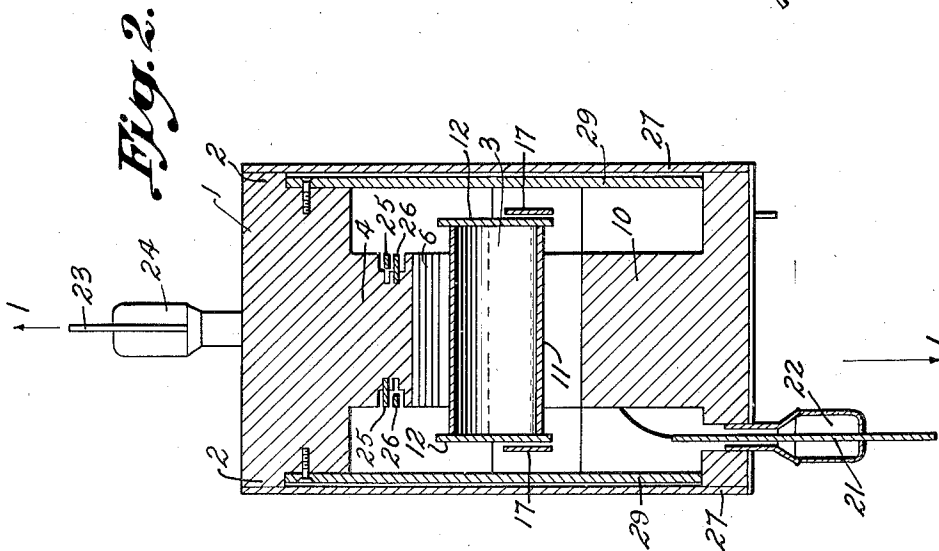
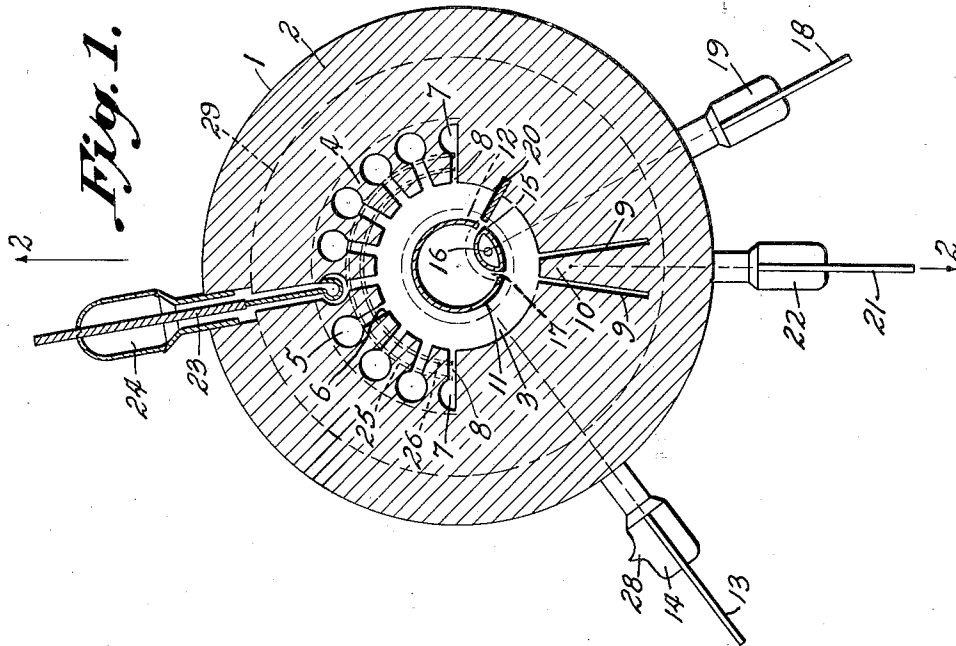


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CAVITY RESONATOR MAGNETRON

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CAVITY RESONATOR MAGNETRON

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This invention relates to apparatus for amplifying or multiplying the frequency of electrical oscillations of high frequency, especially, but not exclusively, of frequency as high as or higher than 3000 megacycles per second.

One of the most effective forms of apparatus which has been developed for generating electrical oscillations of very high frequency is the magnetron oscillator, and the object of this invention is to adapt for the purpose of amplifying and frequency multiplying, the principles on which the magnetron depends for the generation of oscillations.

In the well known magnetron oscillator in which a cylindrical cathode is surrounded by a ring of hollow resonators, energy is transferred from direct current field to an oscillatory field by the reaction of electrons energised by the direct current field with the oscillatory fields within the hollow resonators, a magnetic field applied transversely of the direct current field ensuring that electrons which receive energy from the oscillatory fields are immediately returned to the cathode whereas electrons which give up energy to the oscillatory fields travel round the cathode in synchronism with a potential wave travelling round the resonators so that these electrons give up energy to a plurality of resonators in succession.

According to the present invention a magnetron amplifier or frequency multiplier for amplifying or multiplying the frequency of an input oscillation of high frequency comprises means for producing a stream of electrons, means for density modulating said stream in accordance with the amplitude and frequency of the input oscillation, electrodes defining an electron orbit space along which said density modulated stream can flow under the influence of an electrostatic field between said electrodes and a transverse magnetic field, a plurality of coupled resonant output circuits spaced apart along said electron orbit space so as to be excitable in succession by said density modulated stream and resonant as a whole at a frequency $n f$, where n is an integral number and f is the frequency of the said input oscillation, and means for extracting the required output oscillation from the said output circuits. For an amplifier n equals one and for a frequency multiplier n is an integer greater than one. For frequency-multiplying the density modulation of the electron stream must be non-sinusoidal.

The successive excitation of the output circuits sets up a system of potential variation having a

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travelling wave component which, with the resonant output circuits spaced in accordance with the mean velocity of the electrons, is synchronised with the flow of the electrons so that a considerable transfer of energy is obtained and a strong output oscillation built up.

The term resonant output circuits is used instead of hollow resonators since the resonators might in some cases be replaced by resonant fingers or possibly by physically distinct resonant output circuits connected across slits between adjacent anode segments.

In general, and especially for very high frequency use, all the electrodes and circuits will be enclosed within or form part of the walls of the evacuated enclosure in which the electrons are adapted to move, but in some cases parts of the apparatus, and especially parts of the input and output circuits, may be located or extend outside the walls of the enclosure.

It may also be noted that the output circuits need not be individually resonant at the frequency, or an integral multiple of the frequency, of the input oscillation so long as the combined output circuit formed by the coupling together of the individual output circuits is effectively resonant at the required output frequency; thus the "rising sun" arrangement often used in resonant cavity magnetrons may be adopted to ensure wide mode-spacing.

The coupling together of the output circuits will in general be effected merely by their disposition, but in some cases special coupling means may be used. There must, of course, be substantially no coupling between the output circuits and the input circuit or the system may be self-oscillating and not function as an amplifier or frequency multiplier.

Further it may be noted that, as with other forms of amplifier, the apparatus may have utility even if the amplitude of the output oscillation is less than that of the input oscillation; accordingly it will be understood that in this specification the term "amplifying" does not necessarily imply that the output oscillation is of greater amplitude than the input oscillation, although this will often be the case.

The preferred method of producing a density modulated stream of electrons in apparatus in accordance with the invention is to arrange a thermionic cathode opposite an input circuit which is excitable by and resonant at the frequency of the input oscillation so that the emission from the cathode is controlled by the input circuit, and to arrange a non-secondarily emissive

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electron-intercepting electrode adjacent to the cathode so that by the application of crossed electrostatic and magnetic fields, which may be the same as those applied in the electron orbit space, the electrons emitted from the cathode are directed to the intercepting electrode in the absence of any input oscillation; then when the input oscillation is applied electrons which are retarded by the input circuit are diverted from the intercepting electrode and flow on to excite the output circuits along the electron orbit space, the effect being that isolated groups of electrons are released to the electron orbit space, the number of electrons in each group corresponding to the amplitude of the input oscillation and the spacing between the groups corresponding to the frequency of the input oscillation; the spacing between the output circuits is arranged to be half the spacing between the group of electrons. This method of density modulation results in a non-sinusoidally modulated stream which is well suited for frequency multiplying.

It will be appreciated that either amplifying or frequency multiplying apparatus in accordance with the invention need not be of the circular form similar to the well known magnetron oscillator; a linear form in which the cathode electrode and a co-operating anode electrode are substantially plane may be used; but the circular form is preferred and one embodiment of the invention in this form, which is an amplifier, will now be described by way of example with reference to Figures 1 and 2 of the accompanying drawing.

Figure 1 shows a section at right angles to the circular axis and Figure 2 a section containing the circular axis; the section of Figure 2 is in the plane 2—2 of Figure 1, looking from the right, and the section of Figure 1 is in the plane 1—1 of Figure 2, also looking from the right.

In this embodiment, the apparatus comprises a cylindrical metal block anode 1 recessed at each end face to leave an annular peripheral flange 2 and pierced co-axially by a cylindrical hole 3 which provides the electron orbit space. Around one half of this hole the block is further recessed deeply at each end face to form a thinner semi-circular ring 4 which is pierced parallel to the axis by eight holes 5, each communicating with the hole 3 through a radial slot 6 pierced through the ring 4 parallel to the axis, and, each adjacent to the thicker part of the block, two semi-circular holes 7 each communicating with the hole 3 through a slot 8 of half the width of the slots 5.

The holes 5 and slots 6 constitute output cavities each resonant at the frequency at which the apparatus is adapted to operate, that is amplify, and the holes 7 and slots 8 likewise constitute cavities resonant at the said frequency; these last two cavities are shaped so as to have zero field along the face of the thicker part of the block to avoid coupling with the input circuit.

Near the centre of the thicker part round the central hole 3, the block is pierced parallel to the axis by two radial slots 9, each of radial length effectively one quarter of the wave-length at which the apparatus is adapted to operate, and between the slots the block is recessed from each end face to form a wedge-shaped finger 10, resonant at the said wave-length, having the same axial thickness as the ring 4; the finger 10 constitutes the resonant input circuit.

Along the centre of the hole 3 there is located, coaxially, a cylindrical cathode electrode 11

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which is carried by circular end plates 12 each supported by a stout metal lead 13 sealed through the cylindrical wall of the block by a metal-to-glass thimble seal 14 in accordance with the technique usual in magnetrons. The surface of the cathode electrode 11 is treated to render it everywhere substantially non-secondarily emissive, for example by coating with titanium dioxide.

At about the centre and to one side of the finger 10, the cathode electrode 11 and end plates 12 are cut away to accommodate an indirectly heated primary cathode 15 consisting of a metal box containing a heater 16; the curved outer face of the box, which face is coated with electron emissive material, effectively forms a completion of the cathode electrode cylinder.

The primary cathode is carried by end plates 17 each supported by a stout metal lead 18 sealed through the cylindrical wall of the block by a metal-to-glass thimble seal 19; the leads 18 serve also as current supply leads to the heater 16 and the primary cathode is insulated from the cathode electrode so that the two electrodes can if required be maintained at different potentials by means of the leads 18, 13 respectively.

Between the primary cathode 15 and the adjacent cavity constituting the hole 7 and slot 8 but nearer the cathode 15, a metal strip 20 is set, parallel to the axis, into the block bounding the cylindrical hole 3 and extends radially to within a short distance of the cathode electrode 11; the strip 20 constitutes an electron barrier preventing electrons from re-passing the finger 10.

An input lead 21 to the finger 10 is sealed through the cylindrical wall of the block by a metal-to-glass thimble seal 22, and an output lead 23, terminating in a loop lying within one of the holes 5, is sealed through the wall by a metal-to-glass thimble seal 24.

The resonant cavities formed by the holes 5 and slots 6 constitute the resonant output circuits adapted to be excited by electrons moving round the electron orbit space 3, and the metal tongues formed between adjacent slots are connected together, at each face of the block, by metal mode-spacing straps 25, 26, set into circular slots formed in the tongues, of which on one face of the block strap 25 connects together the odd numbered tongues, that is to say the first, third, fifth, seventh and ninth tongues, and strap 26 connects together the even numbered tongues, that is to say the second, fourth, sixth and eighth tongues, counting round the block, whilst on the other face of the block the outer strap 25 connects the second, fourth, sixth and eighth tongues whilst the inner strap 26 connects the first, third, fifth, seventh and ninth tongues. The spacing between the resonant output cavities is arranged relative to the electrostatic and magnetic fields to be used to correspond to the mean velocity of the electrons round the electron orbit space so that the distance between successive resonators is half the length occupied by a complete cycle of electron density variation.

To each face of the shallow recess from which the flanges 2 project is screwed a potential-equalising plate 29 and the block is sealed off by means of end-plates 27 attached to the flange 2 in accordance with the usual magnetron technique.

The apparatus is evacuated and finally sealed off by means of a pumping tube 28 sealed to the

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glass thimble of one of the cathode electrode lead seals.

For amplification of an input oscillation of frequency 3000 megacycles per second with apparatus relatively dimensioned as shown, the radius of the block 1 should be about two inches.

I claim:

1. A magnetron device comprising an anode electrode and a parallel cathode electrode defining between them an ended electron orbit space, means for producing a stream of electrons originating at one end of said space and flowing along the space, means for receiving a high frequency input oscillation, means for density modulating said electron stream at said end of said space in accordance with the amplitude and frequency of the input oscillation, a plurality of resonant output circuits connected across slots formed in said anode electrode and spaced apart along said electron orbit space so that said circuits are excitable in succession by said density modulated stream of electrons and resonant as a whole at a frequency $n f$, where n is an integral number and f is the frequency of said input oscillation, and means for extracting the required output oscillation from said output circuits.

2. A magnetron device as set forth in claim 1 which functions as an amplifier wherein n equals one.

3. A magnetron device as set forth in claim 1 which functions as a frequency multiplier wherein n is an integer greater than one.

4. A magnetron device comprising a metal block anode electrode and a parallel cathode electrode defining between them an ended electron orbit space through which electrons can flow under the influence of an electric field applied between said electrodes and a transverse magnetic field, said anode block being recessed at one region to form an input cavity system resonant at frequency f and at another region well spaced along the electron orbit space from said first region being recessed to form a plurality of mutually coupled resonant cavities arranged in succession along the electron orbit space to form an output cavity system resonant at frequency $n f$, where n is an integral number, a thermionic cathode whose electron emissive surface occupies a restricted region of said cathode electrode lying opposite said input cavity system, input means for applying an input oscillation to excite said input cavity system at frequency f for controlling the flow of electrons from said cathode, and output means for extracting from said output cavity system oscillations of frequency $n f$ excited by the flow of electrons through said electron orbit space.

5. A magnetron device comprising a cylindrical cathode electrode containing a thermionic cathode whose electron emitting surface extends

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axially along the cathode electrode surface but occupies only a small circumferential width thereof, a cylindrical metal block anode electrode lying concentric with but spaced from the cathode electrode to form between them the magnetron electron orbit space, at least one slot extending axially through the anode block at a region thereof opposite said electron emissive surface to form an input cavity system resonant at a frequency f for controlling the emission of electrons from said cathode, a plurality of adjacent slots each extending axially through the anode block over a restricted region thereof well spaced angularly from the input cavity system to form an output cavity system excitable by electrons flowing from the said cathode through the electron orbit space under the influence of a radial electric field between the anode and cathode electrodes and an axial magnetic field and resonant at frequency $n f$, where n is an integral number, an electron barrier electrode extending radially between said anode and cathode electrodes at a region between said input and output cavity systems for preventing repeated circulation of electrons round said electron orbit space, input coupling means for exciting said input cavity system at frequency f , and output coupling means for extracting an output oscillation of frequency $n f$ from said output cavity system.

6. A magnetron device according to claim 5 wherein the slots in the output cavity system define metal tongues, and wherein said tongues are connected together on each side of the block by two conductive mode spacing straps of which one strap connects together the odd numbered tongues and the other connects together the even numbered tongues, counting around the anode block.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,411,953	Brown	Dec. 3, 1946
2,412,772	Hansell	Dec. 17, 1946
2,412,824	McArthur	Dec. 17, 1946
2,414,085	Hartman	Jan. 17, 1947
2,416,298	Fisk	Feb. 25, 1947
2,418,117	Hale et al.	Apr. 1, 1947
2,423,716	McArthur	July 8, 1947
2,429,291	Okress	Oct. 21, 1947
2,437,279	Spencer	Mar. 9, 1948
2,487,656	Kilgore	Nov. 8, 1949