June 26, 1951 | J. H. FREMLIN | 2,557,959

ELECTRON DISCHARGE DEVICE OF THE VELOCITY MODULATION TYPE

Filed Oct. 5, 1946 | 2 Sheets-Sheet 1

FIG. 1.

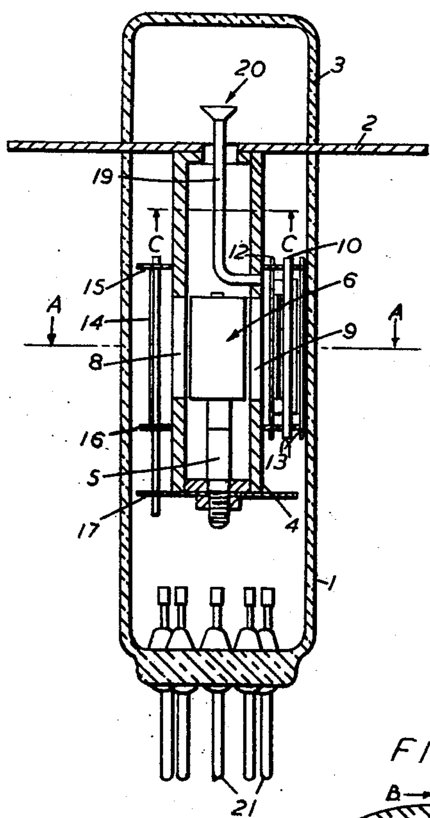


FIG. 2.

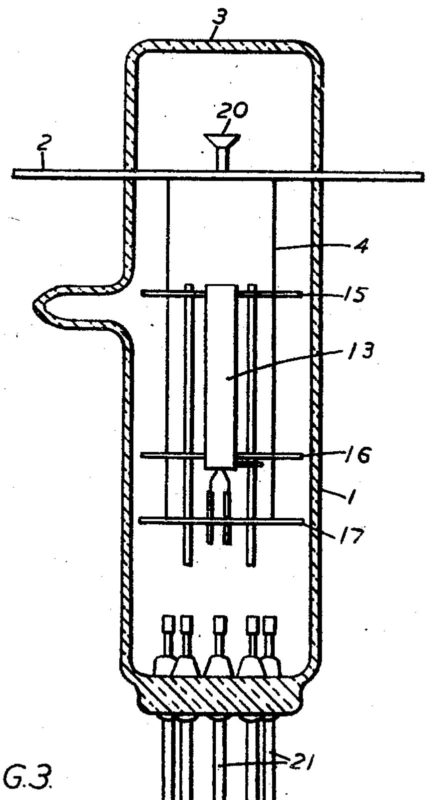
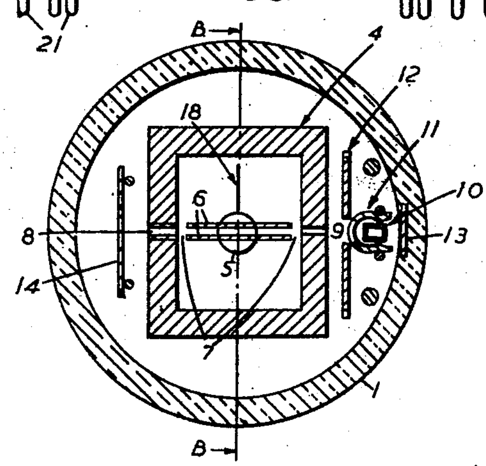


FIG. 3.



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June 26, 1951 — J. H. FREMLIN — 2,557,959

ELECTRON DISCHARGE DEVICE OF THE VELOCITY MODULATION TYPE

Filed Oct. 5, 1946 — 2 Sheets-Sheet 2

FIG. 4.

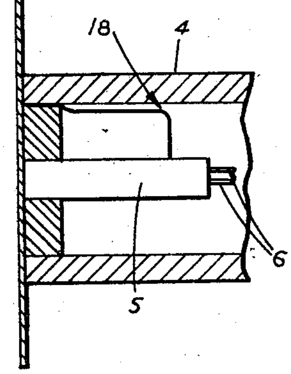


FIG. 5.

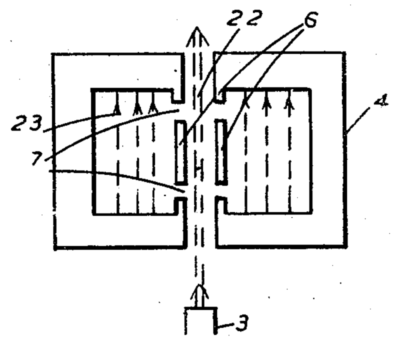
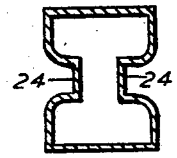


FIG. 6.



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2,557,959

ELECTRON DISCHARGE DEVICE OF THE VELOCITY MODULATION TYPE

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In Great Britain June 16, 1945

Section 1, Public Law 690, August 8, 1946
Patent expires June 16, 1965

1 Claim. (Cl. 315—5)

1

The present invention relates to ultra high frequency oscillation generators of the electron velocity modulation type, and is concerned particularly with a construction suitable for operation at wavelengths of the order of 3 centimeters or less.

As the wavelength of the oscillations decreases to the neighbourhood of a few centimeters, it becomes exceedingly difficult to design an electric resonator or circuit having a sufficiently low resistance loss. This is particularly troublesome in velocity modulation devices in which the starting current (which is the amount of current required to maintain oscillations in the resonator in the absence of any external load) is for a given resonator proportional to the equivalent series resistance of the resonator. It can also conveniently be regarded as inversely proportional to the equivalent shunt impedance of the resonator.

The reduction in wavelength also increases the difficulty of obtaining a sufficiently small starting current. The resonator necessarily gets smaller as the wavelength decreases, and the area of the cathode which can be used to supply the current tends to become smaller in proportion to the square of the wavelength.

In ultra short wave generators of this kind, it is also very desirable that there should be available a large range of electronic tuning; that is, it should be possible to vary the frequency by a relatively large amount by varying the operating currents or voltages of the device without having to make any mechanical tuning adjustments. This facility also becomes difficult as the cathode area decreases. In this connection the effective shunt impedance of the resonator is not of much importance so long as it is high enough to make the starting current sufficiently low, but the electronic tuning range is inversely proportional to the effective capacity of the resonator, and so as the wavelength diminishes, it is all the more important that this capacity should be low in order to minimise the difficulty of maintaining sufficient current when the maximum permissible current density is being approached.

Both these difficulties are particularly serious with single transit devices, which have so many important advantages in other respects.

The difficulties which have been explained are overcome at least in part according to the invention by the use of a velocity modulation device which in construction is similar to the well known device having a coaxial line type of resonator excited by an electron stream directed

2

transversely across it, as described for example in British Patent Specification No. 537,490, but with this important difference that a different mode of oscillation is employed. As the device would have a strong tendency to oscillate at a lower frequency in one of the modes more usual to the coaxial line type of resonator, means is provided for damping or absorbing oscillations in such modes so that they cannot occur, such means being disposed so that the oscillations in the desired mode are not affected.

The several features of the invention are set out as claims 1 to 4 respectively of the statement of claim.

The invention will be explained with reference to the accompanying drawings in which:

Fig. 1 shows a partially sectional view of an ultra high frequency generator according to the invention;

Fig. 2 shows a view looking at the right hand side of Fig. 1;

Fig. 3 shows an enlarged sectional view at A—A of Fig. 1;

Fig. 4 shows a partial sectional view at B—B of Fig. 3;

Fig. 5 shows a diagrammatic sectional view of a resonator employed to explain the action of the device according to the invention; and

Fig. 6 shows a cross-section at C—C of Fig. 1 to illustrate a slightly modified resonator.

Referring to Figs. 1 to 4, a device according to the invention comprises a glass envelope **1** sealed to one side of a metal disc **2**, to the other side of which is sealed a glass cup **3** which completes the envelope. Mounted on the disc **2** is a hollow metal resonator **4** of rectangular cross-section, closed at the lower end. The resonator has a central conductor **5** fixed to the lower end. Fixed to the upper end of the central conductor **5** are a pair of thin plates **6** acting as fins to define a narrow passage for the electron beam. The usual gaps **7** to enable the beam to interact with the field of the resonator are provided between the ends of the plates **6** and the adjacent walls of the resonator. Two slots **8** and **9** are cut in the walls of the resonator **4** opposite the ends of the plates **6** to allow the electrons to pass through the resonator.

The beam is generated from a long narrow cathode **10** arranged parallel and opposite to the slot **9**. A control electrode **11** intended to be negatively polarised with respect to the cathode, and an accelerator electrode **12**, to be positive polarised, are arranged between the cathode **10** and the resonator **4** for generating the beam according to known methods. A screen electrode 13 is provided to catch electrons projected backwards from the cathode, and a target electrode 14 placed opposite the slot 8 is provided for collecting the electrons after passage through the resonator. The elements 10 to 14 are suitably mounted on mica discs 15, 16, 17 fixed to the resonator 4.

A loop of resistance wire 18 seen in Figs. 3 and 4 is connected between a point on the conductor 5 and a point near the side wall of the resonator at the closed end. The plane of this loop should be at right angles to the plane of the electron beam, as shown. This loop is provided for preventing oscillations in the undesired mode or modes as will be more fully explained later, and should be bent so as to enclose as large an area as possible.

Waves are extracted from the resonator by means of the loop 19 which is fixed to the wall of the resonator 4, and which passes through a hole in the disc 2 and terminates in an antenna 20 which is located inside the cup 3.

Terminals 21 for the electrodes are sealed through the base of the envelope 1. The connections to the electrodes are not shown, and may be arranged in any convenient way.

The diagram Fig. 5 shows the manner in which the device is intended to operate. The electron beam is directed across the resonator from the cathode 3. When the device oscillates in the desired mode, the electric lines of force are substantially in the direction of the dotted lines 23, as indicated by the arrows, namely, parallel to the electron beam. The magnetic lines of force form closed loops substantially in planes parallel to the electron beam, and are perpendicular to the electric lines of force, and also to the plane of the diagram, Fig. 5, in the neighbourhood of the plates 6. It is to be noted that no current flows along the central conductor 5. This conductor is therefore not essential and could be omitted, so long as suitable means are provided for supporting the plates 6.

As already mentioned, the device could also be excited so as to oscillate in one of the normal coaxial modes in which the current runs longitudinally down the walls of the resonator and up the central conductor. In this case, the electric lines of force radiate outwards from the central conductor and terminate on the walls, the magnetic lines being closed curves round the central conductor. As is well known, in order to excite a coaxial mode, the electron velocities must be so adjusted that the transit time from one pair of gaps to the other is $(n+\frac{1}{4})$ oscillation periods, while in order to excite the desired mode according to the present invention, the transit time must be $(n+\frac{3}{4})$ periods, n being an integer. It will be seen that in the case of the coaxial mode, the magnetic lines of force link the loop 18 (Figs. 3 and 4) and the loop will therefore damp the oscillations in this mode very heavily, so that it will be difficult if not impossible to excite this mode. The plane of the loop is however parallel to the magnetic lines of force in the case of the desired mode, so that there will be no damping of the oscillations in this mode.

The resistance of the loop should preferably be chosen so that it absorbs a maximum of power from the undesired oscillations. It should be added that although the wire has been shown as anchored at the lower end of the resonator for convenience in fixing, the wire could, if desired comprise a short length connected directly across the resonator at a point near the plates 6. The wire should then be arranged to be parallel to the electric lines of force corresponding to the undesired mode or modes so that it will introduce the maximum dissipation to the oscillations in that mode.

The same results could also be obtained by using a closed loop of wire suitably supported in the field of the resonator, so that its plane is parallel to the magnetic lines of force of the desired mode and links the magnetic lines of force of the undesired mode.

Such a loop should however either have sufficient resistance to be substantially unresonant, or should be adjusted to resonate at the frequency of the undesired oscillations, otherwise it may cause a high order coaxial mode to be excited which it would not be able to damp effectively.

The arrangement according to the invention has the important advantage that the two gaps 7 are effectively in series, since the current circulates round the section of the resonator, while in the case of oscillation in the coaxial mode they are effectively in parallel. The capacity loading introduced by the gaps is therefore effectively reduced to roughly one quarter in the arrangement according to the invention, other things being equal. This, as already explained, gives a much increased range of electronic tuning.

A further advantage is that a resonator of the form shown, in which the current circulates round the walls, is easier to manufacture with a low resistance than the coaxial type.

A moderate range of mechanical tuning may be obtained by suitably coupling the resonator to an adjustable resonator or wave guide.

The principle of the arrangement which has been described can be extended by providing more than two gaps in series between the passage defined by the plates 6 and the resonator field. This would further lower the starting current and increase the electronic tuning range.

While it is usually preferable to provide the two gaps 7 immediately adjacent to the slots 8 and 9, as shown in Fig. 3, it may in some cases be convenient or desirable to attach short fins to the resonator walls as indicated in Fig. 5, so that the gaps can be placed nearer the centre of the resonator. The use of such short fins is desirable when the walls of the resonator are thin, in order to prevent escape of the high frequency waves through the slots 8 and 9.

It is, of course, to be understood that magnetic focussing of the electron beam may be employed according to the usual practice, and this will be particularly desirable when the device is operated at low voltage.

It should be pointed out that the coupling loop 19 (Fig. 1) is at right angles to the suppressing loop 18, and therefore links the magnetic lines of force of the desired oscillation mode. It should not be placed too close to the plates 6 if a large range of electronic tuning is desired, because it may couple the resonator too closely to the external circuit, thus unduly increasing the "Q" value of the resonator. If however some external mechanical tuning is desired, the coupling should be close, and the loop 19 may be placed only a friction of a millimetre from the plates 6 and 7. Some of the electronic tuning range will be inevitably sacrificed, but the loss may be minimised by reducing the size of the external resonator as far as possible.

The device shown in Figs. 1 and 2 may be coupled to a wave guide or resonator by inserting the portion 3 of the envelope through a hole in the wall of the resonator or guide, the disc 2 being placed in contact with the outside of the wall in order to maintain the continuity thereof. The antenna should be arranged to be parallel to the electric lines of force of the waves to be excited in the guide or resonator. The antenna should be well coupled, and this may be effected by means of a disc or conical termination such as that shown.

The resonator 4 may be coupled to the external wave guide or transmission line without using a loop and antenna such as 19 and 20. If the cross section of the resonator above the plates 6 is changed to the form such as that shown in Fig. 6, the waves may be transmitted through the open end of the resonator directly into the wave guide. The cross section shown in Fig. 6 has two re-entrant portions 24 which enable it to transmit the waves whose frequency is too low for efficient transmission by the plain rectangular section of the resonator. The disc 2 should, of course, have an aperture of the same shape and size as the section shown in Fig. 6. The section of the lower part of the resonator will, of course, be unaltered, and the change in section should be smoothly effected by a suitable taper.

The following numerical particulars are given as an illustration of the performance of a device according to the invention:

Internal width of resonator (parallel to beam, Fig. 3)	0.164″
Internal breadth of resonator (perpendicular to beam)	0.425″
Length of conductor 5 (below plates 6)	0.280″
Length of plates 6	0.400″
Width of gaps	0.01″
Transit time ____ periods	3¾
Operating voltage ____ volts	310
Starting current (about) ____ milliamps	8
Wavelength of oscillations ____ cm.	3

The form of construction shown is very suitable for low-voltage oscillators giving a power output of one or two watts at wavelengths in the neighbourhood of 3 cm. In this case the gaps 7 may have to be increased somewhat in width. The power to be dissipated by the plate 14 will however be considerable, perhaps of the order of 50 or 100 watts, and in that case the device may be enclosed in a copper envelope, for example in the manner described in the British specification of application No. 778/44, the envelope being used to collect the electrons instead of the plate 14.

What is claimed is:

An electron discharge device of the velocity modulation type comprising a cavity resonator of the coaxial line type provided with aligned apertures defining a beam path on a diameter therethrough, means adjacent said resonator for directing a beam of electrons along said path for exciting oscillations in said resonator, parallel plate conductors disposed in said resonator on opposite sides of said beam path, a closed conducting loop disposed inside said resonator in a plane at right angles to said plates to link the magnetic lines of force of oscillations of the type to be prevented, the plane of said loop being substantially parallel to the magnetic lines of force of desired oscillations, a support for said plates, said support being carried by the bottom end wall of said resonator, and said loop comprises said support, said end wall and a wire extending laterally from said support to a point adjacent a side wall of said resonator and then substantially parallel to said side wall to said end wall.

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