Nov. 22, 1949 E. W. HEROLD 2,489,132

ELECTRON DISCHARGE DEVICE

Original Filed April 24, 1942 2 Sheets-Sheet 1

Fig. 1.

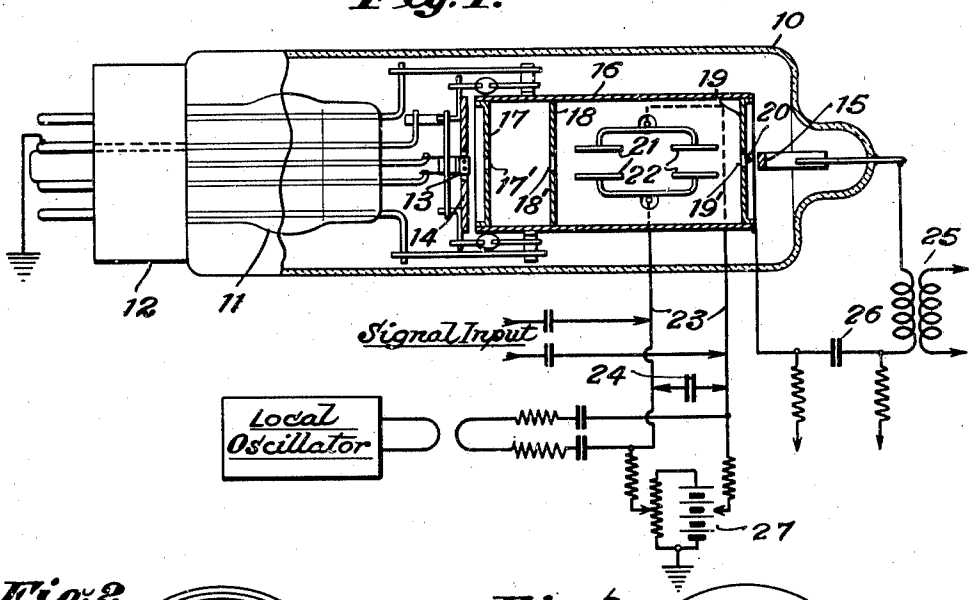


Fig. 2.

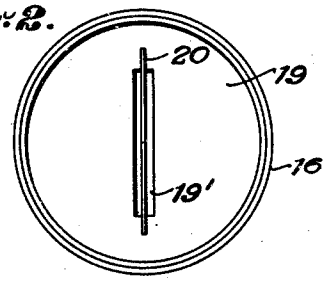


Fig. 3.

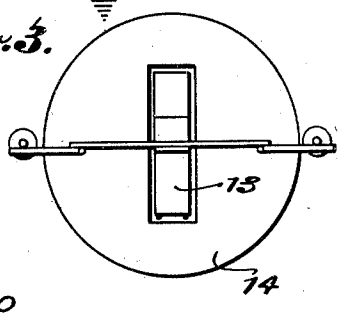
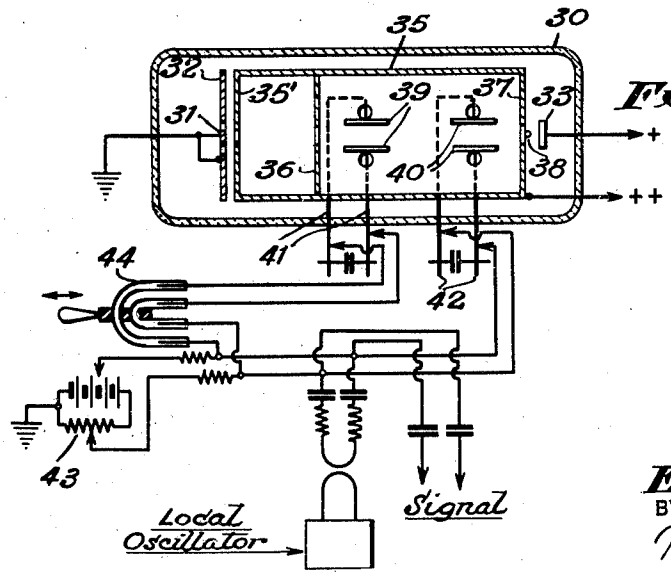


Fig. 4.



INVENTOR
Edward W. Herold
BY
William A. Zalesak
ATTORNEY

Nov. 22, 1949 E. W. HEROLD 2,489,132

ELECTRON DISCHARGE DEVICE

Original Filed April 24, 1942 2 Sheets-Sheet 2

Fig. 5.

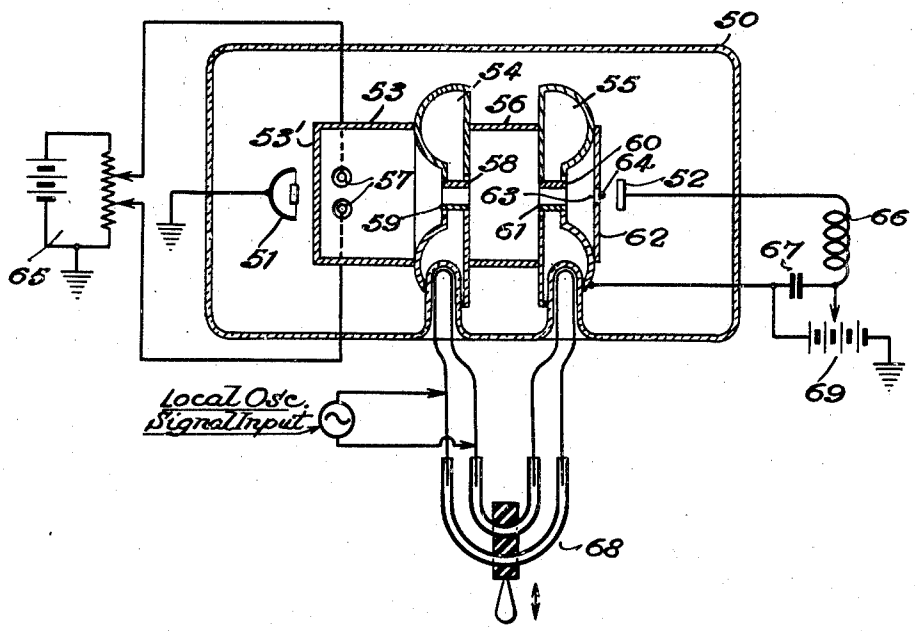


Fig. 6.

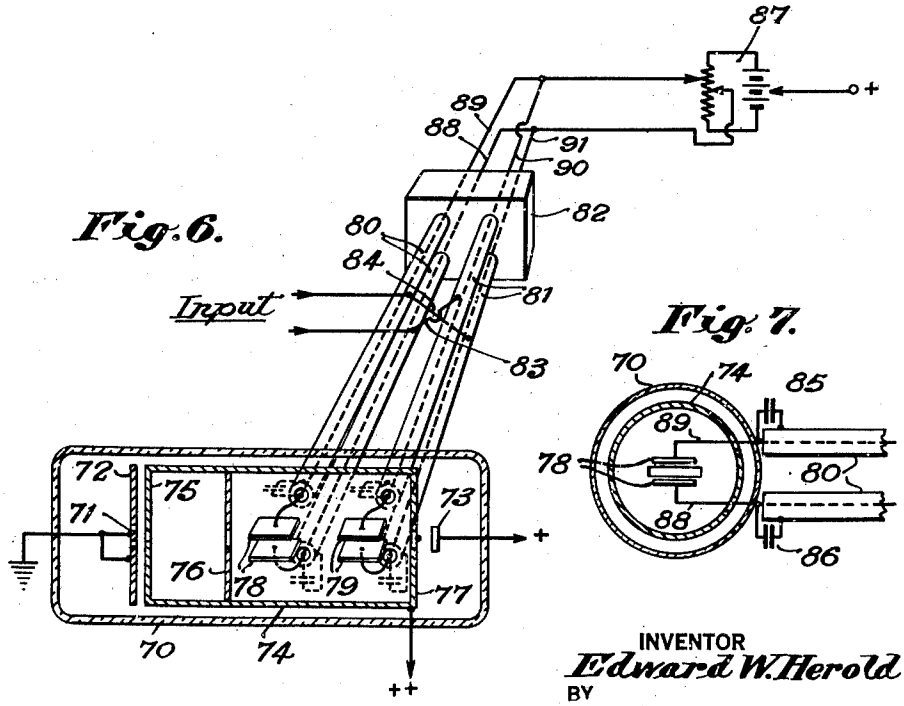


Fig. 7.

INVENTOR
Edward W. Herold
BY
William A. Zalesak
ATTORNEY

Patented Nov. 22, 1949

2,489,132

UNITED STATES PATENT OFFICE

2,489,132

ELECTRON DISCHARGE DEVICE

Edward W. Herold, Kingston, N. J., assignor to Radio Corporation of America, a corporation of Delaware

Original application April 24, 1942, Serial No. 440,283. Divided and this application July 23, 1948, Serial No. 40,300

2 Claims. (Cl. 315—5)

1

My invention relates to electron discharge devices, more particularly to such devices utilizing beam deflection and suitable for use at very high frequencies.

This application is a division of my copending application Serial No. 440,283, filed April 24, 1942, now Patent No. 2,462,496, dated February 22, 1949, and assigned to the same assignee as the present application.

In conventional tubes of the type under consideration a beam of electrons is directed between a pair of deflecting electrodes toward an apertured electrode behind which is usually placed a collector. Alternating radio frequency voltages are applied to the deflecting electrodes to cause the electron beam to be deflected across the aperture in the apertured electrode to thus control the amount of current flowing to the collector, which may be used as an output electrode. At frequencies above 600 megacycles per second it becomes difficult to obtain high transconductance because of the transit time effects resulting when the transit time of the electrons between the plates is equal to an appreciable part of a period of the applied radio frequency voltages. It has been found best to make the deflecting plates with a dimension in the direction of travel of the electron beam substantially equal to the distance traveled by an electron during a half period of the applied controlling voltage, or the electrical length is π radians, as expressed in the transit angle $\omega\tau$.

This may best be explained by the following illustration: Assuming that the deflecting plates between which the electron beam is directed are comparatively long and that a high frequency signal is applied to the plates, an electron which enters between the plates at the beginning of the cycle will be deflected in one direction, but before it has traveled to the end of the plates the high frequency electric field will be reversed so that deflection is reduced. As a result the electron may leave the space between the plates with little deflection. However, if the time which the electron spends between the plates, or the transit time of the electron between the plates, is equal to a half period of the applied voltage, the deflection of the electron will always be in the same direction and will be a maximum, since the electron leaves the space between the plates before reversal of the field takes place, which occurs every half period of the high frequency signal. The maximum length of the deflecting plates therefore should be such that electron transit time is about one-half period.

2

Expressed mathematically, if τ is the transit time then

$$\tau=\frac{1}{2}T=\frac{1}{2f} \text{ or } 2f\tau=1$$

where T is the period, and f the frequency of the high frequency signal. The electrical angle ωt of the high frequency signal before it reverses phase is equal to π, so expressed in angular form the above relation becomes $2\pi f\tau=\omega\tau$, which is equal to π and it may be said that the electrical length of the deflecting plates should be π radians, as expressed in the transit angle $\omega\tau$.

While it has been found that maximum deflection will result when the dimension of the deflecting electrode in the direction of travel of the beam is equal to the distance traveled by an electron during a half period, at the higher frequencies the time spent by an electron between the deflecting plates becomes increasingly small so that the amount of deflection also decreases since each individual electron is subjected to deflection field for a shorter period of time.

Attempts have been made to increase the deflection sensitivity or the transconductance of the tube by multiple deflection brought about by a plurality of successively positioned oppositely disposed deflecting elements cross connected. This arrangement, however, is open to the objection that the D. C. or static deflection is lower than the dynamic high frequency deflection, that is the tube is difficult to test and in addition the structure required is not simple and does not lend itself readily to mass production.

In addition, due to accidental factors, such as possible space charge, misalignment and like factors, the phase relationship of the controlling voltage on the deflecting plates to the deflected beam may not be such as to produce with optimum results the additive deflection sought. In other words, while the phase angle of the deflecting voltage on one pair of plates may be proper for maximum deflection, the voltage on the next pair of deflecting plates may have a phase relationship leading or lagging that required for additive deflection. As a result of the out-of-phase relationship, the second pair of plates may not deflect the same group of electrons to the same extent as a preceding pair of plates or a succeeding pair of plates.

In tubes intended for operation at ultra high frequencies, the conventional input circuits usually employed are subject to low resonant impedance resulting in an excessive amount of power being required to drive the tube. This

decreases the effective gain of the tube operated, for example, as an amplifier. Causes of such high input loading include, among other things, ohmic and radiation losses due to high circulating currents in the electrodes and leads. The usual output circuit does not have the desired high impedance for producing maximum output voltages so that voltages developed in the output do not reach the values they would otherwise have, thus reducing the effectiveness of the device.

It is an object of my invention to provide an electron discharge device of the beam deflection type which is particularly suitable for use at high frequencies and which has a comparatively high transconductance.

It is another object of my invention to provide an improved device of the type described utilizing multiple additive deflection and of a simple mechanical construction.

A still further object of my invention is to provide an electron discharge device of the multiple deflection type, in which proper phase relationship of the electron beam and the radio frequency controlling voltage exists to insure optimum operation.

It is another object of my invention to provide such an electron discharge device utilizing low loss-high impedance circuits, thereby increasing the effectiveness of the input controlling voltages and available output voltages for given conditions.

The novel features which I believe to be characteristic of my invention are set forth with particularity in the appended claims, but the invention itself will best be understood by reference to the following description taken in connection with the accompanying drawing in which Fig. 1 is a longitudinal section of an electron discharge device made according to my invention and its associated circuits, Figs. 2 and 3 are enlarged details of construction of the device shown in Fig. 1, Fig. 4 is a longitudinal schematic view of a modification of the device shown in Fig. 1 with a phase adjusting circuit attachment, Fig. 5 is a schematic longitudinal section of still another form of my invention utilizing low loss-high impedance circuits, Fig. 6 is a schematic longitudinal section and partial perspective of a still further modification of my invention, and Fig. 7 is a section of Fig. 6 showing details of construction.

Referring to Fig. 1, an electron discharge device made according to my invention comprises the evacuated envelope 10 containing the usual press 11 and base 12. Supported from the press by means of support and lead wires are the indirectly heated cathode 13 and beam forming electrode 14, the relative positions of which are shown in Fig. 3. Mounted at the other end of the envelope 10 is the collector 15. Positioned between the cathode and collector is the beam deflecting system comprising the tubular member 16 having a plurality of transverse partition-like elements 17, 18 and 19 provided with aligned apertures 17', 18' and 19'. A conducting element in the form of a rod 20 extends longitudinally of the aperture 19' as shown in Fig. 2 to provide a double aperture so that the desired control voltage anode current characteristic is obtained.

In accordance with my invention, between the transverse elements 18 and 19 are a plurality of successively positioned pairs of deflecting electrodes 21 and 22, the elements on the same side of the path of the electron beam between cathode 13 and collector 15 being electrically connected together and supported by the same support and lead wires. The distance between the centers of these electrodes is equal to the distance traveled by an electron during a full period of the applied deflecting voltage. The result of this arrangement is to produce successive additive deflection of the electron beam. Preferably the dimension of the deflecting electrodes in the direction of travel of the electron beam is equal to substantially a half period although this dimension is not critical. A pair of Lecher wires 23 shorted by the shorting bar 24 provides the input circuit to which signal input voltage and local oscillator voltage may both be applied to produce an intermediate frequency voltage in the output circuit, which is connected between collector 15 and tubular member 16, and comprises output transformer 25 and by-passing condenser 26, the condenser 26 permitting different D. C. voltages to be applied to the collector and to the tubular member 16. The collector 15 may be coated with secondary emitting material, the secondary electrons being collected by partition 19 or the primary electrons may be absorbed by the collector 15 without any secondary emission amplification. The source of voltage and divider arrangement 27 permits the relative voltages on deflecting elements 21 and 22 to be adjusted so that the beam, with no radio frequency or oscillator voltage on the plates, will be directed at the rod 20 to center it with respect to the electrode system.

In operation electrons from the indirectly heated cathode 13 are formed into a beam and directed through apertures 17' and 18' in elements 17 and 18, which last element in combination with the deflecting element 21 may be arranged to provide an electron lens arrangement for providing a sharply focused beam on the rod 20. The electrons in passing through elements 18 and 19 must pass between the deflecting elements 21 and 22, the centers of the successive pairs of which are spaced a distance apart equal to the distance traveled by an electron during a whole period. Thus, an electron which is deflected upwardly between the first set of plates 21 and 22 will again be deflected upwardly between the second set of plates 21 and 22, since the phase relationship of the voltage on the deflecting plates with respect to the electron is the same between each pair of plates since a whole period is required for the electron to travel from any point between one pair of plates to a similar point between the next pair of deflecting plates. Thus the deflection is amplified. The electron beam is being deflected across aperture 19' and rod 20 has the effect of passing through a double apertured electrode so that the electron current with respect to deflecting voltage decreases to substantially zero when the beam is directed on rod 20 and rises on either side of the minimum to a maximum and again to zero depending upon the angle of deflection.

Thus with the arrangement shown the support for the deflecting elements is simplified because all deflecting elements on one side of the beam path can be connected together. The transconductance or deflection sensitivity is increased by insuring successive additive deflection. It is, of course, obvious that more than two pairs of deflecting elements could be used

for the purpose of bringing about additive deflection.

In Fig. 4 I show an arrangement whereby the need for spacing the centers of the pairs of deflecting elements predetermined distances determined by the frequency of operation is unnecessary. As here shown the envelope 30 contains cathode 31, beam forming electrode 32 and collector 33. The deflecting electrode system includes tubular member 35, which is provided with apertured transverse partitions 35', 36 and 37, the last aperture being provided with the rod 38 which bisects the aperture longitudinally to produce a double aperture to bring about the desired control voltage-output current characteristic. Successive pairs of deflecting elements 39 and 40 are positioned between elements 36 and 37. These electrode elements may be connected to Lecher wire systems 41 and 42 to which the oscillator and signal voltages may be applied.

In order to insure that a proper phase relationship exists between the beam passing through the deflecting electrode system and the controlling voltages on the deflecting elements, a phasing arrangement including a "trombone" tuning element 44 is connected between the two Lecher wire systems. By proper adjustment the coupling between the two deflecting systems may be varied as to length so that the signal and oscillator voltages may be fed to the Lecher wire systems in proper phase to produce maximum additive deflection between each pair of the deflecting elements, regardless of the spacing between pairs of deflecting elements. This simplifies manufacturing construction and also provides means for compensating for irregularities and accidental factors in construction and operation of the tube.

In order to increase further the efficiency of the tube disclosed, it is possible to utilize circuits having high resonant impedances, such for example as resonant cavity circuits or so-called resonators.

In Figure 5 is shown a modification of an electron discharge device utilizing my invention. In this form a pair of resonators are used for producing additive deflection in combination with the phasing arrangement shown in Figure 4. The envelope 50 contains at one end cathode means 51 for providing a directed beam of electrons and at the other end a collector 52. The deflecting system comprises tubular elements 53 and 56, and a pair of resonators 54 and 55, each of which is provided with opposed deflecting elements 58 and 59 and 60 and 61 positioned within the resonators, one element of each pair being connected to an opposite wall. As is well known the resonators may be set into oscillation, and in one mode of operation an alternating voltage can be made to appear between the opposite walls of the resonator at the apertures, the elements 58 and 59, for example, assuming the voltage of the side of the resonator to which it is attached so that a transverse electrostatic field appears between the deflecting elements to deflect the beam of electrons laterally during operation of the device. To insure a properly directed beam I may employ a pair of beam directing elements 57 positioned between the apertured partition 53' and one wall of the resonant cavity circuit 54. The second resonator 55 is provided with apertured member 62, provided with the rod-like connecting element 64 to provide a double aperture. A voltage source and divider arrangement 65 permits the proper biasing voltages to be applied to beam directing elements 57. The output is taken between resonator 55 and collector 52 by means of the output circuit including transformer 66 and by-passing condenser 67, the voltage source 69 providing the necessary biasing voltages. To insure proper phase relationship between the electron beam and the voltages appearing on the deflecting elements 58 and 59, and 60 and 61 I again employ a "trombone" method of tuning using slide 68 to vary the length of the coupling circuit and hence controlling the phase relationship of the voltages appearing between the pairs of deflecting elements and the electron beam.

A still further modification of my invention is shown in Figure 6 employing a four-wire transmission line. In this arrangement the envelope 70 has positioned at one end the cathode 71 and beam forming element 72, which may be electrically connected to the cathode lead. The collector 73 is positioned at the other end of the envelope and the deflecting system is positioned between the cathode and collector. The deflecting system includes tubular member 74 provided with apertured transverse elements 75, 76 and 77. The pairs of deflecting electrodes 78 and 79 are positioned between transverse elements 76 and 77 and are connected to transmission line comprising elements 80 and 81 shorted by shorting bar 82 which may be positioned so that the distance from the plates to the shorting bar is equal to one-quarter or three-quarters of a wavelength. The input voltage may be applied as indicated, the two sides of the lines being cross connected by means of conductors 84 and 83 so as to bring about a proper phase relationship of the radio frequency voltages appearing between the deflecting elements. To permit proper biasing potentials to be applied to the deflecting elements 78 and 79, conductors 88, 89, 90 and 91 extend through tubular elements 80 and 81, the elements 80 and 81 being connected to deflecting elements 78 and 79 for radio frequency by means of coupling condensers such as 85 and 86. Voltages for applying proper D. C. potentials to the deflecting elements are obtained from voltage source 87. With the arrangement shown the D. C. static characteristics of the device may be examined by changing the connections to the deflecting elements.

While I have indicated the preferred embodiments of my invention of which I am now aware and have also indicated only one specific application for which my invention may be employed, it will be apparent that my invention is by no means limited to the exact forms illustrated or the use indicated, but that many variations may be made in the particular structure used and the purpose for which it is employed without departing from the scope of my invention as set forth in the appended claims.

I claim:

1. An electron discharge device having a cathode for supplying a beam of electrons and a collector for receiving said electrons, and an apertured member positioned between said cathode and collector, and through which the beam of electrons may be directed toward said collector, and deflecting means positioned between the cathode and apertured member and including a plurality of successive pairs of oppositely disposed deflecting elements between which the beam of electrons is directed and adapted to have an alternating potential of high frequency applied

between the elements of each pair, the spacing between the centers of adjacent successive pairs of deflecting elements being equal substantially to the distance travelled by an electron during a period of the applied alternating high frequency potential, all of the deflecting elements on one side of the beam path being electrically connected together and all of the deflecting elements on the other side of the beam path being electrically connected together.

2. An electron discharge device having a cathode for supplying a beam of electrons and a collector for receiving said electrons, and an apertured member positioned between said cathode and collector and through which the beam of electrons may be directed toward said collector, and deflecting means positioned between the cathode and apertured member and including a

plurality of successive pairs of oppositely disposed deflecting elements between which the beam of electrons is directed and adapted to have an alternating potential of high frequency applied between the elements of each pair, the spacing between the centers of adjacent successive pairs of deflecting elements being equal substantially to the distance travelled by an electron during a period of the applied alternating high frequency potential, all of the deflecting elements on one side of the beam path being electrically connected together and all of the deflecting elements on the other side of the beam path being electrically connected together, and apertured conducting means surrounding said deflecting elements.

EDWARD W. HEROLD.

No references cited.