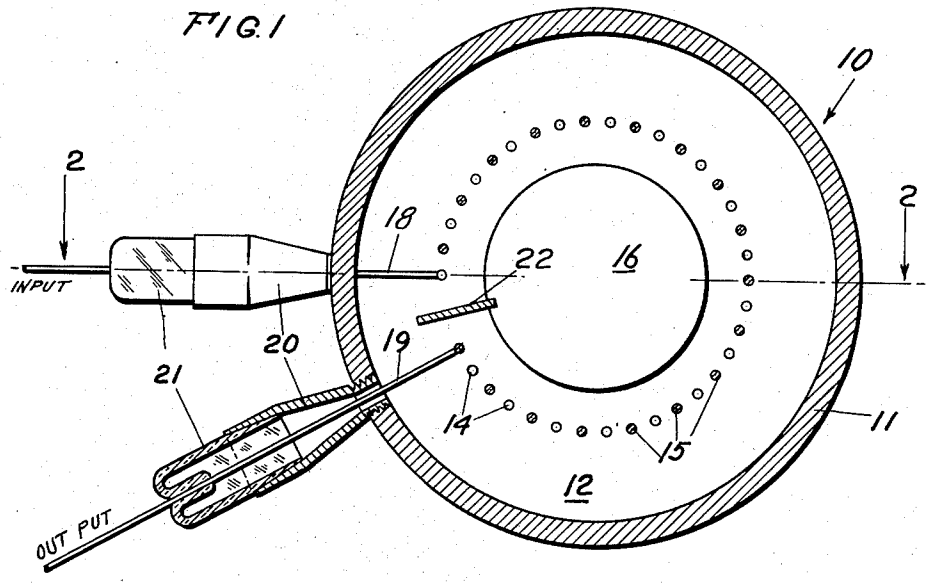
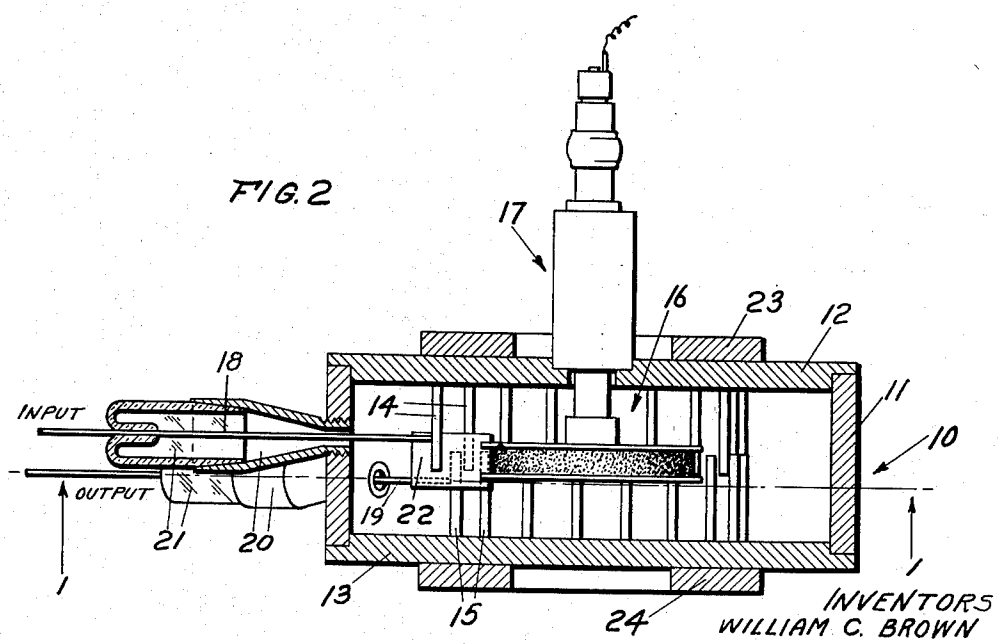


FIG. 2



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FIG. 3

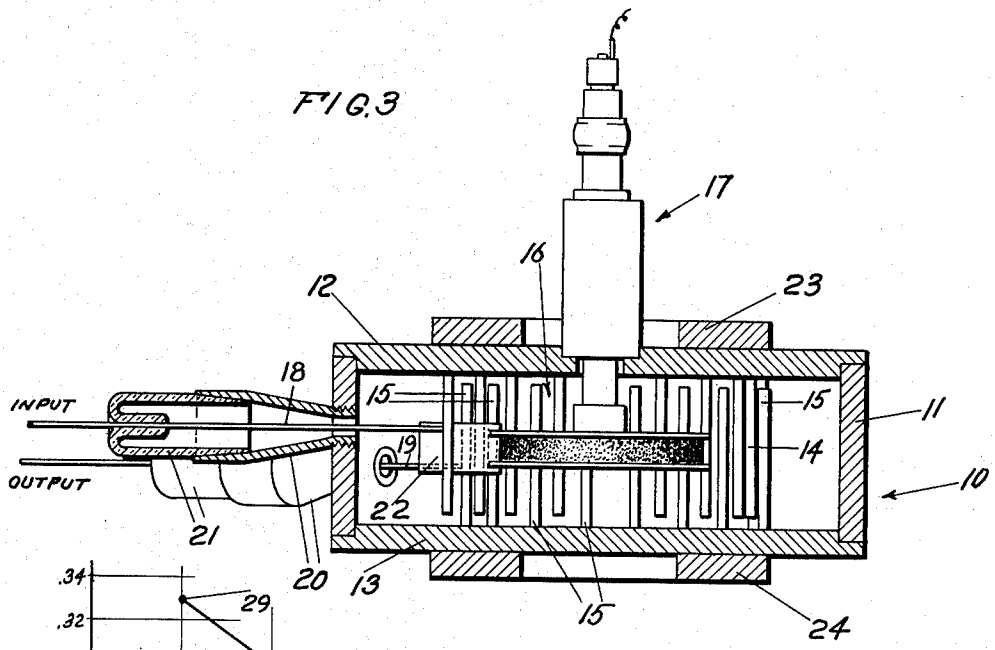
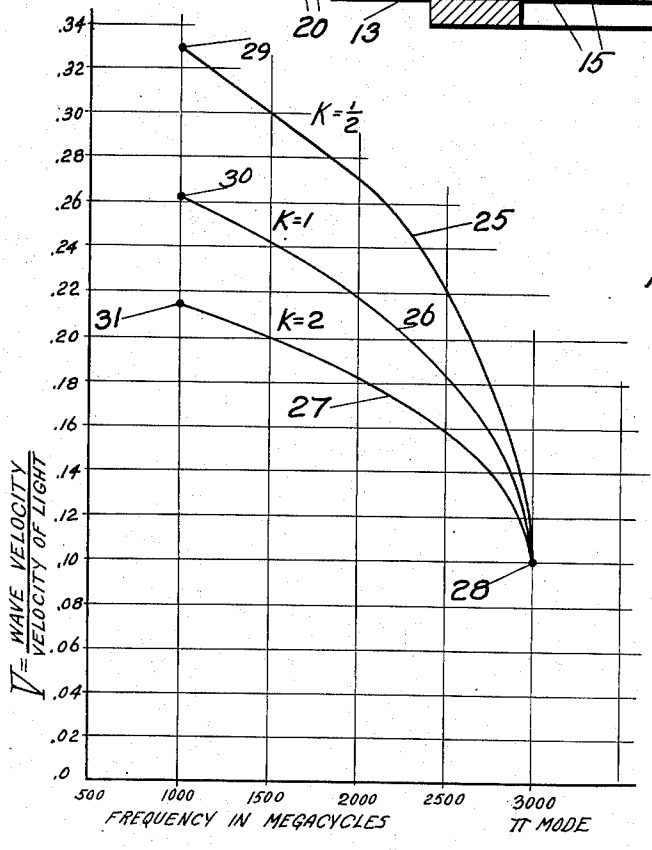


FIG. 4



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MICROWAVE AMPLIFIER

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Application April 23, 1949, Serial No. 89,178

7 Claims. (Cl. 315—40)

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This application relates to electron discharge devices and more particularly to microwave amplifiers utilizing the principle of interaction between a stream of electrons and an electromagnetic wave moving parallel to the stream of electrons at approximately the same velocity as the stream of electrons.

It has been found, and as is more completely disclosed in copending application, Serial Number 81,804, filed March 16, 1949, that the path of the electron stream and electromagnetic wave may be made circular under the influence of a magnetic field, thus becoming similar to the conventional magnetron.

While this circular structure takes advantage of the inherently high operating efficiency and compactness of the conventional magnetron structure, the use of a conventional vane type anode structure has some disadvantages, one of which is the variation of the signal wave velocity along the anode structure with frequency.

Since the signal wave velocity is controlled by the electron velocity, and since the electron velocity is controlled by the D. C. potential applied to the device, it follows that, if the signal wave velocity varies a large amount for variation in signal frequency, the band of frequencies which may be amplified by the device will be relatively narrow for any given setting of the D. C. potential. On the other hand, if the signal wave velocity remains relatively uniform over a wide range of frequencies, a wide frequency band may be amplified.

It is, therefore, an object of this invention to produce anode structures having more uniform wave velocity vs. frequency characteristics.

Other and further objects of this invention will become apparent as the description thereof progresses, reference being had to the accompanying drawings wherein:

Fig. 1 is a transverse cross-sectional view of a microwave amplifier built in accordance with this invention taken along section line 1—1 of Fig. 2;

Fig. 2 is a transverse cross-sectional view of the species shown in Fig. 1 taken along section line 2—2 of Fig. 1;

Fig. 3 is a modification of the species shown in Fig. 2; and

Fig. 4 is a graph illustrating operational characteristics of the species shown in Figs. 1 and 2.

Referring now to Figs. 1 and 2, there is shown an anode structure 10 comprising a cylinder 11 whose upper and lower ends are covered by end plates 12 and 13, respectively. Extending down from the underside of the end plate 12 into the

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space defined by the cylinder 11 and the plates 12 and 13 is a plurality of rods 14. These rods are arranged such that their axes are parallel to the axis of cylinder 11. The locus of the points of attachment of the rods to the end plate 12 is a circle concentric with cylinder 11 and somewhat greater than one-half the diameter of cylinder 11.

Another set of rods 15 extends upward from the upper side of the lower end plate 13 for a distance somewhat greater than one-half the length of the cylinder 11 such that their upper ends extend slightly beyond the lower ends of the rods 14. The rods 15 are spaced in circular form similar to the rods 14, the locus of the points of attachment of the rods 15 to the plate 13 being concentric with cylinder 11. The rods 15 are so spaced that they each extend between an adjacent pair of the rods 14. As is more particularly shown in Fig. 1, each of the rods 15 is an equal distance from each of a pair of rods 14, the spacing between the rods 14 and the adjacent rods 15 being somewhat greater than the diameter of the rods.

Inside the cylindrical space defined by the rods 14 and 15 is a cathode 16 and insulating support means 17 similar to that described in the aforementioned copending application.

At one point three of the rods, comprising a rod 14, an adjacent rod 15 and a next adjacent rod 14, have been omitted and the remaining adjacent rods have been connected, at a point approximately two-thirds the length of the rod from the point of attachment to the end plates, to input and output leads 18 and 19, respectively. These leads 18 and 19 extend through openings in the walls by means of insulating seals comprising metallic bushings 20 threaded into holes in the cylinder 11 and glass seals 21 which seal the space between the rods 18 and 19 and the bushings 20 in a well-known manner.

Extending radially outward from the cathode 16 is a vane 22 comprising a flat metallic plate attached to the cathode 16 and whose plane surface is parallel to the axes of the rods 14 and 15. This plate bisects the space between the points of attachment of the leads 18 and 19 to the rods 14 and 15 and acts to prevent electrons from being carried around from the output area of the device to the input area, thereby eliminating this form of feedback.

A magnetic field is applied parallel to the axis of cylinder 11 throughout the space between the rods 14 and 15 and the cathode 16 by means of magnetic pole pieces 23 and 24 positioned against

the outer surfaces of the upper and lower end plates, respectively. These magnetic pole pieces are then attached to the opposite poles of a permanent or electromagnet as may be desired.

With a suitable heater voltage applied to the cathode heater, a suitable magnetic field applied between the pole pieces 23 and 24, and a suitable potential applied between the cathode 16 and the anode rods 14 and 15, electrons emitted from the cathode 16 will travel in substantially concentric rings about the cathode. A radio frequency potential introduced by means of lead 18 into the anode network comprising the rods 14 and 15 will travel along the rods interacting with the outer rings of the electrons causing amplification. When the wave reaches the output lead 19 it is picked up thereby and fed to any desired load.

An analysis of this anode network will result in a low-pass filter similar to that shown in the aforementioned copending application. The adjacent rods 14 or 15 behave as two lines of less than quarter wave length, at frequencies below the π mode which is cut off, and, therefore, represent inductances. The largest capacitance exists between members 14 and adjacent members 15. Other capacitances are the capacitance between the cathode 16 and the rods 14 and 15, the capacitance between adjacent rods 14 and the capacitance between adjacent rods 15.

With the capacitances between the rods 14 and the rods 15 designated C_1, the capacitance between adjacent rods 14 or adjacent rods 15 designated as C_2 and the ratio of C_2 to C_1 designated as K, a plot may be made of wave velocity along the anode structure vs. frequency of various values of K.

This plot is shown in Fig. 4 wherein the abscissa axis represents frequency in megacycles from 500 to 3,000 and the ordinate axis represents V which equals wave velocity divided by the velocity of light. Three curves are shown, curve 25 illustrating characteristics having a value of $K=\frac{1}{2}$, curve 26 illustrating characteristics having a value of K=1 and curve 27 illustrating characteristics of a value of K=2. At 3,000 megacycles, which represents the π mode of operation of the device, all the curves are coincident at point 28 which occurs at a value of V=.1. As frequency decreases, the curves diverge with the curve 25 rising very rapidly to a value of about .33 at 1,000 megacycles as shown by point 29, the curve 26 illustrating characteristics for a value of K=1 rising less rapidly to a point of V= approximately .26 at 1,000 megacycles, as shown by point 30, and curve 27 illustrating characteristics of the value of K=2 rising to a velocity V= to about .215 at 1,000 megacycles, as shown by point 31.

Thus it may be seen that the larger the value of K, the less will be the wave velocity variation with variations in frequency, with a resultant broadening of the band of frequencies which may be amplified.

Referring now to Fig. 3, there is shown another modification of my invention. The details of this modification are similar to those shown in Figs. 1 and 2 except that the rods 14 and 15 extend nearly the full length of the cylinder 11, the spacing between the unattached ends of the rods and the opposite end plates being approximately equal to the distance between adjacent rods 14 and 15.

In this structure the value of C_2 has been greatly increased over C_1 so that the velocity characteristic approaches a substantially uniform value for variations in frequency.

Another method of analysis of this structure results from regarding each of the members 14 with an adjacent member 15 as forming a parallel wire transmission line. The wave travels along the parallel wires until it comes to one of the end plates which then acts as a part of the parallel wire structure bending the wave around in a U shape causing it to travel back down along the other side of one of the rods and the next adjacent rod. This produces a continuous parallel wire structure which is bent repeatedly back on itself in a U shape. Since each of the rods 14 and 15 acts twice as the side of the parallel wire line, the effective inductances of these rods are halved with the result that the phase velocity of the wave along the parallel wire line is equal to substantially twice the velocity of light. However, even with this high velocity, a resultant tangential velocity around the structure may be achieved which is on the order of one-tenth the speed of light, so that electrons traveling in concentric circles about the cathode will interact favorably with a wave traveling along the anode structure to cause amplification of said wave.

This completes the description of the embodiments of the invention illustrated herein. However, many modifications will be apparent to persons skilled in the art; for example, the anode structure may be made linear instead of circular, various diameters of the rods 14 and 15 may be used as well as various diameters of the anode cylinder and cathode structures, and the rods could be made in the form of flat plates extending in a plane radial to the axis of cylinder 11. Therefore, applicant does not wish to be limited to the particular details of the invention as described herein except as defined in the appended claims.

What is claimed is:

1. An electron discharge device comprising a source of electrons, an anode structure adjacent said source having signal input and output means coupled thereto, and signal isolating means between said input means and said output means, said anode structure comprising a plurality of anode members, adjacent anode members being connected to said anode structure in different parallel planes and alternate anode members only being connected to said anode structure in the same parallel planes, said signal input means being coupled to one of said anode members, and said signal output means being coupled to another of said anode members.

2. An electron discharge device comprising a source of electrons, an anode structure adjacent said source having signal input and output means coupled thereto, and signal isolating means between said input means and said output means, said anode structure comprising means for transmitting signals lying in the desired operating frequency range of said device between said signal input and output means comprising a plurality of parallel plates, a plurality of alternate anode members being attached to each of said parallel plates and extending toward but spaced from the other of said parallel plates, said signal input means being attached to one of said anode members, and said signal output means being attached to another of said anode members.

3. An electron discharge device comprising a source of electrons, a continuous anode structure

surrounding said source having signal introducing and extracting means coupled thereto, and signal isolating means between said input means and said output means, said anode structure comprising a plurality of parallel plates, a plurality of alternate rods attached to each of said parallel plates and extending toward but spaced from another of said parallel plates, said introducing and extracting means being coupled to said anode structure at opposite sides of said isolating means.

4. An electron discharge device comprising a continuous anode structure having signal introducing and extracting means coupled thereto, and signal isolating means between said introducing and extracting means, said anode structure comprising a plurality of parallel plates, a plurality of alternate rods attached to each of said parallel plates and extending toward but spaced from another of said parallel plates for a distance slightly greater than half the distance between said plates, said introducing and extracting means being coupled to said anode structure at opposite sides of said isolating means.

5. An electron discharge device comprising a source of electrons, an anode structure adjacent said source having signal input and output means coupled thereto, signal isolating means between said input means and said output means, said anode structure comprising a plurality of anode members, adjacent anode members being connected to said anode structure in different parallel planes and alternate anode members only being connected to said anode structure in the same parallel planes, said signal input means being coupled to one of said anode members, said signal output means being coupled to another of said anode members, and means adjacent said anode structure for producing a magnetic field substantially parallel to said anode members.

6. An electron discharge device comprising a conductive support structure, a plurality of anode members extending from said support structure in overlapping spaced relationship, the overlapping area of opposing adjacent anode members being less than the total opposing area of either of said adjacent anode members, said anode members forming a continuous, frequency-responsive energy translation structure for transmitting signals lying in the desired operating frequency range of said device between the ends thereof, signal energy transfer means coupled at the operating frequency of said device to said structure substantially at one end thereof, signal energy absorbing means coupled at the operating frequency of said device to said structure substantially at the other end thereof, signal isolating means between said transfer and said absorbing means, and means adjacent said structure for directing electrons along paths adjacent said network.

7. An electron discharge device comprising a conductive support structure, a plurality of anode members extending from said support structure in overlapping spaced relationship, the overlapping area of opposing adjacent anode members being less than the total opposing area of either of said adjacent anode members, said anode members forming a continuous, frequency-responsive energy translation structure for transmitting signals lying in the desired operating frequency range of said device between the ends thereof, signal energy transfer means coupled at the operating frequency of said device to said structure substantially at one end thereof, signal energy absorbing means coupled at the operating frequency of said device to said structure substantially at the other end thereof, signal isolating means between said transfer and said absorbing means, and means adjacent said structure for directing electrons along paths adjacent said network comprising means adjacent said structure for producing a magnetic flux perpendicular to the direction of motion of electrons along said path.

References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
2,135,033	Linder	Nov. 1, 1938
2,147,159	Gutton	Feb. 14, 1939
2,409,222	Morton	Oct. 15, 1946
2,432,466	Burns	Dec. 9, 1947
2,446,826	McArthur	Aug. 10, 1948
2,473,567	Brown	June 21, 1949
2,511,407	Kleen et al.	June 13, 1950
2,562,738	Ramo	July 31, 1951
2,566,087	Lerbs	Aug. 28, 1951
2,579,654	Derby	Dec. 25, 1951
2,582,185	Willshaw	Jan. 8, 1952