

Jan. 22, 1946.

C. H. BROWN

2,393,284

ULTRA SHORT WAVE SYSTEM

Filed April 30, 1941

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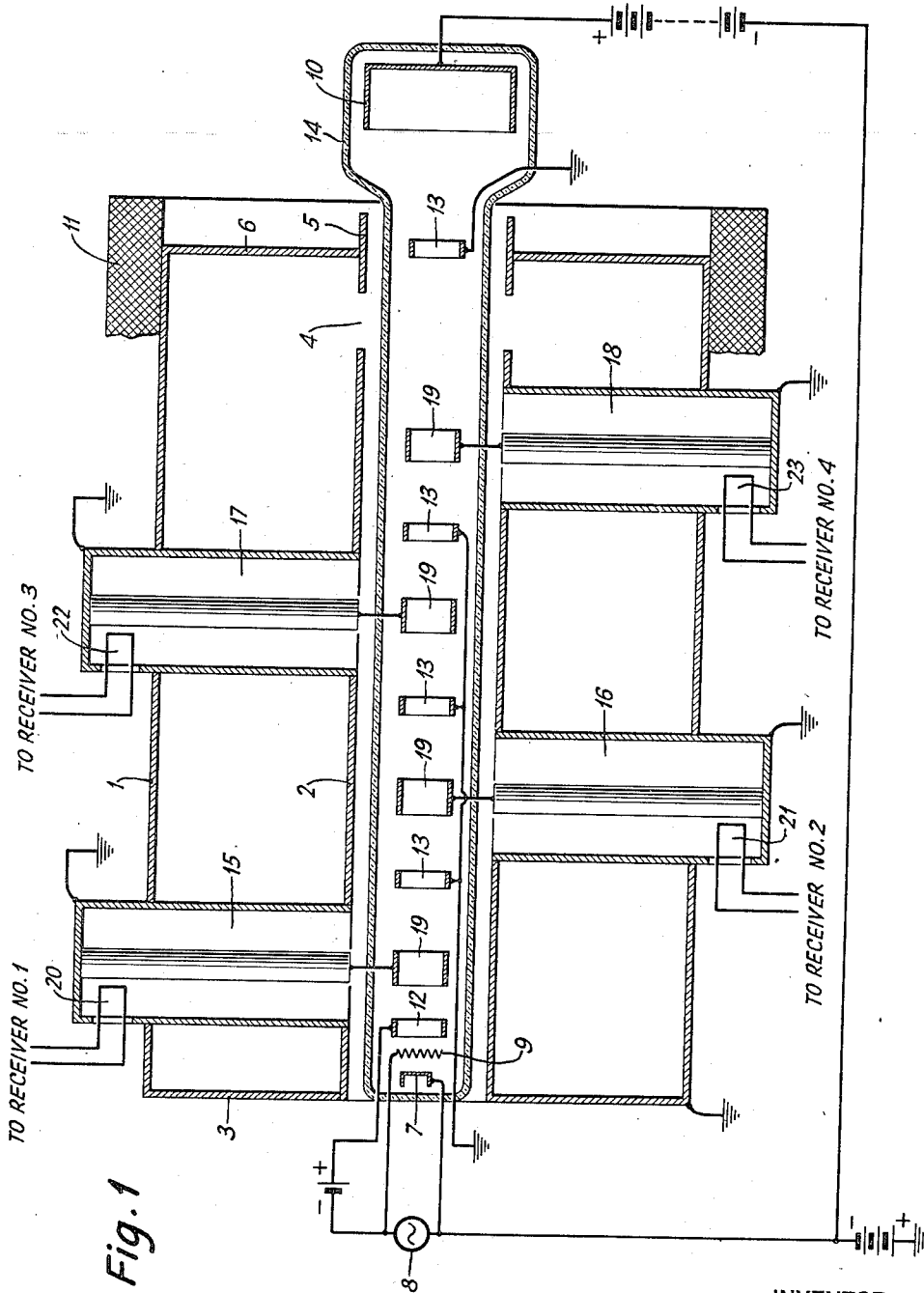


Fig. 1

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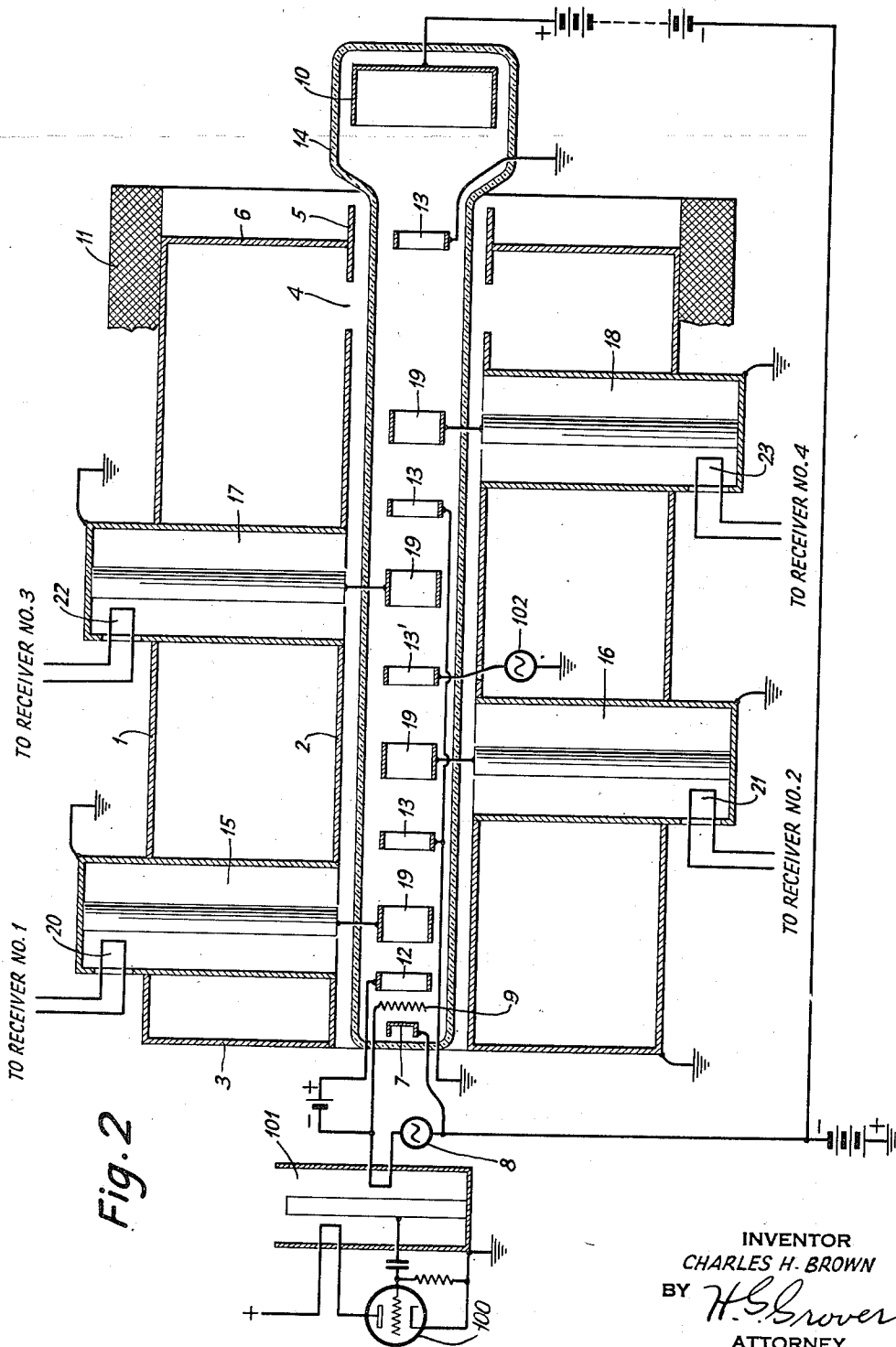
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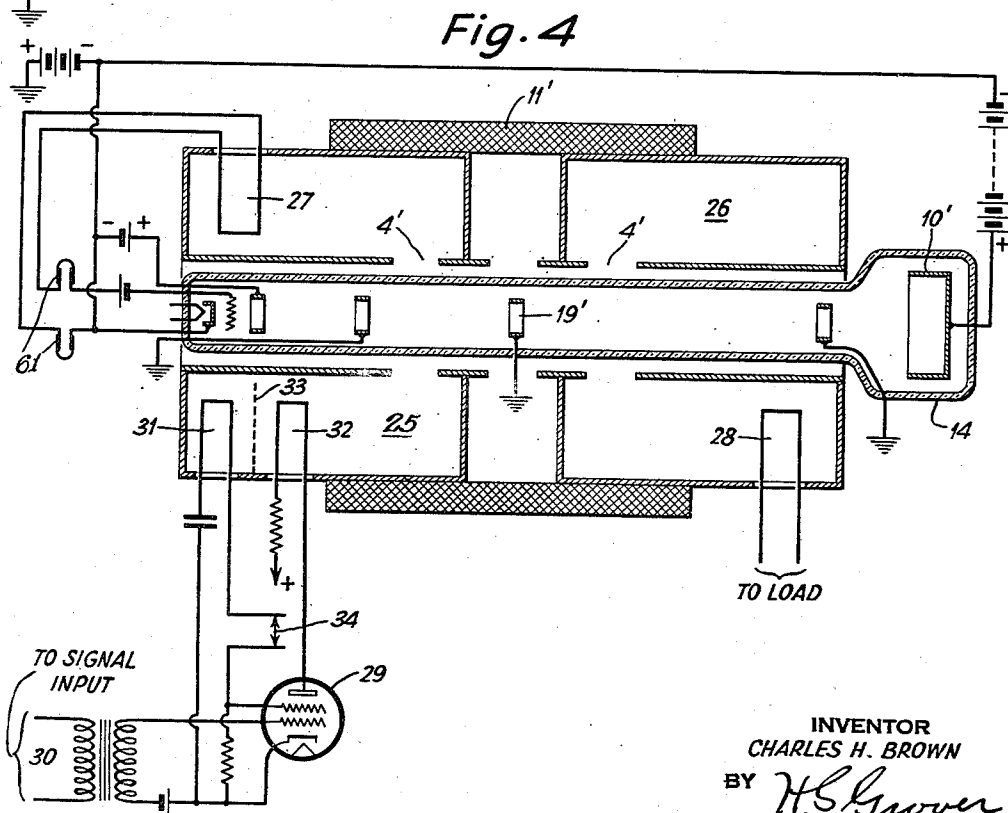
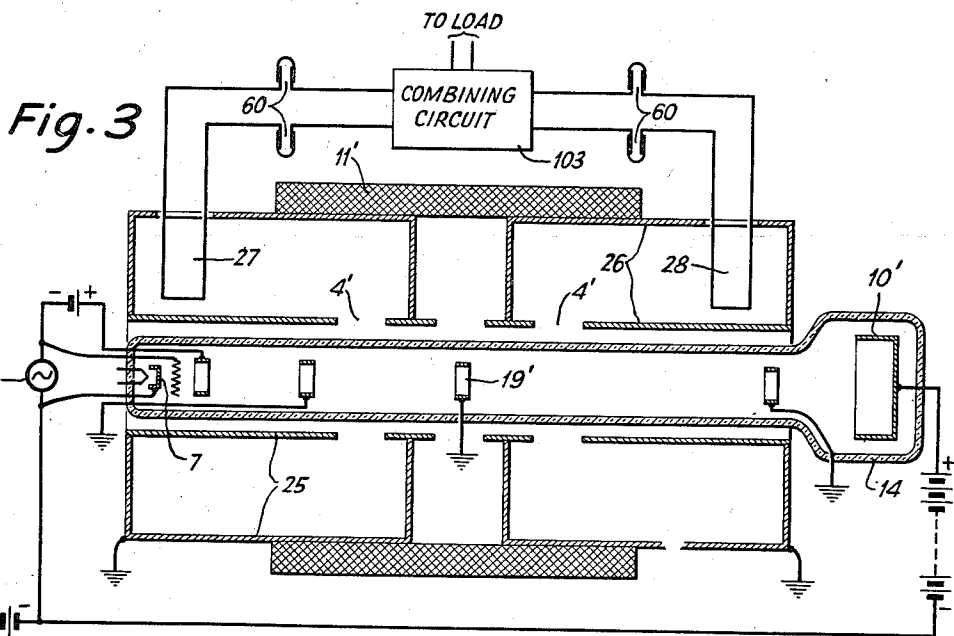
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Fig. 5

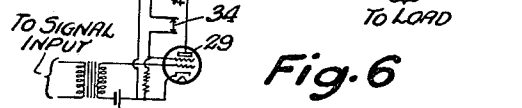
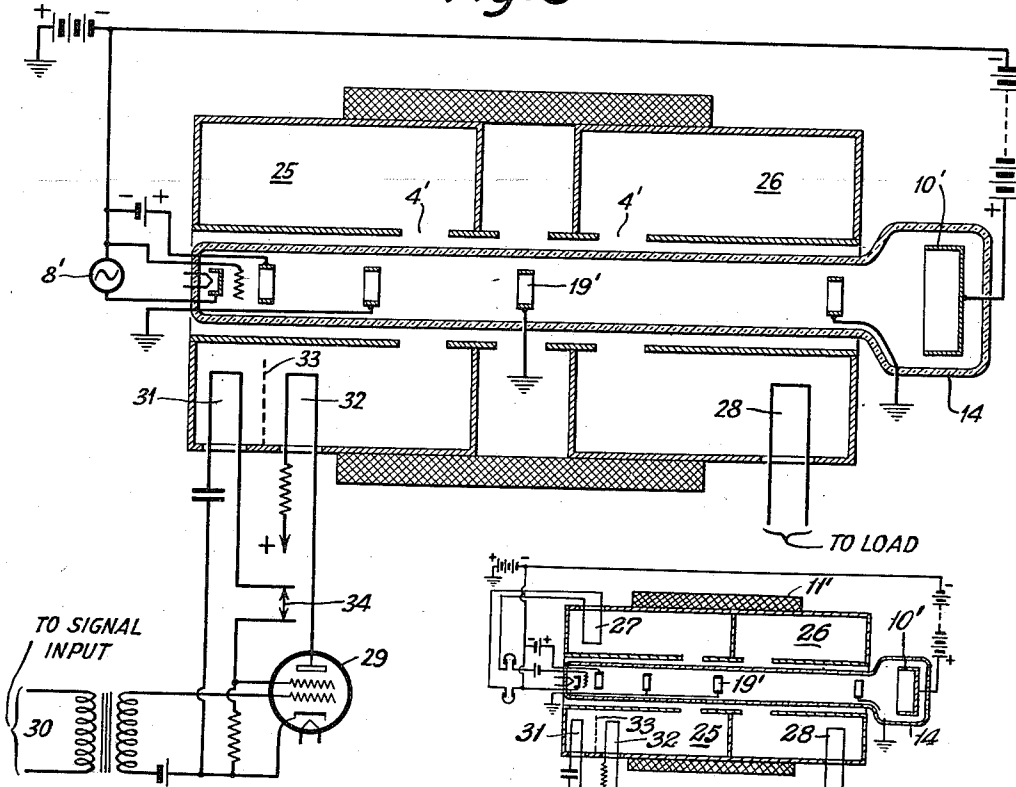
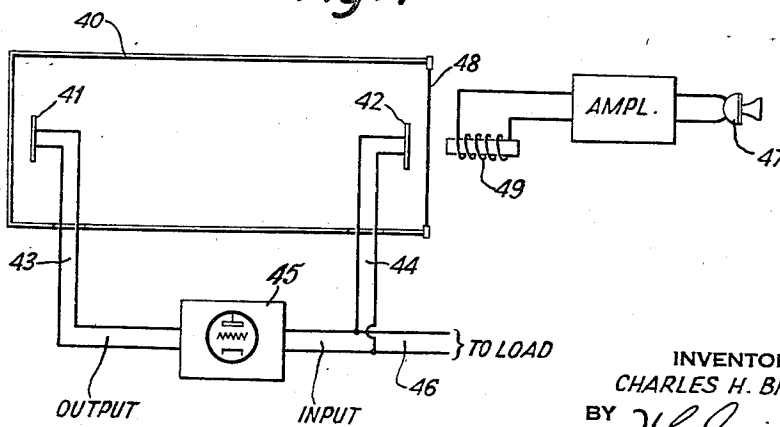


Fig. 6

Fig. 7



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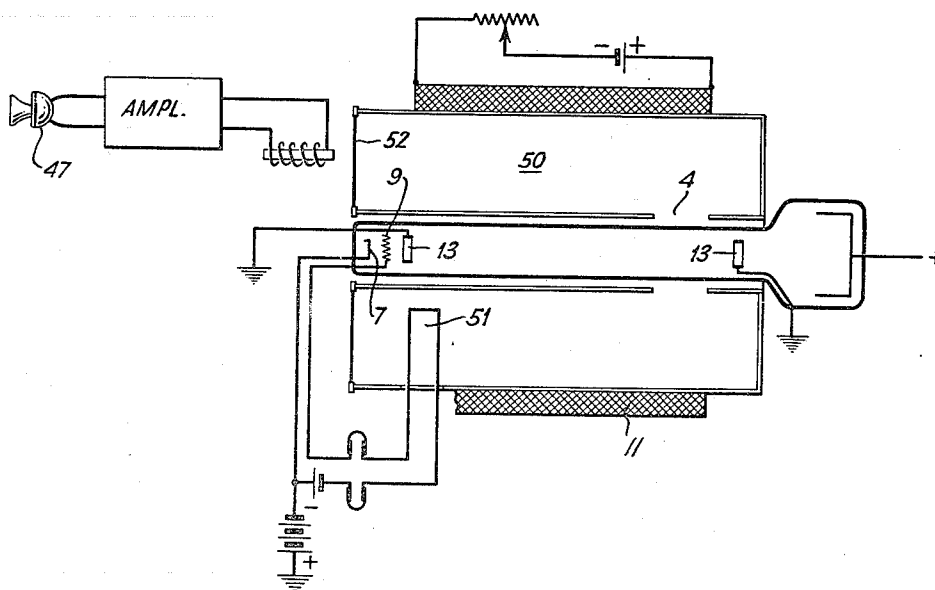
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Fig. 8



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ULTRA SHORT WAVE SYSTEM

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Application April 30, 1941, Serial No. 391,063

15 Claims. (Cl. 179—171.5)

This invention relates to electron discharge devices and circuits therefor, for use particularly with ultra short waves below five meters, and is a continuation-in-part of my copending application Serial No. 293,044, filed September 1, 1939, now United States Patent No. 2,280,026, granted April 14, 1942.

One of the objects of the present invention is to provide an improved electron discharge device arrangement in which the electron transit-time effects are minimized and which will function with relatively small losses at extremely high frequencies on the order of five meters to five centimeters.

Another object is to provide an improved electron discharge device circuit for obtaining a plurality of outputs of unrelated and/or related frequencies from a single electron beam.

A further object is to provide an electron discharge device and circuit therefor wherein a single electron beam is modulated by different carriers and there is obtained therefrom several outputs of different unrelated frequencies.

A still further object is to provide an electron discharge device arrangement including a pair of resonant tank circuits which are excited in succession by a single electron beam.

Other objects and various features of novelty will appear hereinafter from a reading of the following description.

Generally stated, the present invention consists of improvements in the ultra high frequency electron discharge device art, reference being made to the article by Dr. A. V. Haeff, entitled "An Ultra High Frequency Power Amplifier of Novel Design," which appeared in "Electronics" for February, 1939, page 30 et seq., published by McGraw-Hill, Inc., for an understanding of the fundamental principles involved herein. The invention is useful in its application to oscillation generators, amplifiers, frequency converters and detectors, although not limited thereto.

A description of the invention follows in conjunction with drawings, given by way of example only, wherein:

Figs. 1 and 2 are simplified diagrammatic representations of the structure of an electron discharge device employing a single electron beam for exciting a plurality of tank circuits from which outputs may be individually taken;

Fig. 3 is a longitudinal section of two tank circuits arranged according to the invention, whereby a single electron beam traverses substantially the entire length of both tanks in succession;

Figs. 4 and 5 are modifications of the circuit employing the device of Fig. 3;

Fig. 6 shows the two tank circuits of Figs. 3, 4 and 5 compactly arranged in a preferred mechanical construction; and

Figs. 7 and 8 show other embodiments of the invention.

Throughout the figures of the drawings, the same or equivalent elements are designated by the same reference numerals.

Referring to Fig. 1, there is shown an electrically quarter-wave concentric line tank circuit having an outer conductor 1 and an inner hollow conductor 2, both of which may be cylindrical in cross-section, electrically coupled together by the conducting end plate 3. The conductors 1 and 2 are separated at one end by a gap 4, there being provided a second tubular conductor 5 which is an aperture extension, so to speak, of the inner conductor 2 and coaxial therewith. This tubular extension 5 and the outer conductor 1 are connected by conducting plate 6. This arrangement provides a quarter-wave tank.

A suitable cathode 7 produces a beam of electrons whose density is modulated by a high frequency wave impressed by source 8 on grid 9 and which traverses the gap 4 before impinging upon the positively charged collector electrode 10. It is preferred that collector electrode 10 be a hollow structure, conical, semi-circular, rectangular or otherwise, upon whose interior the electrons impinge. By means of magnetic focusing coil 11 and electrostatic focussing electrode 12 the electron stream is caused to travel along the axis of the electron discharge device. Suitable electrodes 13, maintained at a positive potential relative to the cathode, serve to accelerate the electrons. These electrodes as well as the cathode 7, grid 9 and electron collector 10 are positioned within an evacuated glass envelope 14. The electron beam is broken up into a series of groups of electrons by the grid, and delivers high frequency power to the resonant concentric line tank 1, 2, in the manner described in more detail in the article by Dr. A. V. Haeff, supra. Power may therefore be abstracted from this tank 1, 2 in any suitable manner.

In order to derive separate outputs from the electron discharge device there are provided a plurality of concentric line tank circuits 15, 16, 17, 18 spaced along the length of the tank 1, 2 in the manner shown. The inner conductors of these additional tank circuits are each provided with a ring 19 surrounding the electron beam for

obtaining by induction a charge in the tank circuit associated with the ring as the electrons pass through the ring. The rings 19 are suitably dimensioned to provide a proper time relation between the entry of an electron into the ring and its exit from the ring, it being preferred that the time of an electron to pass through any one ring correspond to one-half a period of the wave to which the particular tank associated with that ring is tuned. Each of the tanks 15, 16, 17 and 18 are provided with separate output circuits 20, 21, 22 and 23, respectively, comprising loops inductively coupled to the inner conductors of the tanks. It will thus be seen that if the electron beam from cathode 7 is modulated with different carriers, indicated herein diagrammatically by source 8 and grid 9, or putting it another way, if the electron beam is modulated by the pick-ups from different short wave stations (television or otherwise) and the tank circuits 15, 16, 17 and 18 suitably dimensioned or tuned to the frequencies of the carriers or intermediate frequencies derived therefrom, then different outputs can be taken from the loops 20, 21, 22 and 23 to feed different receiving circuits. It is preferred, of course, that a local oscillator be employed in a separate circuit to provide the different intermediate frequencies to be impressed on grid 9, although the invention is not limited to such an arrangement. Where desired, the tanks 15, 16, 17 and 18 may be dimensioned to tune to different related frequencies (i. e., multiple harmonic frequencies) or even to the same frequency. In the latter instance there will be derived output currents from tanks 15, 16, 17, 18 of the same frequency but of different phase, which, if desired, can be combined in known manner to provide an amplified signal. From what is stated above, it will be apparent that the system of Fig. 1 provides a plurality of outputs obtainable from a single electron beam.

Fig. 2 shows a circuit arrangement somewhat similar to that of Fig. 1, except that there is additionally provided a local oscillator 100 coupled to a concentric tank circuit 101 in order to modulate the electron stream of Fig. 2 before said stream passes through rings 19, 19, so that where different pick-ups are initially impressed upon the electron stream, the individual tanks 15 to 18, respectively, tuned to different intermediate frequencies, can derive energy of these frequencies from the electron stream; in this way the electron discharge device of the invention may function as a frequency converter. A suitable radio frequency input circuit 102 for varying the potential of ring 13' illustrates one way by which the electron stream may be velocity modulated between the rings 19, 19 of the auxiliary tank circuits.

Fig. 3 illustrates an amplifier arrangement wherein two quarter wave concentric line tanks 25 and 26, each substantially similar in construction to tank 1, 2 of Fig. 1, are arranged end to end in cascade, so that a single electron beam from the cathode 7 traverses the lengths of the inner conductors of both tanks, to excite them in succession. Tanks 25 and 26 may have the same or different dimensions. The gaps 4', 4' across the conductors of both concentric line tanks are positioned adjacent each other to reduce the transit time of the electrons exciting the two tank circuits, thereby maintaining the same electron grouping at both gaps. An electrode 19' may be positioned between the two tanks 25 and 26 and maintained at a suitable potential

for focussing the beam, and a single focussing coil 11' may also surround the two gaps 4', 4'. The electron collector electrode 10' and the various accelerating electrodes are all maintained at suitable positive potentials relative to the cathode 7. Individual output circuits 27 and 28 are respectively coupled to the two tanks 25 and 26. If desired, these two outputs can be combined in a single combining circuit 103 to provide an amplified output, in which case both tanks 25 and 26 will have identical dimensions. The lines from loops 27 and 28 are adjustable by means of trombone slides 60 to provide the proper phase relations between the currents in 27 and 28 to make them add. In this way the circuit of Fig. 3 can be used to obtain a wider frequency band than is possible with only a single tank.

Fig. 4 shows a modification of the system of Fig. 3, wherein the first tank 25 is employed as an oscillator stage, while the second tank 26 is employed as an amplifier or output stage. In Fig. 4 the output circuit 27 is utilized as a feedback circuit to modulate the electron stream, while the output circuit 28 extends to a suitable utilization circuit. Trombone slides 61 serve to adjust the lengths of the feedback leads. If it is desired to modulate the oscillations produced by the oscillator stage for transmission purposes, there may be employed, by way of example, a suitable frequency modulating circuit such as vacuum tube 29 to the control grid of which is coupled a source of signals 30 and to whose screen grid and anode are coupled loops 31 and 32, respectively, electrostatically isolated from each other by a shield 33. In circuit with loop 31 there is provided a 90° phase changer 34 so adjusted that tube 29 will draw either a leading or a lagging current, as desired, thus providing minimum amplitude modulation accompanying the desired frequency modulation.

By adjusting stage 25 to be an amplifier, as shown in Fig. 5, there will be obtained phase modulation effects. In Fig. 5, there is provided a stable source of carrier oscillations 8', and it will be noted that the feed-back path 27 of Fig. 4 is eliminated. The phase modulated oscillator of Fig. 5 may be converted to a frequency modulation system while still employing the constant frequency generator 8' by predistorting the signal input 30 so that the output thereof varies in inverse proportion to the signal frequency. This may be accomplished by inserting an amplifier in the signal input lines having the desired characteristic.

Fig. 6 shows a preferred compact mechanical construction for the two tank circuits of Figs. 3, 4, and 5 which can be used in these figures. In Fig. 6 a single partition wall 35 separates the two tanks and further reduces the electron transit time between the gaps of the two tanks. If desired, the two tanks may have different dimensions, as indicated, the tank nearest the collector electrode 10' preferably having the smaller dimension in order to derive therefrom energy of a harmonic frequency relative to the resonant frequency of the preceding tank. A coupling loop may be used when it is desired to couple the two tanks together. A similar coupling effect can be obtained merely by providing a suitable size aperture in the partition 35.

Fig. 7 shows a scheme for obtaining frequency modulated waves at ultra short wavelengths below one meter from a cavity resonator. In this figure, the element 40 represents a cavity resonator of suitable dimensions and designed to reso-

nate at a frequency preferably below one meter, let us say, for example, at a frequency in the range between 5 centimeters and 30 centimeters. In the interior of the resonator and suitably spaced apart from each other are a pair of dipole antenna elements 41, 42 coupled respectively by way of lines 43 and 44 to the output and input of an oscillator 45 located externally of the resonator. Obviously, other coupling elements than dipoles can be used, such as circular loops. This oscillator is preferably mounted on the resonator to conserve space. A pair of leads 46 extend to a suitable load or utilization circuit. If desired, a suitable limiter may be coupled to leads 46 to insure a constant amplitude of oscillations in the output. By suitably spacing the dipole elements from the ends of the resonator 40, the resonator will be driven by the oscillator and resonate at the frequency determined by its dimensions. According to the invention, it is proposed to vary these dimensions and also the resonant frequency of the resonator in accordance with signal modulations, as a consequence of which the frequency of oscillations of the oscillator 45 will vary. In this way it is possible to obtain from leads 46 waves modulated as to frequency in accordance with signal modulations. One way of varying the dimensions of the resonator 40 is to make one end wall 48 of the resonator movable in response to voice currents. It should be understood, of course, that end wall 48 is directly connected, electrically, by contact with the side walls of the resonator. To achieve this, the movable end wall may include or consist of a magnetic diaphragm which is controllable by a solenoid 49, in turn coupled to the microphone 47. If desired, the stationary solenoid may be replaced by a moving coil scheme mounted in a magnetic field, the moving coil being responsive to the voice currents. This coil can be arranged in the air gap of a permanent or an electromagnet. It will thus be seen that the ultra high frequency field within the resonator 40 will be modulated at an audio frequency rate. The distance between the dipoles 41 and 42 need not be critical, although certain spacings will give better results than others. It will also be found that there will be maximum efficiency for certain spacings to be determined by trial and error between the dipoles and the end walls.

Fig. 8 illustrates another way of obtaining frequency modulation effects by means of an inductive output tube. In this figure, 50 represents an inductive output type coaxial resonator, generally of the type shown in Fig. 1, provided with a gap in its inner conductor and surrounded by a magnet coil 11 to provide a focussing effect for the electron stream of the vacuum tube 14. The resonator and tube are similar to the identically numbered elements of Figs. 1 and 2. A feed-back coil 51, coupled to the grid 9 and cathode 7, insures the production of continuous oscillations in the system. A permanent magnet diaphragm 52 in one end wall of the resonator 50, movable in response to audio signal modulations from microphone 47, serves to change the dimensions and hence the resonant frequency of the tank 50 and to modulate the frequency of oscillations produced in the system.

What is claimed is:

1. Electron discharge apparatus comprising first and second hollow resonators each of which has electron permeable confronting surfaces defining the boundary of a gap, means for projecting a stream of electrons through the interiors of

said resonators in succession, including a cathode positioned outside the field of said first resonator and a collector electrode positioned outside the field of said second resonator and in a straight line with said cathode, said collector electrode gathering the electrons after they have passed through both of said resonators, and a grid electrode positioned between the gap of said first resonator and said cathode, a source of energy coupled to said grid for modulating the density of said stream, a feed-back loop located in the interior of said first resonator and coupled to said grid, a loop located in the interior of said second resonator for deriving energy from said last resonator, and a load coupled to said last loop.

2. Electron discharge oscillator comprising a hollow resonator having a gap, means for projecting a stream of electrons across said gap including a cathode and a collector electrode on opposite sides of said gap, a grid positioned between said cathode and said gap, a feed-back circuit coupling said resonator to said grid, and means for modulating the frequency of the oscillations produced by said oscillator comprising a multi-grid reactance tube having its input grid electrode and cathode coupled to a signal input circuit and its screen grid electrode and anode coupled to loops located in the interior of said resonator.

3. In electronic apparatus having means for producing a beam of electrons, the combination which includes a series of tubular elements of different dimensions arranged to be axially traversed by the beam, said elements being axially spaced to provide a plurality of gaps between them, a conductive structure concentrically surrounding each of said tubular elements and electrically connected thereto to form in combination therewith a resonant system, whereby said tubular elements comprise parts of different resonant systems, means for modulating the density of said beam of electrons prior to passage through one of said resonant systems, and means for abstracting energy from another of said resonant systems subsequently traversed by said beam.

4. In electronic apparatus having means for producing a beam of electrons, the combination which includes a series of tubular elements of different dimensions arranged to be axially traversed by the beam, said elements being axially spaced to provide a plurality of gaps between them, a conductive structure surrounding each of said tubular elements and electrically connected thereto to form in combination therewith a resonant system, whereby said tubular elements comprise parts of different resonant systems, means for abstracting energy from one of said resonant systems and feeding back said energy to modulate said beam of electrons, means for abstracting energy from another of said resonant systems subsequently traversed by said beam, and means in the interior of one of said resonators for varying the frequency thereof in accordance with signal modulation.

5. Electron discharge apparatus comprising first and second hollow resonators, means for projecting a stream of electrons through the interiors of said resonators in succession, including a cathode positioned outside the field of said first resonator and a collector electrode positioned outside the field of said second resonator and in a straight line with said cathode, said collector electrode gathering the electrons after they have passed through both of said resonators, a grid electrode in the form of a screen whose plane is at

right angles to the path of travel of the stream of electrons and positioned between the gap of said first resonator and said cathode, a circuit coupled to said grid for modulating the density of said stream, said cathode, grid electrode and collector electrode being located within an evacuated container, a load coupled to said second resonator, a vacuum tube having a control electrode, a screen electrode and an anode, a source of audio frequency signals coupled to said control electrode, a pair of conducting loops located in the interior of said first resonator, one of said loops being coupled to said anode and the other of said loops being coupled to said screen electrode, and a phase changer in circuit with one of said loops, whereby said apparatus constitutes an angular velocity modulation system.

6. Electron discharge apparatus comprising first and second hollow resonators each composed of a cylindrical hollow outer conductor and a coaxial hollow inner conductor, said outer conductors being continuations of one another, said inner conductors being located on the same straight line and separated from each other by gaps, said resonators being separated from each other by a single metallic partition extending at right angles to the directions of said outer and inner conductors from a point on said outer conductors to a point on said straight line, means for projecting a stream of electrons through the interiors of said resonators in succession, including a cathode positioned outside the field of said first resonator and a collector electrode positioned outside the field of said second resonator and in a straight line with said cathode, said collector electrode gathering the electrons after they have passed through both of said resonators, a grid electrode in the form of a screen whose plane is at right angles to the path of travel of the stream of electrons and positioned between the gap of said first resonator and said cathode, a circuit coupled to said grid for modulating the density of said stream, said cathode, grid electrode and collector electrode being located within an evacuated container, means coupled to said first resonator for producing angular velocity modulation effects therein, and a load coupled to said second resonator.

7. In electronic apparatus having means for producing a stream of electrons, the combination which includes a hollow cavity resonator through which said stream passes, and a vacuum tube circuit for producing angular velocity modulation effects in said resonator, said vacuum tube including a pair of cold electrodes, said circuit including a pair of loops located in the interior of said resonator but electrostatically isolated from each other and coupled to different cold electrodes of said vacuum tube, and a signal input circuit coupled to another electrode of said tube.

8. A modulation system comprising an electron beam tube, a resonant chamber associated with said tube, means for modulating the beam of electrons in said tube, coupling means entering the interior of and coupled to said resonant chamber, and means for altering the modulated electron beam into a different form of modulation by varying the effective impedance of said coupling means, comprising a circuit for causing a reactive current to flow in said coupling means, and means for varying the amount of reactive current flowing in said coupling means in accordance with control voltages.

9. A modulation system comprising a modulation tube of the type employing a beam of elec-

trons having means for modulating a characteristic thereof, a resonant chamber associated with said tube for regulating the frequency of operation of said tube, coupling means entering the interior of and coupled to said resonant chamber, and means for altering the modulation of said electron beam into a different form of modulation by varying the effective impedance of said coupling means comprising a circuit for causing said coupling means to act as an effective reactance, and means to vary the amount of reactance presented by said coupling means in accordance with modulation potentials.

10. A modulation system comprising a modulation tube having an electron beam passing therethrough, means for impressing a modulation on said beam, a resonant chamber associated with said tube for regulating the frequency of operation of said tube, coupling means entering the interior of and coupled to said resonant chamber, and means for altering the modulation of said beam into a different form of modulation by varying the effective impedance of said coupling means comprising a variable capacitive reactance coupled to said coupling means, and means for varying the capacity of said reactance at a modulation frequency rate.

11. In a frequency or phase modulation system, electronic apparatus for producing a stream of electrons, a cavity resonator through the interior of which said stream passes, said resonator having a gap through which said stream passes, a loop in the interior of said resonator, and connections from said loop to a source of signal modulation, and means including said loop and connections to produce angular velocity modulation effects in said system.

12. In a frequency or phase modulation system, an oscillation generator circuit including as a part thereof a resonator having uniformly distributed inductance and capacitance, said resonator having an outer conductor and a coaxial inner conductor, and a reactance tube modulator having a pair of cold electrodes individually coupled to said resonator by means of loops in the interior thereof, a connection from a source of signal modulation to an electrode of said modulator, the connections from said reactance tube to said resonator being so arranged as to produce angular velocity modulation effects in said system.

13. In a frequency or phase modulation system, an oscillation generator circuit including as a part thereof a resonator having uniformly distributed inductance and capacitance, said resonator having an outer conductor and a coaxial inner conductor connected together at one end by a metallic plate, and a reactance tube modulator having a pair of cold electrodes individually coupled to said resonator by means of loops in the interior thereof located near said one end of said resonator, a connection from a source of signal modulation to an electrode of said modulator, the connections from said reactance tube to said resonator being so arranged as to produce angular velocity modulation effects in said system.

14. In a frequency or phase modulation system, an oscillation generator circuit including as a part thereof a resonator having uniformly distributed inductance and capacitance, said resonator having an outer conductor and a coaxial inner conductor, and a reactance tube modulator having a pair of cold electrodes individually coupled to said resonator, one of said couplings comprising a

loop in the interior of said resonator, a connection from a source of signal modulation to said modulator, the connections from said reactance tube to said resonator being so arranged as to produce angular velocity modulation effects in said system.

15. An oscillation generator comprising a hollow body resonator, means for producing a stream of electrons and for passing said stream through

5 said resonator, means for modulating a characteristic of said stream, means for producing angular velocity modulation effects in said resonator comprising an element entering the interior of said resonator and in energy transfer relation to the electromagnetic field in said resonator, and signal modulation means coupled to said element.

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