Nov. 3, 1936. C. W. HANSELL 2,059,863

HIGH FREQUENCY OSCILLATOR AND MODULATION CIRCUIT

Filed April 22, 1933

Fig. 1

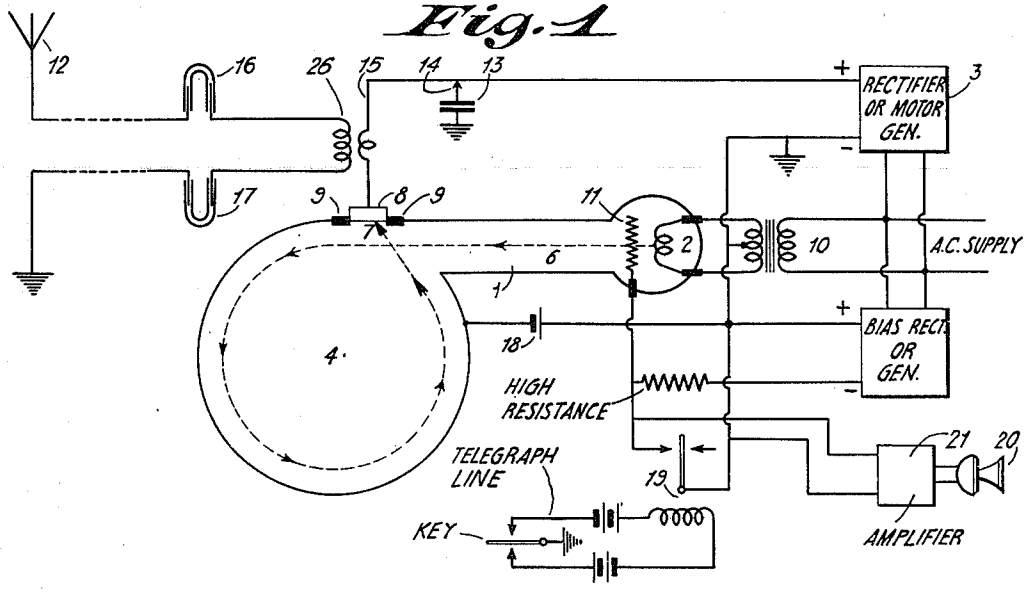
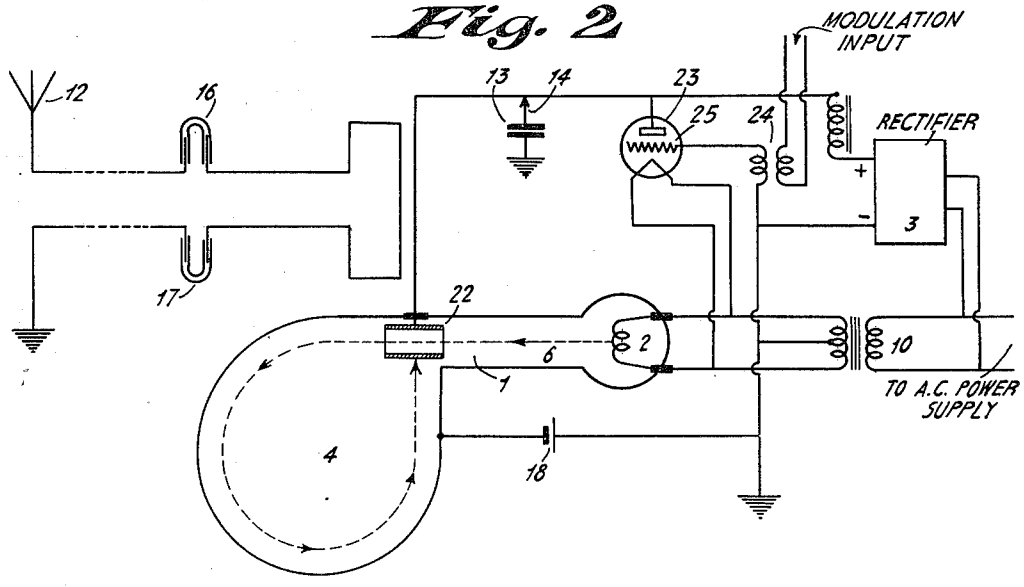


Fig. 2



INVENTOR
C.W. HANSELL

BY

ATTORNEY

Patented Nov. 3, 1936 2,059,863

UNITED STATES PATENT OFFICE

2,059,863

HIGH FREQUENCY OSCILLATOR AND MODULATION CIRCUIT

Clarence W. Hansell, Port Jefferson, N. Y., assignor to Radio Corporation of America, a corporation of Delaware

Application April 22, 1933, Serial No. 667,357

9 Claims. (Cl. 179—171)

This invention relates to modulation circuits for ultra-high frequency oscillators.

In my copending application now issued as Patent No. 2,001,133, dated as of May 14, 1935, there has been disclosed a novel type of ultra high frequency oscillator whereby there may be generated high frequencies of the order of 300,000 kilocycles or higher. In that arrangement oscillations are produced by influencing a stream of electrons emanating from a cathode to travel in a curved path and to cross upon itself so as to obtain a periodically interrupted stream of electrons. The mode of operation, which is quite similar to the functioning of the air stream in an air whistle, applicant has designated as the electron whistle principle. In general, according to one embodiment described in my patent, supra, the oscillator comprises a hot cathode and an anode at opposite ends of a tube-like affair to the anode end of which is connected a curved shell. A voltage applied between the anode and cathode causes the electrons emitted from the cathode to travel toward the anode with an accelerating velocity in such manner that when the electrons enter the shell they have, under proper conditions, such a high velocity that they fly on past the anode due to their momentum. If their velocity has been made sufficiently great, and the shell has the same potential as the cathode, or a still more negative potential with respect thereto, the repulsion between the shell and the electrons will cause the stream to bend around the shell in a loop before arriving at the anode. In order to reach the anode, however, the electron stream is arranged to cross its own path at the anode end of the auxiliary tube, and to thus interrupt the stream entering the shell, due to the mutual repulsion between electrons. The stream remains interrupted until the electrons in the shell have all passed by, after which the electron stream is again admitted to the shell and the whole process repeated periodically.

It is a primary object of the present invention to provide a modulation system for this type of ultra high frequency electron whistle oscillator.

In accordance with one particular embodiment of the present invention, the modulating potentials are caused to control the anode potential through a separate electron discharge device suitably connected to the anode of the oscillator. In another embodiment, there is utilized a control electrode between the anode and cathode of the oscillator, to which the modulating potentials are applied. The latter embodiment has the advantage of dispensing with a separate electron discharge device.

Other objects and advantages will appear in the subsequent detailed disclosure which is accompanied by the drawing wherein Figure 1 illustrates a preferred form of a modulation circuit embodying the principles of the present invention, and Figure 2 illustrates a modification thereof.

In Figure 1 there is shown a radio transmitting circuit including an ultra high frequency oscillator comprising an evacuated device 1 having a tube 6, at one end of which is a cathode 2 energized by a source of current 10, shown herein as alternating, although it will be understood that direct current may be used just as well. At the other end of tube 6 there is positioned a flared circular portion 4 which may be either metal or insulation and in an opening 7 of which is inserted an anode 8 to which is connected a source of positive potential 3. The negative terminal of source 3 is connected to the cathode and to ground. On either side of the anode, in the arrangement of Figure 1, is an insulating mounting or bushing 9. Interposed between the filament and the anode is a control electrode or grid 11 to which varying potentials are applied in accordance with the signals to be transmitted.

Any suitable utilization circuit, such as an antenna 12, may be coupled to the output of the device through a transformer 26, as indicated. Although the form of coupling shown in the drawing is preferred, it is to be understood that the invention is not limited thereto, but that other forms may be employed. For tuning the output circuit there is a condenser 13 one plate of which is connected to ground and the other plate to a movable slider 14 which is arranged to glide over the anode lead 15 extending between the anode and its source of supply. If an antenna circuit is utilized, tuning elements such as trombone slides 16 and 17 may be connected in the transmission line connecting the antenna to the output circuit for tuning the line to the output frequency.

The operation of the device is as follows:

When the cathode of the vacuum oscillator device is energized from the source of current 10, negatively charged electrons are emitted which are attracted toward the circular shell 4 by the positively charged anode 8. These electrons travel in a substantially straight line along the portion 6 of the tube. Circular shell 4, if made of metal, is given a charge similar to

that of the filament by battery 18, or even made slightly more negative, in order to repel the electronic stream and cause it to bend around the shell in the manner shown by the arrows in the drawing. Those electrons which pass closest to the shell tend to be bent more than those which pass further away, and this automatically tends to concentrate the stream so that, under proper conditions, the beam can be substantially focussed upon the anode 8. Anode 8 and opening 7 are so positioned as to be in line with the electrons after they have followed the periphery of the curved portion 4. If desired, as an alternative type of construction, an insulating shell such as glass may be used which, it has been found, will act just as well as a metal shell; in fact, the insulating shell will have advantages in that certain areas of the shell may be more negatively charged by the electrons than others so that the distribution of the negative charge is more in accordance with that required to prevent the impinging of large numbers of electrons at various points. In this case various portions of the inside of the envelope assume automatically the correct potentials for suitable operation of the device.

When the electrons enter the shell 4 from the straight portion 6 they will have under proper conditions such a high velocity that they will fly past the anode 8 due to their momentum. After curving, the electronic stream will point toward the anode, but before reaching the anode the electronic stream must cross its own path. In doing so it will interrupt the stream entering the curved shell 4 from the straight portion 6 due to the mutual repulsion between electrons. Those electrons which are being drawn from the filament 2 while a portion of the stream traversing the shell 4 is arriving at the anode 8, will also tend to flow directly to the anode 8, though their number will be reduced by the space charge set up in the vicinity of the anode 8 by the stream impinging on the anode after traversing the shell 4. In other words, so long as a portion of the stream is returning to the anode from shell 4, substantially no additional electrons are permitted to enter chamber 4. Thus, the oncoming stream from the filament will remain interrupted until the first electrons have reached the anode, after which the stream from the filament will then be enabled to pass by and enter the curved shell 4 and the process will be repeated periodically.

This mode of operation is quite analogous to that of an ordinary air or steam whistle, and a comparison between the two is herein made merely to aid in a better understanding of the invention.

The frequency of interruption of the electronic stream will determine the frequency of the desired oscillations in the anode circuit, and this frequency, experiments have so far indicated, is substantially dependent on the anode voltage and increases with increase in voltage. In other words, it may be said to be determined by the time taken for an electron to travel around the loop of the shell 4, a matter which is determined by the anode voltage and the dimensions of the circuit.

The signals to be transmitted may be applied to the grid of the tube either by a keying relay 19 which is responsive to telegraph signals, or by a microphone 20 in circuit with an amplifier 21, in case it is desired to transmit speech or music. By varying the grid potential the number of electrons taking part in producing oscillations is varied, this variation being arranged to key or modulate the strength of oscillations generated. It will thus be seen that the oscillations generated may be modulated or keyed, either by speech, music or tone signals, etc., or by any combination of these alternatively or simultaneously.

Figure 2 discloses an arrangement similar to that of Figure 1 except for the showing of a different type of anode 22 and the use of a separate electron discharge device modulator tube 23. The anode shown in this modification comprises a cylindrical tube located with its axis lengthwise with respect to the cathode stream so as to enable the passage of the electrons through the cylinder. The stream of electrons returning from shell 4 to the anode 22 will tend to give the anode a negative potential and this negative potential is dependent upon the rate at which the electrons return compared to the rate at which they are dissipated in the anode circuit. If the latter is tuned, the fluctuations in the anode will be a maximum, but will tend to vary sinusoidally rather than according to a square wave variation. These fluctuations vary the number of electrons drawn from the cathode 2 through part 6, and so set a controlling effect upon the strength of the electron stream entering the shell 4. In this manner, under proper conditions, oscillations are produced. In this embodiment the modulating signals are applied through a transformer 24 to the control grid 25 of an electron discharge device 23, the latter, in turn, functioning to modulate the anode potential supplied to 22 in the well known Heising manner. The oscillations are produced in this case due to fluctuations in anode potential rather than due to mutual repulsions directly between free electrons. In the present instance it is preferable to so design the tube that the length of time for an electron to traverse tube 6 is the same as the time to traverse chamber 4. Except for these differences pointed out, the operation of the system is identical with that described above in connection with Figure 1, and for this reason will not be repeated herein. Obviously the modulating systems of Figure 2 could also be applied to the tube of Figure 1.

It is to be noted that since the wave form of the anode current during oscillation is substantially square it is rich in harmonics, and it is possible to obtain any harmonic frequency by tuning the circuit between the anode and the cathode by means of adjustable tap 14.

Although what is believed to be the correct theory of operation has been hereinabove set forth, it is to be understood that the present invention is not to be limited by any theory or combination of theories set forth, since it is possible that future experiments may lead to modifications or to other explanations regarding the reason for the results obtained.

It is further to be understood that the structure set forth is merely illustrative and is not to be considered limiting the present invention thereto, since it will be apparent that certain modifications may be made as regards the shape of the tube and the relative positions of the electrodes. Similarly, the cathode may have other forms and shapes than those indicated and, if desired, may be of the indirectly heated type. Again, any of the well known means for keying or modulating direct current potentials may be

applied to modulating the potentials on the electron whistle tube in order to obtain a modulated output.

What is claimed is:

1. In combination, a device for producing ultra high frequency oscillations comprising a cathode for emitting electrons, a grid for controlling the flow of electrons, an anode for attracting electrons, and means for causing the stream of electrons to travel in a curved path so as to cross itself, said means comprising a curved shell which has a potential at least as negative as that of the cathode, the anode being arranged to permit the passage of electrons from said cathode to said shell and to receive said electrons after they have traveled around the shell, an output circuit coupled to said anode, and means for modulating said oscillations in accordance with the signals to be transmitted, the last said means comprising a modulating circuit connected between said cathode and said grid.

2. In combination, a device for producing ultra high frequency oscillations comprising a cathode for emitting electrons, a grid for controlling the flow of electrons, an anode for attracting electrons, and means for causing the stream of electrons to travel in a curved path so as to cross itself, said means comprising a curved shell which has a potential at least as negative as that of the filament, the anode being positioned in an opening in the curved shell and insulated therefrom, an output circuit coupled to said anode, and means for modulating said oscillations in accordance with signals to be transmitted, the last said means comprising a modulating circuit connected between said cathode and said grid.

3. In combination, a device for producing ultra high frequency oscillations comprising a cathode for emitting electrons, an anode for attracting electrons, a control electrode intermediate said cathode and anode, and means for causing the stream of electrons to travel in a curved path, said means comprising a curved shell which has a potential at least as negative as that of the filament, the anode being arranged to permit passage of said stream of electrons from said cathode to said curved shell and to receive the electrons after their travel around the curved shell, an output circuit coupled to said anode, and means for varying the potential on said control electrode in accordance with the signal wave to be transmitted thereby to vary the density of the electrons traversing said curved shell and impinging upon said anode.

4. A device for producing ultra high frequency oscillations comprising a cathode for emitting electrons, an anode for attracting electrons, and means for causing a stream of electrons to travel in a curved path, said means comprising a curved shell which has a potential at least as negative as that of the cathode, the anode being arranged to permit passage of the electrons from said cathode to said shell and to receive said electrons after their travel around the periphery of said shell, an output circuit inductively coupled to said anode, and a tuning element in circuit with said anode for obtaining a desired frequency in said output circuit comprising a condenser, one plate of which is grounded and the other plate of which is connected to an adjustable tap, and means for modulating said oscillations in accordance with the signals to be transmitted.

5. In a communication system, in combination, a device for producing ultra high frequency oscillations comprising a cathode for emitting electrons, an anode for attracting electrons, a control electrode intermediate said cathode and anode, a source of positive potential and a connection from said source to said anode, and means for causing the stream of electrons to travel in a curved path so as to cross itself, said means comprising a curved metallic shell, a source of negative potential for supplying said shell with a negative potential, said anode being insulated from said shell and arranged to permit passage of said stream of electrons from said cathode into said shell and to receive said stream after its travel around the periphery of said curved shell, modulating means in circuit with said control electrode and filament for varying the potential of said grid in accordance with the signal wave to be transmitted, a tuning element in circuit with said anode connection for obtaining a desired frequency comprising a condenser, one plate of which is grounded and the other plate of which is connected by an adjustable tap to said connection, a utilization circuit inductively coupled to said connection, and adjustable tuning elements in said utilization circuit.

6. In a communication system, in combination, a device for producing ultra high frequency oscillations comprising a cathode for emitting electrons, an anode for attracting electrons, a control electrode intermediate said cathode and anode, a source of positive potential and a connection from said source to said anode, and means for causing the stream of electrons to travel in a curved path so as to cross itself, said means comprising a curved metallic shell, a source of negative potential for supplying said shell with a negative potential, said anode being positioned in an opening in the curved shell and insulated therefrom, modulating means in circuit with said control electrode and filament for varying the potential on said grid in accordance with the signal wave to be transmitted, a tuning element in circuit with said anode connection for obtaining a desired frequency comprising a condenser, one plate of which is grounded and the other plate of which is connected by an adjustable tap to said connection, an output circuit comprising an antenna and a transmission line inductively coupled to said anode connection, said output circuit including trombone slides for tuning said line to the desired frequency.

7. In combination, a device for producing ultra high frequency oscillations comprising a cathode for emitting electrons, an anode for attracting electrons, and means for causing the stream of electrons to travel in a curved path, said means comprising a curved metallic shell, a first source of potential for applying a negative potential to said metallic shell, a source of positive potential, and a connection from said latter source to said anode, said anode being in the form of a cylinder and insulatingly positioned with respect to said shell, said cylindrical anode being arranged with its axis parallel to the stream of electrons emanating from said cathode and arranged to permit passage of said electrons from said cathode to said shell and to receive on its outer surface said electrons after their travel around the periphery of said shell, an electron discharge device having an anode electrode connected to said anode connection for obtaining a positive potential therefrom and a control elec-

trode, a tuning element comprising a condenser in circuit with the anode of said first device and adjustable with respect thereto for obtaining a desired frequency in the anode circuit of said first device, a utilization circuit coupled to said anode circuit, and modulating means in circuit with the control electrode of said electron discharge device for varying the potential on said control electrode whereby there is obtained a modulated output in said utilization circuit in accordance with the signal wave.

8. In a system of the class described, an electron discharge device having a tubular anode and a cathode so disposed with respect to said anode as to project a stream of electrons mainly through the interior of said anode from end to end, means for thereafter forming said stream into a loop whereby most of the electrons are caused to impinge upon an exterior wall of said anode thereby to generate oscillations, a modulation circuit connected between said cathode and said anode, and a utilization circuit coupled to said modulation circuit.

9. In a high frequency communication system having an electron discharge device wherein the envelope, the electrodes, and the potentials applied to said electrodes are adapted to produce oscillations by unidirectionally propelling a beam of electrons along a confined path, deflecting said beam into a looped path so that the beam angularly intersects itself, thereby interrupting itself periodically, the method of modulating said oscillations which comprises applying modulating potentials between the cathode and at least one of the other electrodes of said device and varying the number and velocity of the electrons at the locus of intersection of their paths in accordance with signals to be communicated over the system.

CLARENCE W. HANSELL.