July 20, 1937. R. GUNN 2,087,252

ULTRA HIGH FREQUENCY TUBE

Original Filed July 26, 1932 2 Sheets-Sheet 1

Fig. 1

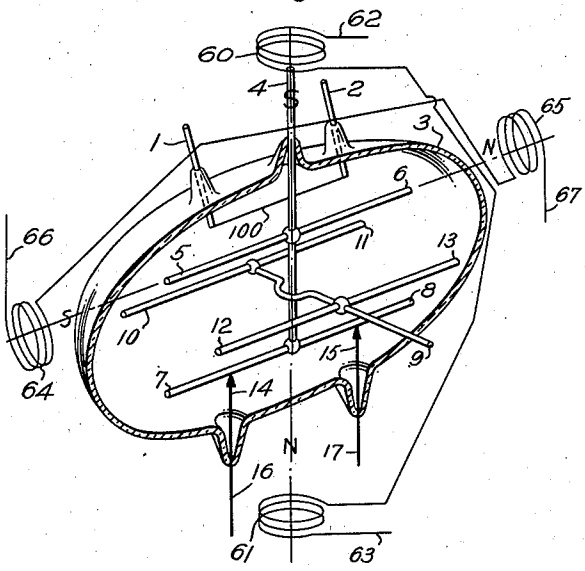


Fig. 2

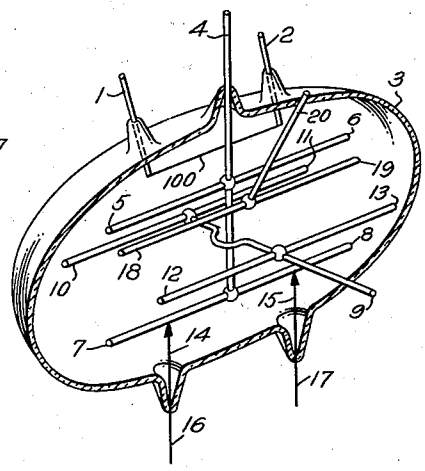
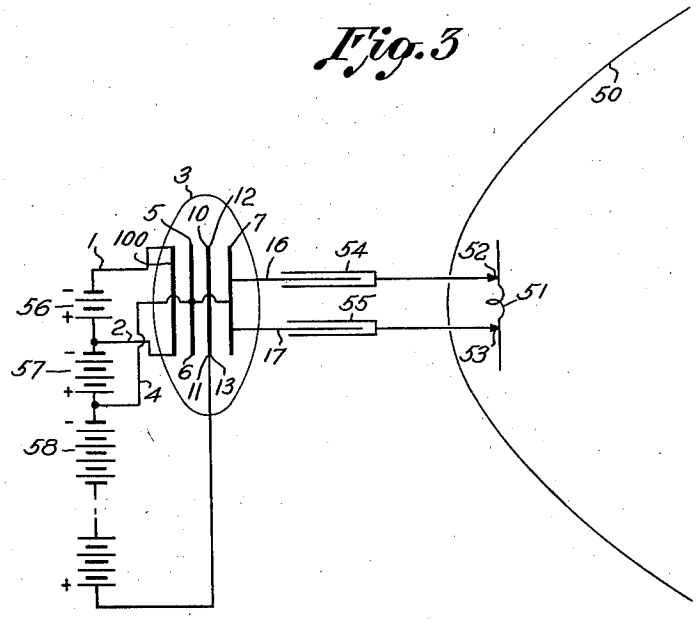


Fig. 3



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Fig. 4

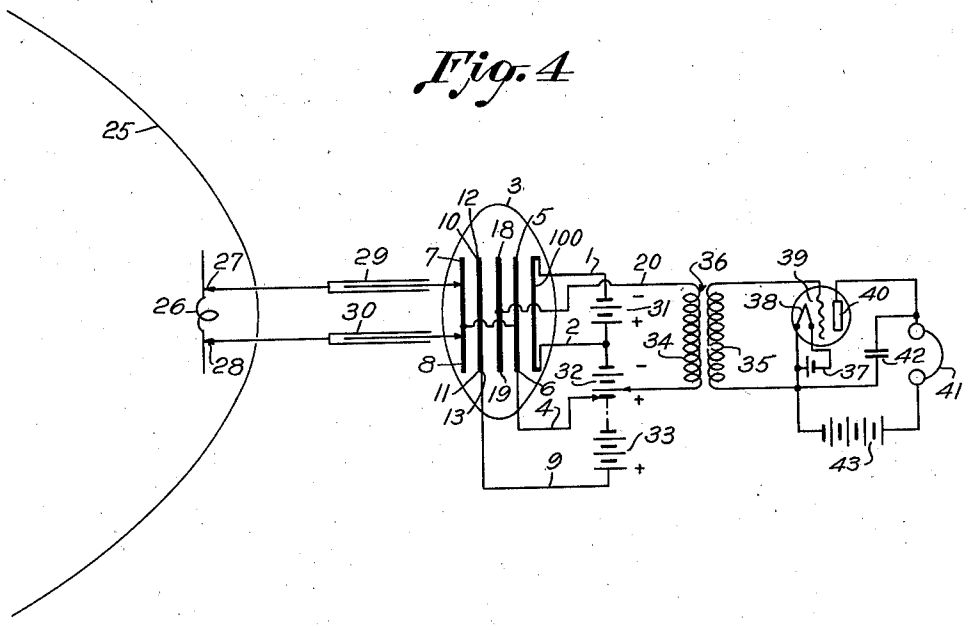
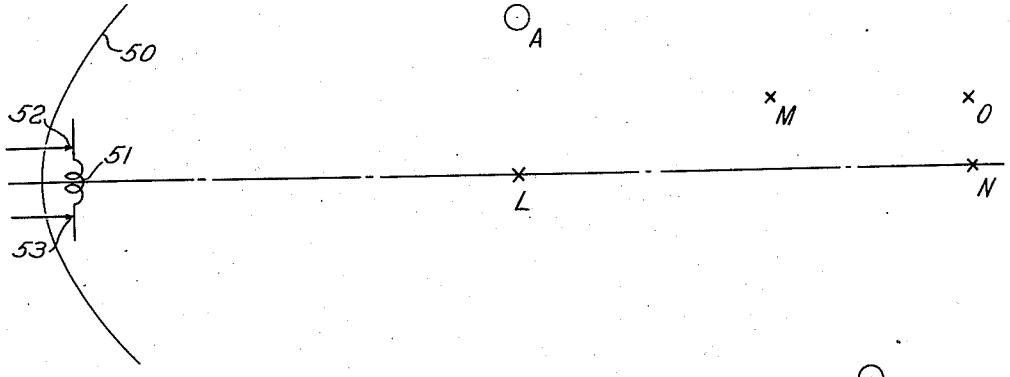


Fig. 5



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ULTRA-HIGH FREQUENCY TUBE

Ross Gunn, Chevy Chase, Md.

Original application July 26, 1932, Serial No. 624,877. Divided and this application November 2, 1935, Serial No. 48,062

14 Claims. (Cl. 250—27.5)

(Granted under the act of March 3, 1883, as amended April 30, 1928; 370 O. G. 757)

This invention relates to high frequency communication systems, and more particularly to an ultra-high frequency tube for use in communication systems of the type disclosed in my application Serial No. 624,877, filed July 26, 1932, which has matured into Patent No. 2,020,310 covering an Ultra-high frequency communication system, of which this application is a division.

An object of this invention is to provide a tube for use in a system for producing considerable amounts of power in the form of ultra-high frequency oscillations.

Another object of this invention is to provide a tube for a system employing electronic oscillations wherein the electrons or ions oscillating within the tube are controlled as to phase whereby neutralizing effects of a multitude of electrons or ions oscillating in different phases are avoided.

Another object of this invention is to provide electron discharge apparatus of novel construction that is particularly adapted for use in connection with the production and reception of ultra high frequency oscillations.

With the above and other objects in view, the invention consists in the construction, combination, and arrangement of parts as will be described more fully hereinafter.

Oscillation generators of the conventional type employing negative resistance in combination with resonant circuits usually do not work well or at all in the ultra-high frequency or quasi-optical range. Generators of the so-called Barkhausen-Kurtz or Gill-Morrell type employing electronic oscillations are found to work at quasi-optical frequencies, but the output and efficiency of this type of generator have been extremely small.

The present invention is concerned with improvements of systems employing electronic oscillations wherein their properties are greatly enhanced by proper adjustment of the phase of the moving particles.

The nature and purpose of the invention may be more readily understood by reference to the accompanying drawings, in which:

Fig. 1 is a perspective view of the elements of a transmitter type tube, the envelope of which has been partially removed for the purpose of clearness;

Fig. 2 is a similar view of the elements of a receiver type tube;

Fig. 3 is a diagrammatic showing of a transmitter employing a tube similar to the tube shown in Fig. 1;

Fig. 4 is a diagrammatic showing of a receiver employing a tube similar to the tube shown in Fig. 2;

Fig. 5 shows diagrammatically a beam transmitter with means to concentrate, reflect, diffract, and scatter ultra-high frequency radiation.

Referring now to Fig. 1, a filamentary cathode is shown at 100 mounted within an evacuated envelope 3 and provided with leads 1 and 2 for supplying heating current thereto. Displaced from the filament 100 within the envelope 3 are a plurality of tuned resonant systems 5—6, 7—8, 10—11, 12—13. Tuned conductors 5—6 and 7—8 lying within the same plane are supported nodally at their midpoints by a conductor 4 which constitutes a lead for supplying the necessary direct current potential to these elements. Tuned conductors 10—11 and 12—13 are supported nodally at their midpoints by a conductor 9 which constitutes a lead for supplying the necessary direct current potential to these elements. Leads 14 and 15 coupled to the resonant element 7—8 are for the purpose of transferring the high frequency oscillations existing on this element to a tuned radiator of appropriate type. In Fig. 1, leads 14 and 15 are shown associated with tuned element 7—8, although it is to be understood that these leads could be connected to other of the tuned elements of the system as for instance, tuned element 10—11 connected to and supported by conductor 9 as shown in Fig. 3.

The structure of the tube shown in Fig. 2 is identical with that of Fig. 1 except that tuned element 18—19 supported at its midpoint by a conductor 20, which serves as a lead thereto, has been added. The tuned element 18—19 occupies a position within the space generally surrounded by tuned elements 5—6, 7—8, 10—11, 12—13, and is parallel thereto.

Because of the high voltages desirable for ultra frequencies, the tube structure must be quite rigid. It is desirable that the oscillating conductor tuned elements be supported at the node. Evidently the tuned elements 5—6, etc., can be approximately any number of half wave-lengths long or they can contain concentrated inductance or capacity values for securing special adjustments of phase without departing from the basic ideas. It is evident, moreover, that arrays of tubes properly arranged in space will give rise to directive beams, etc.

Fig. 3 is a diagrammatic showing of the tube of Fig. 1 connected in circuit with appropriate sources of potential for the generation and radi-

ation of high frequency oscillations. Coupled to the tuned resonant element 7—8 is a radiating system 51 located at an appropriate distance in front of a parabolic metallic mirror 50. Tuning devices 54 and 55 are connected in the coupling leads 16 and 17 between the radiating system 51 and the tuned resonant system 7—8 within the tube for adjusting the circuit for efficient transfer of energy to the radiating system. The battery 56 is connected to leads 1 and 2 so as to energize the filament 100. The battery 57 is connected between the filament and the tuned resonant system 5—6, etc., and is so poled that the tuned system is normally positive with respect to the filament. The battery 58 is connected between the filament and the radiating system 10—11, etc., and is so poled that the tuned system 10—11, etc., is normally highly positive with respect to the filament. In the drawings, the potential applied between the filament 100 and the tuned system 10—11 is shown as being derived from batteries 57 and 58 in series although it is to be understood that a separate battery or other source of potential of proper value may be used instead of the two batteries connected in series.

A magnetic field is applied to the tube for use at the highest frequencies. This magnetic field may in general be applied by means of two units, one designed to produce a very intense field, say 5000 gauss, in a direction parallel to the electric field, the other of moderate value between 0 and 2000 gauss, depending on the frequency desired and the spacing of the elements, is applied in a direction at right angles to both the electric field and the oscillating dipole.

The units for applying magnetic fields to the tube 3 are shown in Fig. 1. (A showing of these units has been omitted from Fig. 3 for the sake of clarity.) Magnetizing coils 60 and 61 are disposed on opposite sides of the tube 3 with their axes passing through the tube normal to the oscillating dipoles and the principal electric field within the tube. These coils are shown connected in series and provided with leads 62 and 63 which may be connected to an appropriate source of potential by way of a variable resistor. Magnetizing coils 64 and 65 are disposed on opposite sides of the tube 3 with their axes parallel to the principal electric field within the tube. Coils 64 and 65 are shown connected in series, although it is to be understood that they may be connected in parallel as may the coils 60 and 61. Coils 64 and 65 are provided with leads 66 and 67 which may be connected to an appropriate source of potential. On the drawings coils 60—61 and 64—65 are shown as being of the air core type although it is to be understood that paramagnetic substances may be used for cores of these magnetizing coils.

The oscillations of ultra frequency, or ultra high frequency that we may expect in this system are:

(a) Electronic oscillations.

(b) Oscillations in tuned resonators as a result of electronic shock excitation.

(c) Phase oscillations.

In general, the electronic oscillations of Barkhausen-Kurtz are very feeble because there are a great many electrons in the tube and they have no definite phase relation to each other so that the mutual radiation largely cancels out.

Consider in Fig. 1 a single electron from the hot filament connected to electrodes 1 and 2, and suppose that it heads for the rod 7—8, passing midway between the electrodes 10—11 and 12—13. When the electron passes through the plane determined by 10—11—12—13 it has its maximum energy and velocity which will be lost by the time it reaches the electrode 7—8. The direction of the force reverses as it passes through the plane of electrodes 10—11—12—13 and therefore by proper positioning of the electrodes, the electric field on each side of the plane can be made roughly proportional to the distance from the plane. That is to say, the electric field is purposely made inhomogeneous.

Suppose the space charge is small and let this proportionality be expressed by

$$E=ky \qquad (1)$$

where E is the electric field, y the distance of the selected point from the plane and k the proportionality factor. We can estimate k from the applied potential V and the spacing s of the electrodes 5—6 (or 7—8) from the plane of reference, i. e.,

$$V=\int_o^s Edy=\frac{ks^2}{2} \qquad (2)$$

Now the force F on the electron is

$$F=Ee=-ke_1y$$

where e is the electronic charge and e_1 is its absolute magnitude. Thus the electron executes simple harmonic motion of frequency

$$F=\frac{1}{2\pi}\sqrt{\frac{ke_1}{m}}=\frac{1}{2\pi s}\sqrt{\frac{2Ve_1}{m}} \qquad (3)$$

This relation shows clearly that for extremely high frequencies the applied potential V must be moderately high and the spacing s kept as small as is consistent with structural difficulties.

The operation of the system shown in Fig. 3, while not definitely understood, is believed to be as follows: The filamentary cathode 100 is heated by current from source of potential 56 and emits electrons. The electrons emitted from cathode 100 are transferred to the region between the tuned elements by the source of potential 57 operating via lead 4 and the element 5—6 which acts as a space charge electrode. The source of potential 57 is of such value that high current densities are not required. The electrons passing into the region between the tuned elements of the system are accelerated toward the plane formed by the anode elements 10—11 and 12—13 as a result of the electric field produced by the battery or other source of potential 58. Due to non-symmetry in the way the electrons initially come off, the tuned resonant systems 5—6, 10—11 and 12—13 individually and as a system are shock excited and resonate at their own natural frequency. The electric field, due to the oscillating potential of the resonators, causes the electric field between the filament 100 and parts of the resonator 5—6 to change with time; thus, when the end 5 is at a higher positive potential with respect to the filament than its mean (steady) value, more electrons will come across at that end than at the end 6. One-half a cycle later more electrons will come across at the end 6, while the end 5 will be so charged as to block the flow of electrons adjacent thereto and the phase of the electronic oscillations will be controlled by the varying potential on the dipole resonators and radiation from the electron oscillations will result.

The receiver is shown in Fig. 4 employing a tube with an auxiliary electrode similar to the tube shown in Fig. 2. The filament 100 is energized from battery 31 by means of the leads 1 and 2. Positive potential is applied to the tuned resonant system comprising elements 5—6, etc., from battery 32 connected to the filament 100 and lead 4. Positive potential is applied to the tuned resonant system comprising elements 10—11, etc., from battery 33 via lead 9. Thus far the receiver is identical with the transmitter except that the batteries 31 and 32 are of lower potential than are used in the transmitter in order that the electron emission be kept at a proper value for receiving purposes. The tuned resonant electrode 18—19 is connected at its midpoint by means of lead 20 to one end of the primary winding 34 of transformer 36. The other end of the winding 34 is adapted is be connected to the battery 32 at a point more positive than the filament. Coupled to the primary 34 is a secondary 35 which is connected to the filament 38 and grid 39 of a suitable thermionic amplifying device. A battery 37 is connected to the filament 38 for heating the same. A battery 43 is connected to the filament 38 and through the receiver 41 or other type of indicator to the anode or plate 40 of the tube. A condenser 42 is connected between the anode 40 and the filament. Coupled to the tuned system 7—8, etc., is a receiving antenna 26 located at the proper distance in front of a parabolic metallic mirror 25. Leads 27 and 28 between the antenna 26 and the tuned system 7—8 are provided with tuning condensers 29 and 30 for tuning the system to effect the most efficient transfer of energy therebetween.

The operation of the receiver, while not definitely understood, is believed to be as follows: The radiated waves from the transmitter traverse the distance from the transmitter to the receiver where they are converged or focused upon the receiving antenna 26 by the mirror 25. Antenna 26 then has induced therein high frequency oscillations of the frequency of the transmitted waves to which it is tuned. These high frequency oscillations are coupled by way of the condensers 29 and 30 to tuned resonant system 7—8, etc., which is caused to oscillate at the frequency of these waves. The total space current through the tuned system 18—19 is controlled by these oscillations in some manner not well understood. This current controlled in accordance with the received oscillations passes through lead 20 to the transformer primary 34 and thence back to the battery 32 and filament 100, inducing currents in the secondary to control the output of the amplifier tube in well known manner. Obviously, any type of amplifier could be used instead of the one shown, or the output of the receiving tube could be coupled directly to a receiver or other type of indicator instead of to the transformer winding 34.

The ultra frequencies have substantially optical properties and normally can be propagated only in straight lines. In general, a beam transmitter is used and the energy in the beam is very large and confined to a small area. Suppose it should be desired to transmit to stations A, B, and C (Fig. 5), as well as station N. This may still be accomplished by placing a scatterer or director at the point L, say, which absorbs and emits or refracts some of the incident energy toward the desired stations A, B, or C. Many devices will serve to scatter or refract the waves, as for instance:

(a) Tuned resonant circuits or arrays of them.
(b) Lens systems.
(c) Diffraction gratings of various kinds.
(d) Metallic reflectors.

This method of diffraction permits the transmission of the ultra frequency beyond the bulge of the earth around skyscrapers, bridges, etc.

It is to be understood that any appropriate system of modulation may be used in connection with the above disclosed transmitter. The amplitude, frequency or phase or any combination of the three may be controlled by electrical means, or the beam transmitted may be controlled directly by shutters in much the same way as is done with visible light in heliograph signaling systems.

The invention herein described may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalty thereon.

What is claimed is:

1. A thermionic device comprising an evacuated envelope enclosing all the following: a cathode, a tuned anode system and an additional tuned system adjacent the electronic path between said cathode and anode system for controlling the electron flow therein in accordance with the oscillations excited in said additional tuned system.

2. An electron discharge device comprising an evacuated envelope containing all the following: a linear cathode, an anode system comprising a plurality of electrically resonant linear elements, and an additional tuned ssytem comprising a plurality of electrically resonant linear elements.

3. An electron discharge device comprising an evacuated envelope containing all the following: a linear cathode, an anode system comprising a plurality of electrically resonant linear elements, and an additional tuned system comprising a plurality of electrically resonant linear elements, said cathode and said electrically resonant elements being mutually parallel.

4. An electron discharge device comprising an evacuated envelope containing a linear cathode, an anode system comprising a plurality of electrically resonant linear elements, an additional tuned system comprising a plurality of electrically resonant linear elements, and means nodally supporting said electrically resonant elements.

5. A thermionic device comprising an evacuated envelope enclosing a cathode, a tuned anode system, an additional tuned system adjacent the electronic path between said cathode and anode system for controlling the electron flow therein in accordance with the oscillations excited in said additional tuned system, and electrically conducting leads connected between potential nodal points of said tuned system and terminals on the outside of said envelope.

6. A thermionic device comprising an evacuated envelope enclosing a cathode, a tuned anode system, an additional tuned system adjacent the electronic path between said cathode and anode system for controlling the electron flow therein in accordance with the oscillations excited in said additional tuned system, electrically conducting leads connected between potential nodal points of said tuned system and terminals on the outside of said envelope, and electrically conducting leads connected between varying potential points of at least one of said tuned systems and other terminals on the outside of said envelope.

7. An electron discharge device comprising an

evacuated envelope, a cathode within said envelope, an anode comprising at least one oscillating dipole within said envelope, lead means connected to the electrical center of said anode, and means comprising at least one oscillating dipole within said envelope for controlling the space charge between said cathode and anode.

8. An electron discharge device comprising an evacuated envelope enclosing a linear cathode, an anode system comprising a pair of linear elements defining a plane, a space charge controlling system comprising a pair of linear elements defining a plane intersecting the plane defined by said anode system, said cathode being mutually parallel to the elements of said anode system and said space charge controlling system.

9. An electron discharge device comprising an evacuated envelope enclosing a linear cathode, an anode system comprising a pair of linear elements defining a plane, a space charge controlling system comprising a pair of linear elements defining a plane intersecting the plane defined by said anode system, said cathode being mutually parallel to the elements of said anode system and said space charge controlling system outside of the planes defined by said systems, and an additional linear element parallel to said cathode.

10. A thermionic device comprising an evacuated envelope enclosing a cathode, a tuned anode system, an additional tuned system adjacent the electronic path between said cathode and anode system for controlling the electron flow therein in accordance with the oscillations excited in said additional tuned system, and means for applying an intense magnetic field to said device in a direction parallel to the electric field between the elements thereof.

11. An electron discharge device comprising an evacuated envelope containing a linear cathode, an anode system comprising a plurality of electrically resonant linear elements, an additional tuned system comprising a plurality of electrically resonant linear elements, and means for applying a magnetic field to said device in a direction perpendicular to the linear elements thereof.

12. An electron discharge device comprising an evacuated envelope containing a linear cathode, an anode system comprising a plurality of electrically resonant linear elements, an additional tuned system comprising a plurality of electrically resonant linear elements, and means for applying a magnetic field to said device in a direction perpendicular to the linear elements thereof and parallel to the electric field between said elements.

13. An electron discharge device comprising an evacuated envelope containing a linear cathode, an anode system comprising a plurality of electrically resonant linear elements, an additional tuned system comprising a plurality of electrically resonant linear elements, means for applying a magnetic field to said device in a direction perpendicular to the linear elements thereof and parallel to the electric field between said elements, and additional means for applying a magnetic field perpendicular to said elements and to said electric field.

14. A generator of high frequency oscillations, comprising an electron emitting cathode, and means for controlling the phase of electrons emitted along said cathode comprising an electrically resonant element adjacent said cathode.

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