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2,373,837

ULTRA HIGH FREQUENCY ELECTRONIC DEVICE

Filed Oct. 31, 1941

FIG. 1.



FIG. 2.

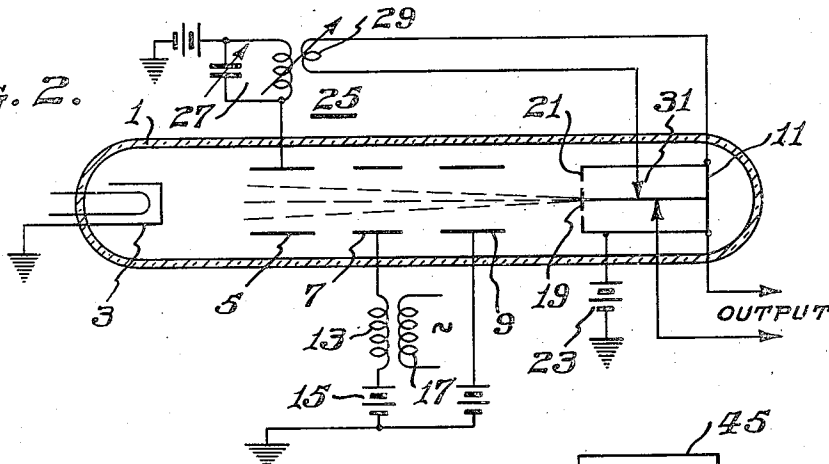


FIG. 3.

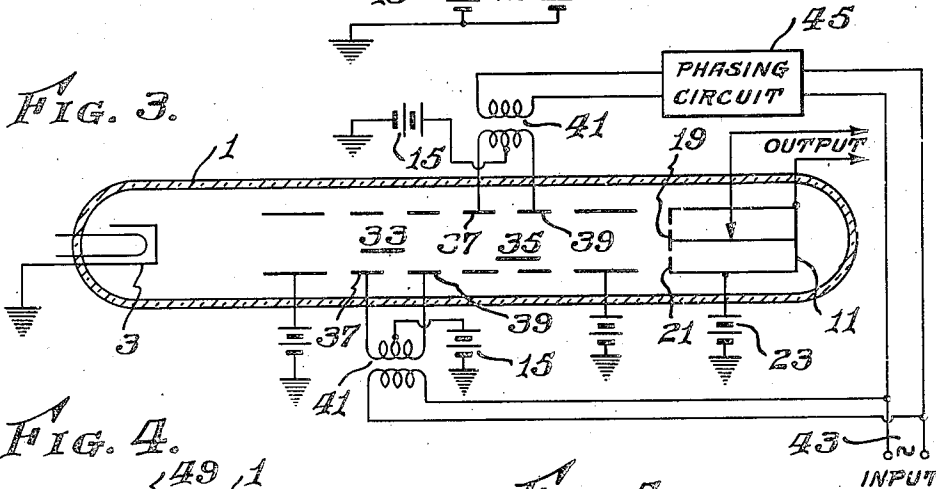


FIG. 4.

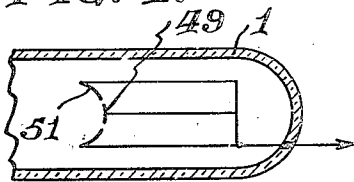


FIG. 5.

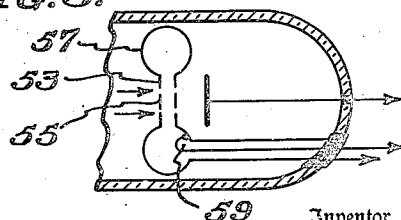
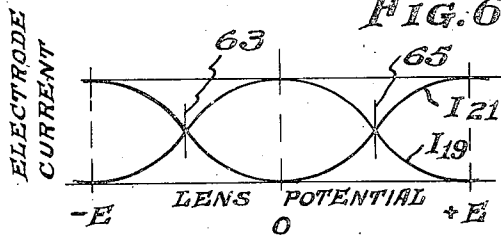


FIG. 6.



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UNITED STATES PATENT OFFICE

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ULTRA HIGH FREQUENCY ELECTRONIC
DEVICEErnest G. Linder, Philadelphia, Pa., assignor to
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7 Claims. (Cl. 250-27)

This invention relates to improvements in ultra high frequency electronic devices, and particularly to an electronic device in which the operating parameters are controlled by an oscillating electric lens.

In ultra high frequency electronic devices the transit time and the course or path of the electrons are important factors. The path of an electron may be altered by subjecting the electron to the influence of a magnetic or electrostatic field. If the field is appropriately shaped, an electric lens will be formed. Electrons passing through such a lens will be focused just as light waves are focused by a conventional lens.

While such electric lenses have been used in electron microscopes, to form images of electron transparent specimens, and in other electronic devices, these lenses are adjusted primarily to obtain a fixed focus. As an object of the present invention, means are provided whereby an electric lens of oscillatory focal length may be used to amplify or to modulate ultra high frequency currents. Another object is in the provision of means, in an ultra high frequency amplifier, for focusing electrons upon different portions of a resonant output circuit as a function of the input currents whereby amplification is obtained. Another object is to provide means for modulating ultra high frequency oscillations by directing electrons through a focusing field which is varied at the modulation frequency.

The invention will be described by referring to the accompanying drawing, in which Fig. 1 is a schematic illustration of an electron lens; Figure 2 is a circuit diagram of one embodiment of the invention; Figure 3 is a circuit diagram of an embodiment of the invention in which push-pull operation is employed; Figures 4 and 5 are fragmentary views of modified output circuits; and Figure 6 is a graph representing the operating characteristics of the invention. Similar reference characters indicate similar elements.

Referring to Fig. 1, if a pair of hollow cylinders *a* and *b* are suitably polarized, an electric lens will be formed. The curved lines *C* indicate the field through which are passed the electrons to be focused. The focal lengths *f*₁ and *f*₂ are indicated by the equation

$$\frac{f_2}{f_1} = -\sqrt{\frac{V_b}{V_a}}$$

where *V*_a and *V*_b are, respectively, the potentials of the cylinders. As the ratio of the cylinder potentials increases, both focal lengths decrease. If an alternating potential is applied to one of

the cylinders, a variation in the focal lengths of the lens will be produced. Under the influence of such a lens, the passing electrons will cover a variable area, at a fixed distance from the lens, as the focus changes.

One application of the variable electric lens to an ultra high frequency device is illustrated in Fig. 2. Within an evacuated envelope 1 are mounted an electron gun 3, a first hollow cylindrical electrode 5, a second hollow cylindrical electrode 7, a third hollow cylindrical electrode 9, and an output circuit 11. The three hollow cylindrical electrodes form an electron lens in which the center electrode is connected through a transformer secondary winding 13 and a biasing winding 15 to ground. The primary winding 17 is connected to a source of signals to be amplified or applied to modulate an ultra high frequency oscillation as hereinafter described.

The output circuit is preferably of the concentric line type and includes a pair of concentrically arranged electrodes 19, 21 which are connected, respectively, to the inner and outer conductors. The output circuit is biased positively by means of a battery 23. The output connection may be made by coupling to the line or by a conductive connection to points of suitable impedance between the inner and outer conductors.

The output circuit may include a feedback connection 25. This connection consists of a tuned circuit 27 which may be connected to the first cylindrical electrode 5, or other electrode intermediate the output circuit and the gun 3. The tuned circuit is coupled to the output circuit 11 by a primary winding 29 and a connection 31 to the inner electrode of the output circuit. The feedback circuit, which may be of the concentric line type, is used to establish regeneration or ultra high frequency oscillations. If no regeneration or self-oscillation is required, the feedback circuit may be eliminated.

The mode of operation is as follows: Electrons from the electron gun 3 are directed through the several cylindrical electrodes 5, 7, 9 toward the concentric electrodes 19, 21. The lens is adjusted by varying the bias 15 until the electrons are focused on the inner electrode 19 in the absence of signals. The transformer 13, 17 connections are adjusted so that the potential of an applied signal will change the focus of the lens and will cause some of the electrons to impinge upon the outer electrode 21. The adjustment may be made so that an applied signal of one polarity will focus the electrons on the inner electrode, and the signal of opposite polarity will focus the

majority of the electrons on the outer electrode. It should be understood that not all of the electrons focused on the outer electrode will fall on that electrode because the impinging electrons will cover a disc shape area, which will include the inner electrode. In any event, if the frequency of the output circuit is suitably adjusted, the alternate focusing of the electrons will establish amplified signal currents in the output circuit.

The feedback circuit may be adjusted to establish ultra high frequency oscillations, and these oscillations may be modulated by applying the modulating signal to the lens electrode. The modulating signals will vary the focus of the lens, and hence will vary the electron beam impinging on the electrodes of the output circuit. The resultant ultra high frequency currents flowing in the output circuit will be modulated at signal frequency.

In the arrangement of Fig. 2, a single adjustable focus electric lens is used in the amplifier or oscillator. The invention is not limited to a single lens, but may be used to advantage with a plurality of lenses and with push-pull input as shown in Fig. 3. In the space between the gun 3 and the output electrodes 19, 21 are arranged two push-pull controlled lenses 33, 35. The first lens 33 includes two hollow cylindrical electrodes 37, 39 which are connected to the balanced secondary of an input transformer 41. The center tap of the secondary may be connected through a biasing battery 15 to ground. The primary of the input transformer 41 is connected to the source 43 of currents which are to be amplified. The second lens 35 includes similar electrodes 37, 39 which are connected through a similar transformer 41 to the input source 43. A phasing circuit 45 may be included in the connections to one of the lenses so that the phase of the currents applied to the lenses may be properly adjusted. While the device of Fig. 3 has been described as an amplifier, it may be used as an oscillator by coupling the output and input circuits as described in connection with Fig. 2. Instead of using inductive coupling the capacitive coupling between the lens elements may be used to couple the output to the input.

If the maximum variation of focal length is desired, both the electron beam velocity and the electrode spacings should be so adjusted that a half period is required for an electron transit from the first lens to the second lens. The transit time through a lens should be a half period or less. Thus adjusted, the device will pass electrons through successive lenses at the same part of the cycle. The phasing circuit 45 permits other adjustments of phase and transit times to be made with respect to the circuit elements between which the phasing circuit is interposed.

As the focal length of the lens is varied, some velocity modulation will occur. Electrons converging upon the nearer or inner electrode 19 will have been accelerated in passing through the lens system and will have a shorter overall transit time. In some cases this velocity modulation may be large enough to distort the wave form of the amplified currents. By extending the outer electrode 51 with respect to the inner electrode 49, as shown in Fig. 4, the distances to the electrodes may be arranged to compensate for the differences in transit times. Moreover, by curving the electrodes the efficiency may be increased by further compensating for the transit time dif-

ferences. The diameter of the inner electrode should be made approximately equal to the diameter of the electron beam with no high frequency voltage applied to the lens. The diameter of the outer electrode should be made equal to the diameter of the electron beam with the maximum high frequency voltage applied to the lens.

Instead of focusing the electron beam on alternate electrodes which are connected to the resonant circuit, the beam may be alternately focused on the outer portion 53 and then on the inner portion 55 of a resonant cavity 57, as shown in Fig. 5. The electrons passing through apertures in the cavity establish waves therein. The output currents are induced in a coupling loop 59. A positively biased target electrode 61 is positioned behind the apertures in the resonant cavity. It should be understood that the electrons moving through the cavity give up energy just as the electrons impinging on the target electrodes 19 and 21 give up energy. In either mode of operation the device may be adjusted to operate about the reference line marked O or either of the reference lines marked 63 and 65 of Fig. 6 by suitably biasing the lens. If the device is biased to operate about the point O, frequency doubling will take place if the potentials applied to the lens extend from $-E$ to $+E$.

I claim as my invention:

1. An electronic device including in combination a source of electrons, an output circuit including electrodes upon which electrons from said source are impinged, means for feeding energy from said output circuit to vary the electrons flowing from said source thereby to establish ultra high frequency oscillations, an electric lens of variable focus located between said source and said electrodes, and means for applying a modulation signal to said lens to vary its focal length and thus to focus electrons from said source upon first one then the other of said electrodes so that said ultra high frequency oscillations are modulated.

2. An electronic device including an electron source, an output circuit including a pair of concentrically disposed electrodes of opposite instantaneous polarity, an electric lens of variable focal length entirely disposed between said source and said electrodes, means for directing electrons from said source through said lens to one of said electrodes, and means for varying the focal length of said lens to direct said electrons upon the other of said electrodes.

3. An electronic device including an electron source, an output circuit including a pair of concentrically disposed electrodes of opposite instantaneous polarity, a pair of electric lenses of variable focal lengths disposed between said source and said electrodes, means for directing electrons from said source through said lenses to one of said electrodes, and means for applying potentials in push-pull relation to said pair of lenses to vary their focal lengths to direct said electrons upon the other of said electrodes.

4. A device according to claim 2 in which said pair of electrodes are positioned at different distances from the center of said lens along its axis.

5. A device according to claim 2 in which said pair of electrodes form curved surfaces for compensating for differences in electron transit times.

6. An electronic device including a source of electrons, a resonant cavity including a pair of electrode surfaces separated by an aperture for passing electrons through said cavity, an electric

lens disposed between said source and said surfaces, means for directing electrons from said source through said lens upon said surfaces, and means for varying the focus of said lens so that said electrons alternately impinge on said surfaces and pass through said aperture.

7. An electronic device for generating ultrahigh frequency potentials including in combination, a source of electrons, an output circuit in-

cluding electrodes upon which electrons from said source are impinged, an electric lens of variable focus disposed between said source and said electrodes, and means for feeding energy from said output circuit to said lens to vary the electrons flowing from said source thereby to establish high frequency oscillations.

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