June 8, 1954 J. T. RANDALL ET AL 2,680,827

MEANS FOR TRANSFERRING POWER TO AND FROM MAGNETRONS

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Fig. 1.

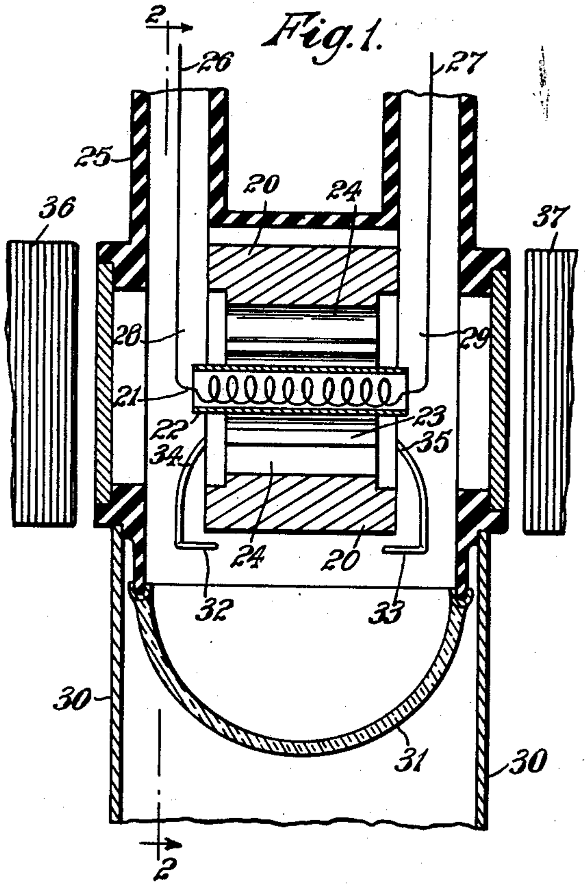

Fig. 2.

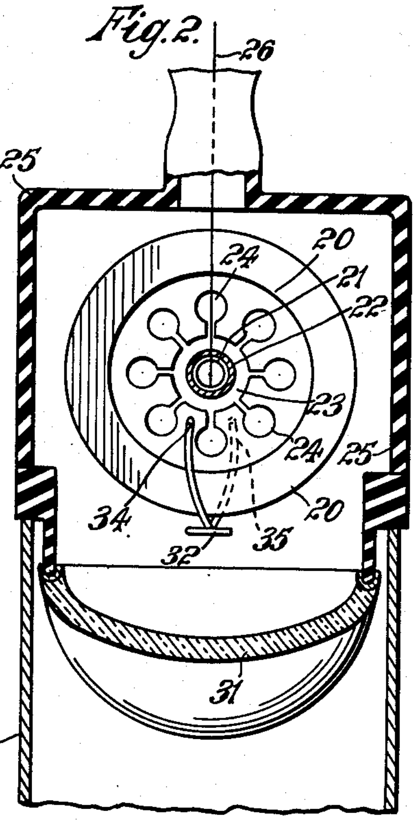

Fig. 3.

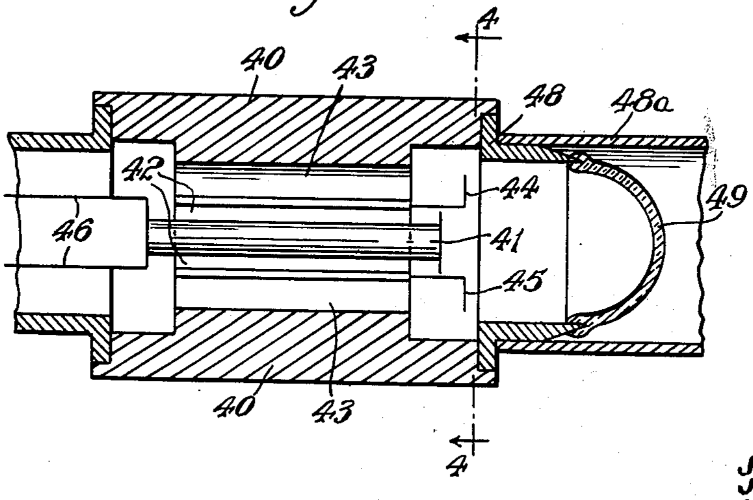

Fig. 4.

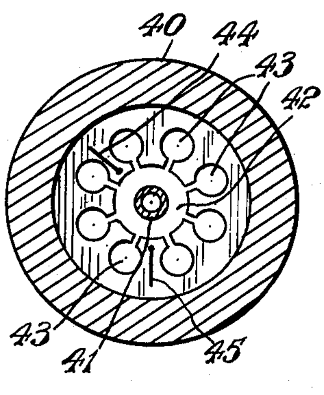

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Fig.5.

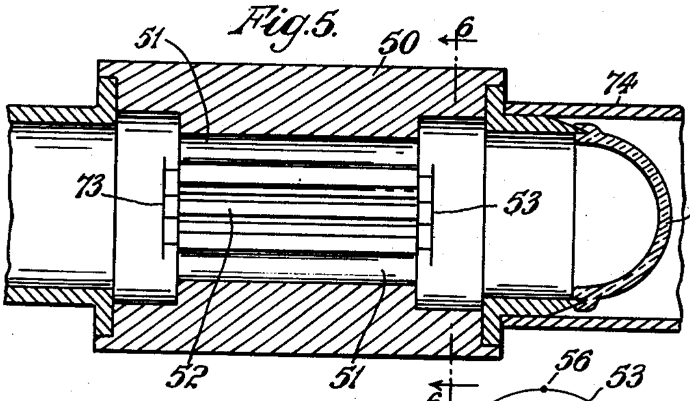


Fig.6.

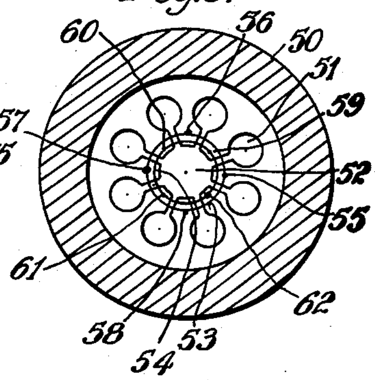


Fig.7.

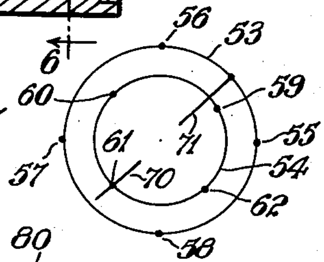


Fig.8.

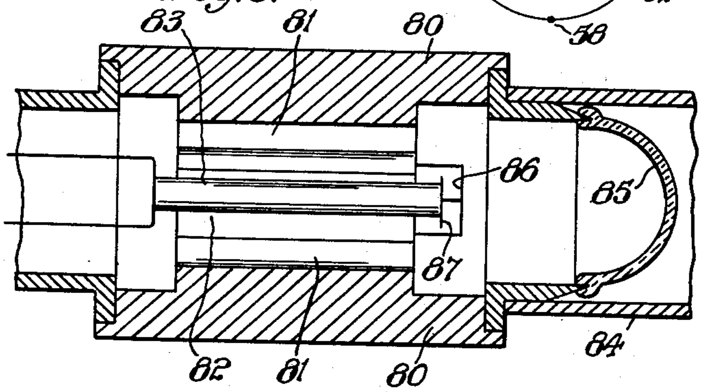
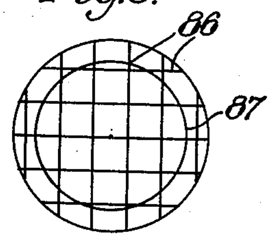


Fig.9.



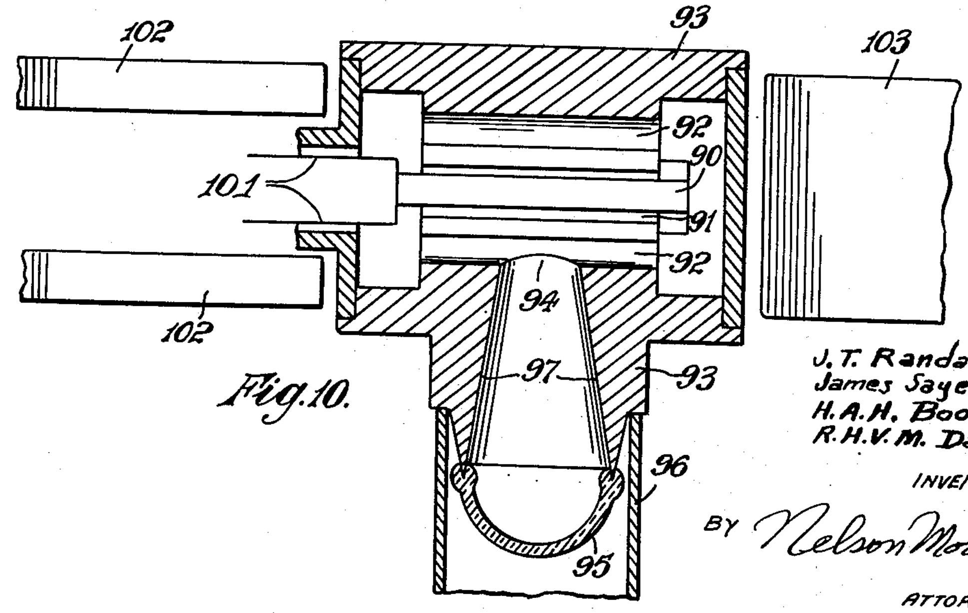


Fig.10.

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MEANS FOR TRANSFERRING POWER TO AND FROM MAGNETRONS

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Application September 4, 1947, Serial No. 772,198. In Great Britain December 17, 1941

Section 1, Public Law 690, August 8, 1946
Patent expires December 17, 1961

2 Claims. (Cl. 315—34)

This invention relates to high frequency electrical oscillators and more particularly to means for extracting power from and/or exciting the oscillating resonators of a magnetron. The magnetron tube to which the invention is preferably applied is of the type having an anode block defining a central cavity and a plurality of resonating cavities opening into the central cavity. The cathode is positioned along the axis of the central cavity. The anode block is a cylindrical metal block having a large axial central hole drilled therein thereby providing the central cavity, and also having a plurality of smaller holes drilled near the side of the main cavity thus providing resonator cavities.

The prior art method of feeding oscillatory energy to and/or from such magnetron oscillators consists in the use of an electromagnetic coupling loop which forms one end of a concentric transmission line and is inserted in one of the resonators. At very short wave lengths (for example, those of less than about five centimeters) the resonators are so small that this method becomes difficult to apply. This invention has as its primary object to feed energy to and/or from magnetron oscillators without the disadvantages of the aforementioned prior art method. The present invention is therefore particularly, but by no means exclusively, applicable to apparatus operating on the very small wave lengths referred to. Other objects of the invention include the provision of simpler and more satisfactory means of feeding energy to and/or from magnetrons than has been heretofore known. Other objects and advantages of the invention will appear as this description proceeds.

It is well known that a conducting tube will act as a wave guide provided its diameter is equal to or greater than a critical value proportional to the wave lengths employed; that is, oscillatory energy fed into the tube will be confined within, and transmitted along it with very little loss. Accoding to the invention high frequency electrical oscillators of the type preferred to are characterized in that the resonator system is arranged to feed energy directly to and/or receive it directly from such a wave guide without the interposition of any other type of transmission system.

According to a preferred arrangement an aperture is formed in one of the walls of the magnetron for the purpose of allowing radiated energy to pass from one of the resonator cavities to a wave guide. The wave guide is arranged to form an electrically continuous surface with the

wall in which the aperture is formed in order to prevent any loss of radiated energy. For the purpose of maintaining a vacuum within the body of the oscillator it will in general be necessary to close the aperture by a seal of glass or other suitable non-conducting material, but if in any particular application it is convenient to maintain a vacuum in the wave guide itself such a seal may, of course, be dispensed with. In one convenient arrangement the wave guide is adapted to fit over a small length of metal tube which is soldered or otherwise secured over the aperture and has a small glass dome or thimble sealed over its outer end.

In the complete specification accompanying copending application of John T. Randall and Henry A. H. Boot, Serial No. 407,680, filed August 20, 1941, now U. S. Patent 2,542,966 granted February 20, 1951, an arrangement is described whereby power is fed to a wave guide from the magnetron through a concentric transmission line, a small "aerial" consisting of the free end of the central core of the transmission line being arranged to project within the wave guide. According to a further arrangement described in the said specification the free end of a coupling loop arranged within one of the resonators is formed into a similar loop which is inserted within a wave guide. Neither of these specific arrangements falls within the scope of the present invention, since in the one case a concentric transmission line, and in the other case the double-ended coupling loop (which forms in effect the central member of a very short length of concentric transmission line) is inserted between the magnetron and the wave guide.

The invention, being generic, not only covers the specific form of our invention briefly mentioned above, but also other forms. In particular one of these other forms is characterized by small antennas attached to the pole pieces of the magnetron thus establishing radiators which will direct waves down a wave guide which faces said antennas. A reflector may be provided to direct the waves into the wave guide. The antennas may be simple radiators attached to the pole pieces, or they may be the straps of the so-called "strap magnetron."

In the drawings:

Figure 1 is a longitudinal cross-section of a magnetron incorporating that form of my invention where antennas are connected to the pole pieces for the purpose of directing the output into a wave guide.

Figure 2 is a sectional view along line 2—2 of Figure 1.

Figure 3 is a longitudinal cross-section of another form of the invention and has an antenna for directing energy into a wave guide.

Figure 4 is a sectional view along line 4—4 of Figure 3.

Figure 5 is a longitudinal cross-section of a so-called strap magnetron embodying the invention.

Figure 6 is a sectional view taken along line 6—6 of Figure 5.

Figure 7 is a detailed view of the straps of a strap magnetron with certain modifications to adapt the same for certain particular applications in connection with this invention.

Figure 8 is a longitudinal cross-section of another form of this invention.

Figure 9 is a plan view showing certain details of the device of Figure 8.

Figure 10 is a longitudinal cross-section of the preferred form of this invention and employs a direct opening from the wave guide into one of the resonator cavities for extracting high frequency energy therefrom.

While the invention is particularly applicable to magnetron oscillators adapted for generating large amounts of power and transmitting such power to a radio or radar transmitting antenna, the invention is also applicable to radio receiving tubes of the magnetron type. Therefore, wherever in these specifications we refer to extracting energy from the resonator it is understood that the same structure may be used for exciting the magnetron with waves received from a radio receiving system.

Referring to Figures 1 and 2 there is shown a metal cylindrical block 20 defining a central cavity 23 and eight smaller resonator cavities 24 arranged about the central one and having slit openings thereinto. An oxide-coated cathode 22 heated by filament 21 is concentric with the inner cavity 23. The block 20 is located within a sealed evacuated glass envelope 25, and leads 26 and 27 pass into the envelope to energize the filament 21.

At opposite ends of block 20 there are end spaces 28 and 29. Beyond these end spaces and outside of the envelope are located the poles 36 and 37 of a powerful magnet. Briefly speaking the mode of operation of the parts of Figures 1 and 2 thus far specifically described is that the cathode 22 emits electrons toward the positively charged anode block 20. Due to the strong cross-field of magnet 36—37 the electrons depart from a radial motion to a motion more nearly concentric to the pole pieces and as they graze the pole pieces and pass the slits leading to the resonators they set up oscillations in the resonators. Hence, currents flow along the inner surfaces of the resonators charging alternate segments with opposite polarities. These alternate polarities react on the electron stream to cause the electrons to tend to bunch and by reason of the interaction of the resonators and the bunches of electrons passing each slit the oscillations are built up to a high degree in each resonator cavity 24. Due to the interaction of the bunches of electrons (which affect all resonator cavities 24) with the currents circulating in each cavity, a load may be placed upon all of the resonator cavities by extracting energy from any one of them. This fact together with a complete statement of the basic theory of operation of the magnetron may be found in the prior

copending application of James Sayers, Serial No. 577,067, filed in the United States Patent Office February 9, 1945, now U. S. Patent 2,546,870, granted March 27, 1951, as well as in the prior copending application of John T. Randall and Henry A. H. Boot above referred to.

We have found that a load may be placed upon the whole system of resonators by connecting two anode segments of opposite polarity to an electrical loading circuit. In Figures 1 and 2 we connect radiators 32 and 33 respectively to anode segments 34 and 35. Furthermore in these figures the radiators 32 and 33 are respectively at opposite ends of the anode block 20. Since these radiators are connected to anode segments 34 and 35 of opposite polarity they form an efficient radiator and the field set up between them causes radiation to pass through the glass envelope portion 31 and down the tuned wave guide 30. Some radiation will of course be accomplished even though one of radiators 32 or 33 is omitted, and moreover some radiation will also take place if both radiators 32 and 33 are connected to anode segments of similar polarity.

Referring to the modified form of Figures 3 and 4, there is shown an anode block 40 defining a central cavity 42 together with a plurality of resonator cavities 43 connected to the central cavity by slits and operating as heretofore described. A cathode 41 is energized by current through leads 46. A wave guide 48*a* is provided to transmit the energy away from the magnetron, and a sealing member 48 is employed to hold the glass seal 49 in proper position. Two radiators, which may also be termed antennas, 44 and 45, are respectively connected to anode segments which are of opposite polarity.

In Figures 5 and 6 we illustrate a so-called "strap magnetron," the cathode being omitted. Like the magnetrons described above, the one shown in Figure 5 has a cathode, a central cavity 52, eight resonator cavities 51 respectively having slits leading to the central cavity 52, and an anode block 50 positively charged. A wave guide 74 leads the energy from the system and the glass seal 75 maintains the cavities evacuated. The straps are circular conducting leads 53 and 54 (see Figure 6). The conductor 53 connects to all the anode segments of one polarity, namely anode segments 55, 56, 57 and 58. The conductor 54 connects to the remaining anode segments which are of course of opposite polarity to those just mentioned, that is conductor 54 connects to pole pieces 59, 60, 61 and 62. Another similar system of straps is preferably located at the left end of the magnetron and is shown at 73. The principle of operation of the straps just mentioned is described in the copending application of James Sayers already referred to. The straps 53 and 54 of Figures 5 and 6 of this specification radiate energy into wave guide 74.

For maximum efficiency the straps 53 and 54 should not be so large as to extend beyond the planes of the several surfaces of the wave guide. In other words, the radiating electrodes should direct their radiations into the wave guide and should therefore be smaller than and facing the opening in the wave guide. When the wave guide becomes so small that this is not possible, the radiators 70 and 71 of Figure 7 may be employed, to direct the energy into the wave guide 74.

The modified form of the invention which is illustrated in Figures 8 and 9 has an anode block 80 defining a plurality of resonator cavities 81 all connected by slits to the central cavity **82**. The cathode **83** of the usual type is provided, but in this case has an end shield **87** connected to the cathode and operating at cathode potential. One function of the end shield **87** is described in the said prior copending application of James Sayers as preventing stray electrons from passing into the end spaces. In the present invention, the end shield **87** has the additional function of acting as a reflector to direct the energy into the wave guide **84** through the glass seal **85**. Preferably the reflector **87** should lie one-quarter wave length behind the radiator **86** which may be any of the radiators already mentioned but is shown in Figures 8 and 9 as a plurality of wires forming radiator **86** of grid-like formation. The radiator **86** is preferably connected to one or more voltage antinodes of the system. If connected to more than one, they should preferably coincide in amplitude and phase. The radiator **86** lies in a plane at right angles to the axis of the wave guide **84** and therefore the energy is directed into the wave guide.

The preferred form of our invention is disclosed in Figure 10 wherein an anode block **93** is connected to the positive side of a high voltage power supply. The cathode is connected to the negative side of such source and wires **101** energize the filament to heat the cathode. A central cavity **91** feeds a plurality of resonator cavities **92**. The magnetron of Figure 10 generates power in its resonators in the manner hereinbefore described, and the power is extracted by a small hole **94** in one of the resonator cavities **92**. In the usual constructions of the prior art a coupling loop system is inserted into one of the resonators half way along its length. Instead of this arrangement, however, the hole **94** in the resonator system may be used as a radiating aperture. At wave lengths of the order of ten centimeters the aperture obviously cannot be such as to act directly as a wave guide. The aperture **94** and wave guide **96** may therefore be joined by a suitable metal cone **97**, the vacuum enclosure being completed by the glass seal **95**. Should a rectangular wave guide be preferred a suitable adaptor can be provided, and the axis of the resonator slot will be parallel to the long axis of the wave guide. Like in the case of all the magnetrons described herein, the magnetron must have magnetic flux in line with the axis of the central cavity and in Figure 10 the magnet poles **102** and **103** provide the desired flux.

It is clear from the drawings that an advantage of our invention resides in the fact that the end of the wave guide is contiguous with the anode block. For example, in Figure 3, the wave guide **48a** is anchored and supported by the heavy anode block **40**. Likewise in Figure 10, the wave guide **96** is attached directly to the anode block **93**, resulting in a simple, rigid and reliable arrangement.

We claim to have invented:

1. A magnetron comprising an anode block defining a main cavity and a plurality of cavity resonators opening into the main cavity, said anode block having anode segments separating the cavity resonators from each other, antennas respectively connected to anode segments of opposite polarity and at opposite ends of the anode block, a magnet having magnetic flux along the axis of said main cavity, pole pieces respectively adjacent opposite ends of the anode block, said antennas extending from said anode segments in a direction generally perpendicular to the said magnetic flux to a region beyond the side of the anode block, and a wave guide having its axis perpendicular to the path of said flux and in the path of the field set up by said radiators.

2. A magnetron comprising an anode block defining a central cylindrical main cavity and a plurality of resonator cavities about and opening into the main cavity, a cathode extending along the axis of the main cavity, magnet poles at opposite ends of the main cavity for establishing a field through the block parallel to said axis, means connected to said block and associated with one of said resonator cavities and extending away from that resonator cavity at substantially right angles to said axis for transferring electromagnetic energy from that resonator cavity away from said block in a direction perpendicular to that of the first-named axis, and a wave guide surrounding an outer portion of said means to thereby interchange energy with it, said means comprising a pair of antennas respectively directly connected to opposite ends of the anode block and respectively connected to the anode segments at opposite sides of said one resonator cavity, said antennas extending generally perpendicular to the axis of the main cavity and into the said wave guide.

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