Sept. 22, 1936. H. E. HOLLMANN 2,054,816

ELECTRONIC OSCILLATOR

Filed July 8, 1930

Fig. 1.

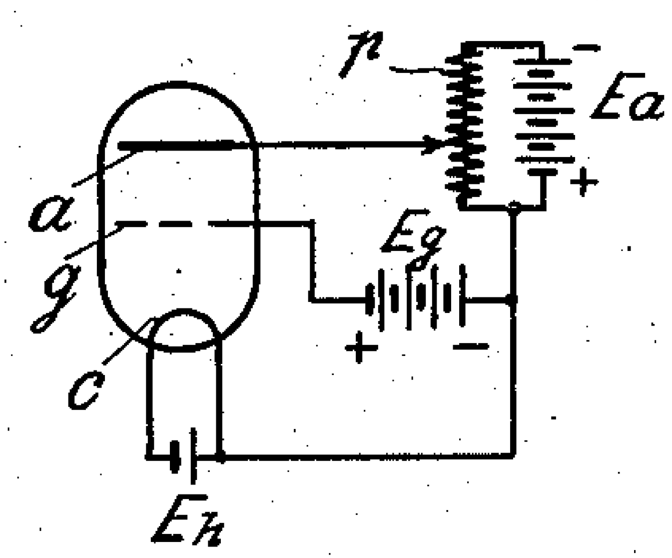



Fig. 2.

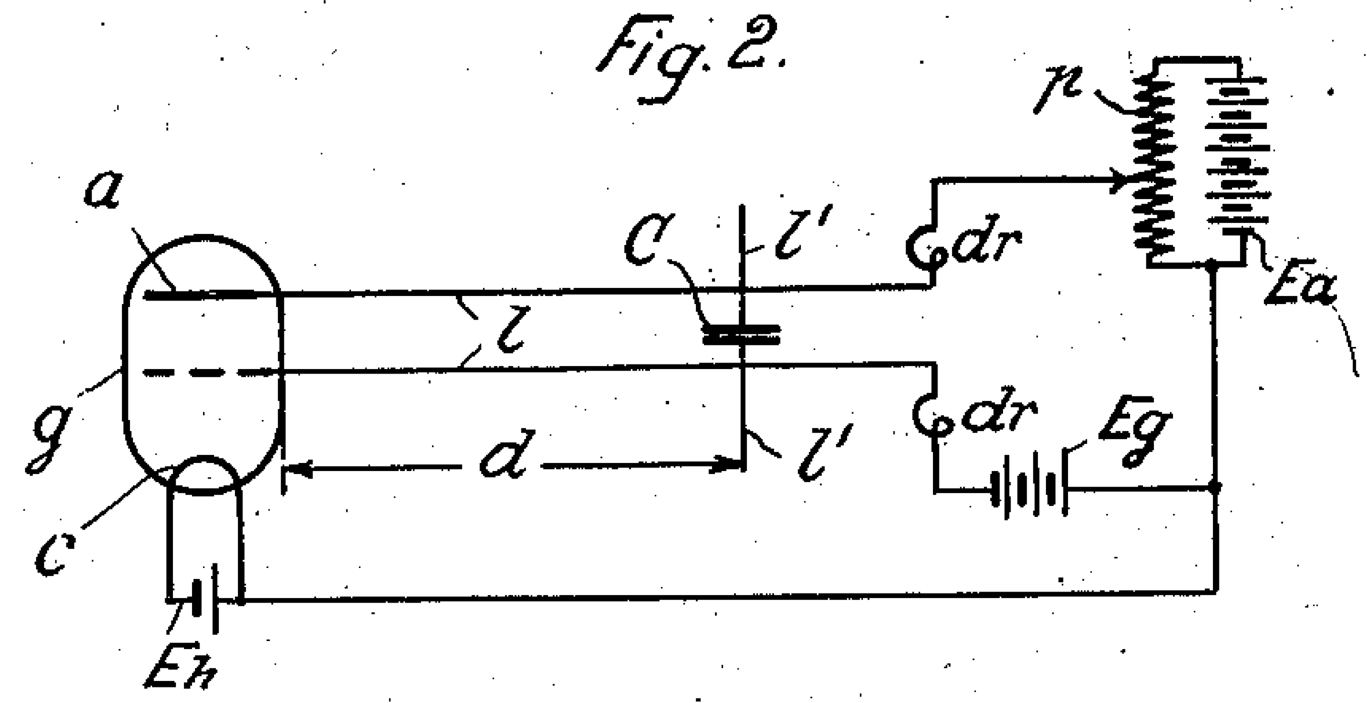



Fig. 3.

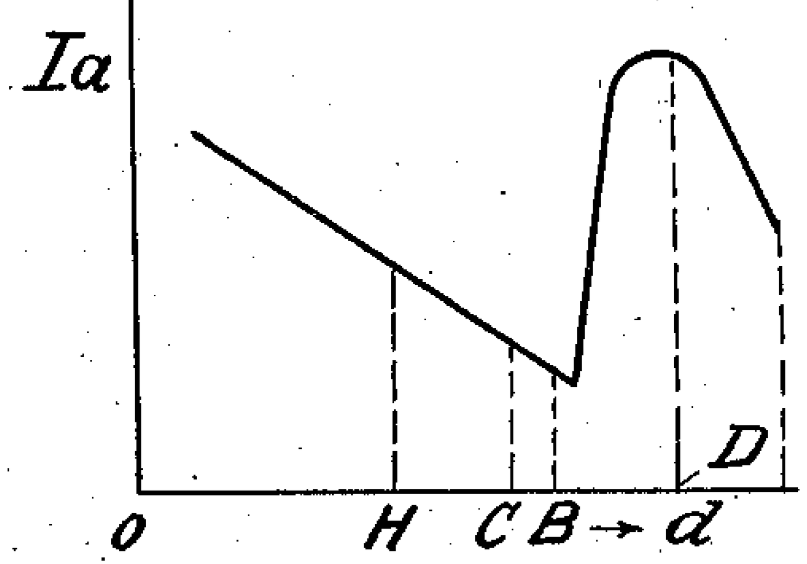



Fig. 4.

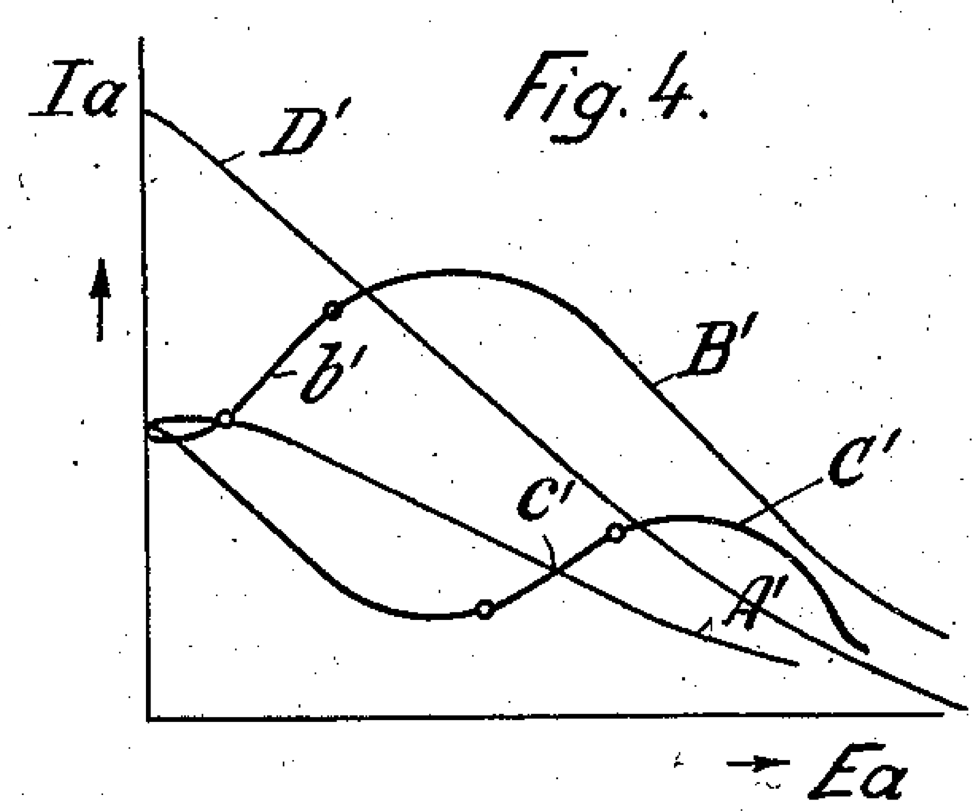
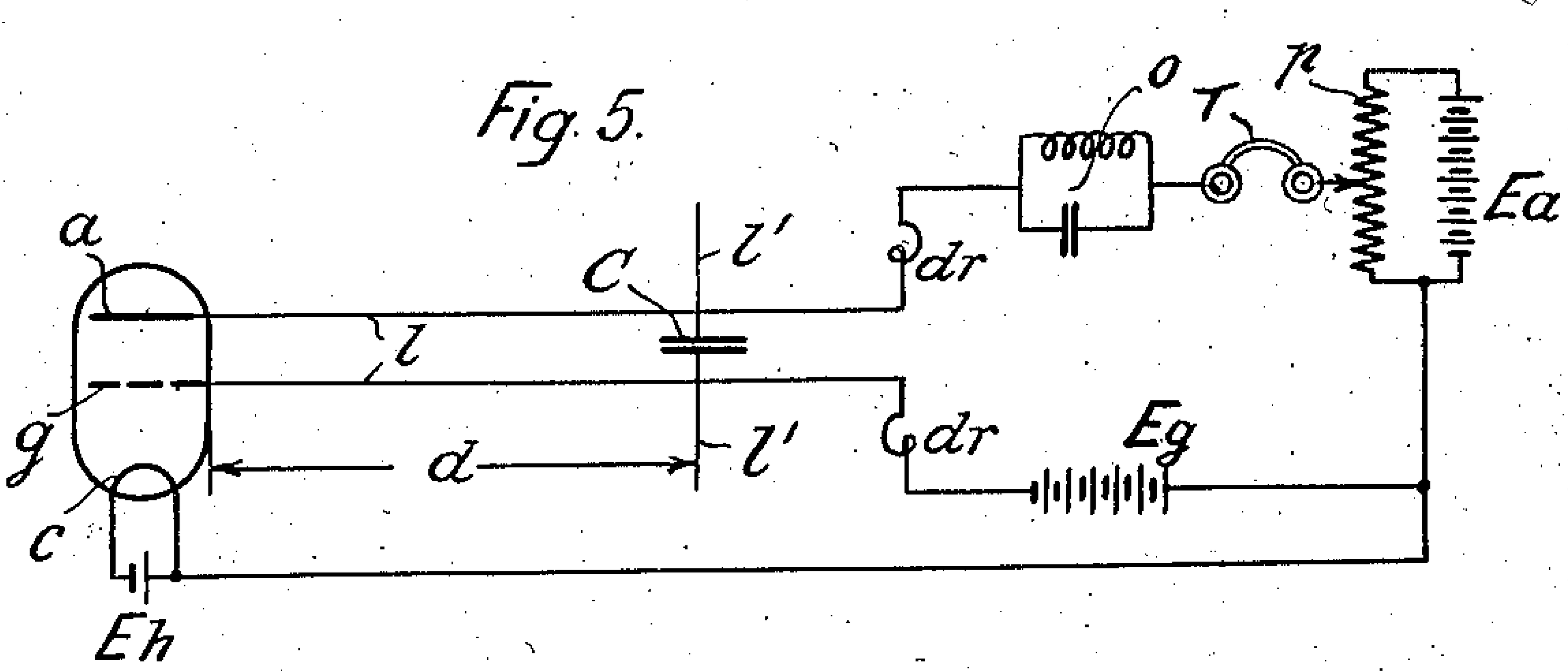



Fig. 5.

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2,054,816

# UNITED STATES PATENT OFFICE

2,054,816.

## ELECTRONIC OSCILLATOR

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Application July 8, 1930, Serial No. 466,524
In Germany July 10, 1929

6 Claims. (Cl. 250—36)

My invention relates to improvements in ultra high frequency electronic oscillators and more particularly to oscillators of the Barkhausen type.

In the generation of short electric waves by means of the customary regenerative arrangements there is a lower limit of wave length attainable occasioned by the fact that the time of transit of the electrons within the tube can no longer be ignored as compared with the period of oscillations determined by the constants of the oscillatory circuits. Consequently the ordinary regenerative coupling conditions as far as they concern the phase relations of the grid and anode alternating potentials are no longer sufficient. For commercial tubes it has been found that the lower limit of the wave length obtainable in such arrangements is about 1 meter.

Shorter waves can be generated by what is called the braking field method according to Barkhausen and Kurz in which the frequency is mainly determined by the time of transit of the electrons in the interelectrode space. In contrast with the ordinary method of operating a three electrode tube, the grid potential is highly positive and the plate potential is negative. The wave lengths produced are found to be primarily determined only by the dimensions of the tube and the applied potentials and are not greatly influenced by the constants of the associated circuits.

The object of my invention is to provide an improved circuit for transmitting as well as for receiving utilizing the above method, and which insures increased efficiency and ease of operation.

A more specific object of the invention is to provide means in connection with an electronic oscillator of the type to which reference has been made to impress a note of different frequency upon the high frequency oscillations for purposes of transmission and reception.

This and further objects of my invention will become more apparent by the following description taken with reference to the accompanying drawing, in which I have illustrated one form of embodiment of the invention.

I wish it to be understood however that the embodiment of the invention shown in the drawing should be illustrative only of the principle of the invention which, it is understood, may be embodied in various forms coming within its broad and comprehensive scope as expressed in the annexed claims.

In Fig. 1 I have shown, for purposes of illustration and explanation the most simple circuit arrangement for producing high frequency oscillations according to the above mentioned braking field method.

Fig. 2 shows a similar circuit to Fig. 1, with an oscillatory system associated with the oscillator tube for purposes of practical utilization of the oscillations.

Figs. 3 and 4 are theoretical curves illustrating the physical phenomena taking place in a circuit according to Fig. 2 which are made use of in accordance with the spirit of the present invention.

Fig. 5 illustrates a circuit arrangement adaptable for transmission as well as for reception embodying the novel improvements.

Similiar reference characters refer to similar elements throughout the different views of the drawing.

Referring more particularly to Fig. 1, I have shown an electronic tube of the thermionic type comprising a heated cathode *c*, grid electrode *g*, and anode *a*. The cathode is maintained at electron emitting temperature by means of a heating battery $E_h$. A positive potential with respect to the cathode is applied to the grid electrode by a grid battery $E_g$, and a negative potential with respect to the cathode is applied to the anode by a battery $E_a$ in combination with a potentiometer *p*, which latter serves to adjust a proper value of anode potential. As explained above the electrons emitted from the cathode and attracted by the positive grid will pass through the meshes of the grid and will be reversed by the counter-acting field of the negative anode whereby a kind of to and fro movement of the electrons about the grid takes place at a frequency dependent on the dimensions of the tube and the operating potentials applied, as may be readily understood.

In this manner high frequency oscillations may be easily produced having a wave length less than 1 meter down to fractions of a centimetre.

In order to utilize these oscillations it is customary to associate with the tube a parallel wire oscillating system *l*, as shown in Fig. 2. The two wires are connected by a bridge comprising a blocking condenser of large capacity and two open wires *l'* which latter may serve for radiation of the oscillations into space. For this purpose the length of the wires *l'* has to be equal to the wave length, or a multiple thereof, of the oscillations produced within the tube. Furthermore it is necessary that the distance *d* of the bridge from the tube electrodes be a multiple of the wave length. In order to block the voltage sources $E_g$

and $E_a$ against the high frequency portion of the system choke coils *dr* are provided in the supply leads as seen in Fig. 2.

If in the manner as described in connection with Fig. 1 a high positive potential is applied to the grid of an electronic tube and if at the same time a negative potential is placed on the anode, it might be expected that all the electrons emitted from the cathode would be attracted by the positive grid and that no electrons at all would reach the negative anode. It is observed, however, and may be verified by experiment that nevertheless an anode current occurs, which flows in a negative direction, that is, in a direction opposite to the anode voltage, which anode current is due to the high frequency to and fro movement of the electrons about the grid.

This "negative" anode current which flows against the anode potential or which, in other words, charges the anode battery, is in general an indication of the occurrence of the electronic oscillations. An explanation for the flow of this current may be given in that part of the electrons moving forth and back about the grid, assume an additive kinetic energy and are forced to the anode beyond the plane of zero potential within which ordinarily the electrons are reversed. With increasing negative anode potential this plane of zero potential moves more and more away from the anode whereby the number of electrons reaching the anode and consequently the negative anode current decreases gradually.

These simple conditions change considerably if the grid and anode of the tube are connected with an oscillatory system, such as is shown in Fig. 2. In such a circuit, the movement of the electrons is no longer exclusively determined by the stationary interelectrode fields corresponding to the operating voltages, but it is subject also to the influences of the alternating voltages induced in the oscillatory system and superimposed upon the direct current potentials applied to the electrodes. The alternating fields have the effect of building up the electron frequency within the tube until it is equal to the resonance frequency of the oscillatory circuit, which phenomenon in analogy to the well known amplitude feed back or reaction may be described as "frequency regeneration."

Concomitant with these wave changes due to the frequency reaction an increase of the oscillating energy takes place in that by the controlling action of the alternating fields a larger number of electrons is forced to take part in the back and forth movements. This is observed by an immediate and very rapid rise of the negative anode current such as is seen from the curve of Fig. 3. This curve, which shows the "negative" anode current as a function of the tuning of the oscillatory system is obtained by moving the condenser bridge to different distances *d* from the tube electrodes. Immediately after passing the point B the frequency reaction sets in and a rapid rise of the anode current takes place.

The setting in of the frequency reaction and the increase of the anode current associated therewith is not only dependent on the tuning of the oscillatory system, but also on the electron frequency within the tube. The setting in of the frequency reaction will move to higher frequencies, the higher the original frequency of the electron movements. This provides an opportunity to control the frequency reaction either by detuning the oscillatory circuit or by changing the operating conditions, as, for example, by varying the direct current potentials applied to the electrodes. In the latter case the "negative" anode current becomes of particular importance in connection with changes of the anode voltage $E_a$.

I have shown in Fig. 4 the relation between anode current and anode voltage. The curve A' which corresponds to the operating point A according to Fig. 3 illustrates the gradual decrease of the current with increasing negative anode potential, that is for the case that the oscillatory wire system *l* is considerably out of tune with the oscillating frequency of the electrons within the tube. These conditions however change with the parallel wire system being tuned to a point directly before the setting in of the frequency reaction, such as point B or C according to Fig. 3, to which correspond the curves of B' and C' in Fig. 4. These latter curves also show at first a gradual decrease of the anode current $I_a$ until an account of the frequency increase of the exciting electron oscillations the frequency reaction sets in giving rise to an increase of the anode current $I_a$. With further increase of $E_a$, $I_a$ begins to decrease again. If the tuning condition of the oscillatory system is moved further away from the critical resonance point for the frequency reaction (point C according to Fig. 3) it is seen from curve C' that a higher change of the exciting frequency and accordingly a higher anode potential will be necessary in order to produce the frequency reaction. Curve D' which corresponds to the operating point D shows that beyond the range of frequency reaction the anode current decreases again gradually with increasing anode voltage.

The rise of the anode current as seen from the portions *c'* and *b'* of the curves B' and C' with increasing negative or in general with decreasing positive anode potential illustrates that this braking field arrangement acts as a "negative" resistance owing to the reaction of the anode potential upon the tuning conditions of the system.

Similar devices, such as an electric arc, the dynatron vacuum tube and others, exhibiting a "negative" resistance characteristic, i. e. rising current with falling voltage, are well known in the art and are used for exciting an oscillatory circuit and sustaining the free natural oscillations of such circuit. The resistance is identical to a source of energy compensating for the losses of the circuit and thus maintaining undamped oscillation.

In accordance with the present invention this phenomenon is made use of for producing a current of different frequency to be utilized in connection with the high frequency oscillations for the purpose of practical application of these ultra-high frequency currents, such as for transmission and receiving of wireless signals. This is shown in Fig. 5 which differs from Fig. 2 in that an oscillatory circuit *o* of the ordinary type comprising a concentrated inductance and capacity in parallel is included in the anode leads. If at the same time the operating conditions, that is the tuning of the parallel wire system *l* (by properly choosing distance *d*) and the proper adjustment of the operating anode voltage $E_a$ are such that the tube presents a negative resistance characteristic (operating range *b'* or *c'* according to Fig. 4), such as set forth above, the circuit *o* will oscillate in a frequency equal to its own natural frequency, which may be chosen at will by proper tuning in the manner well known in the art.

If the system is used as an oscillator for transmission and if the oscillations produced by the oscillatory circuit *o* are within the audible range, the oscillations may be observed by means of a telephone receiver T included in the anode lead. In this case the oscillations produced by the oscillatory circuit *o* are impressed upon the high frequency oscillations produced by the tube system or, according to common language, the high frequency electronic oscillations are modulated in accordance with the frequency equal to the natural frequency of the circuit *o*. This makes a system according to Fig. 5 suitable for use as a transmitter for wireless signals.

If the same circuit according to Fig. 5 is to be used as a receiver, care must be taken that the open wires *l'* as well as the distance *d* are properly tuned to the frequency radiated by the transmitter. Furthermore in this case the tube is so operated, that it produces only very weak oscillations (for instance by decreasing the heating current). Whenever incoming waves impinge upon the wires *l'*, the oscillations are increased and the circuit *o* in this case too acts by a kind of self modulation by which an effect similar to the well known super regenerative action in radio receivers is obtained, producing a considerable increase of the receiving current intensity.

I wish it to be understood that I do not desire to be limited to the exact details of construction shown and described for obvious modifications will occur to a person skilled in the art.

I claim:

1. In combination with a high frequency system, an electronic oscillator comprising an electron discharge tube, having electron emitting cathode, anode, and auxiliary grid electrode, means to apply suitable positive and negative potential to said grid and anode electrodes, respectively, to produce ultra high frequency oscillations, a utilization circuit for said ultra high frequency oscillations, connected to said discharge tube, means whereby the discharge path within said tube exhibits negative resistance characteristic, and an oscillatory circuit comprising an inductance and capacity in parallel connected to said tube to be excited in its own natural frequency by said negative resistance to impress a modulating note of substantially different frequency upon said high frequency oscillations.

2. In combination with a high frequency system an electronic oscillator comprising an electron discharge tube having a cathode, anode, and grid electrode, means to apply suitable positive and negative potential to said grid and anode, respectively, for producing ultra high frequency oscillations, a two-wire oscillating system connected to said grid and said anode, said oscillating system being so adjusted in respect to the natural frequency of the electron movements, that the discharge path of the tube exhibits negative resistance characteristic, and an oscillatory circuit comprising an inductance and a capacity in multiple connected to said tube to be excited in its natural frequency by said negative resistance to impress a modulating note of substantially different frequency upon said ultra high frequency oscillations.

3. In combination with a high frequency system an electronic oscillator comprising an electron tube having cathode, anode and grid electrode, means to apply suitable positive and negative potential to said grid and anode, respectively, for producing ultra high frequency oscillations, a two-wire oscillatory system, connected to said anode and said grid, means to adjust the length of said oscillating system in respect to the natural frequency of the interelectrode electron movements in such manner that the tube operates within its range exhibiting negative resistance characteristic and an oscillatory circuit consisting of an inductance and capacity in parallel connected to said tube to be excited in its natural frequency by said negative resistance to impress a modulating note of substantially lower frequency upon said ultra high frequency oscillations.

4. In an ultra high frequency system, a three electrode electron tube having cathode, grid and anode, means for applying positive potential to said grid with respect to said cathode, means for applying a potential to said anode at least as negative as that of said cathode, whereby high frequency oscillations are produced, a two-wire oscillatory system connected to said grid and said anode, a condenser bridge for adjusting the length of said wire system, and an oscillatory circuit consisting of an inductance and capacity in parallel and inserted in series with said second means, said potentials being furthermore so adjusted as to secure negative resistance characteristic of said tube to excite said auxiliary circuit in its own frequency to impress a modulating note upon said high frequency oscillations.

5. In a high frequency system in accordance with claim 4, according to which the natural frequency of said oscillatory circuit is within the audible range and a translating device connected in the circuit for rendering the high frequency oscillations audible.

6. In a high frequency system, a three electrode electron tube having cathode, grid and anode, means for applying positive potential to said grid with respect to said cathode, means for applying negative potential to said anode with respect to said cathode, whereby ultra high frequency oscillations are produced, a two-wire oscillating system connected to said grid and said anode, a condenser bridge for adjusting the length of said system, said potentials and the tuning of said wire system being so related that the tube operates within its operating range exhibiting negative resistance characteristics and an oscillatory circuit consisting of an inductance and a capacity in parallel inserted in series with said first means for applying potential to impress a modulating note of substantially different frequency upon said high frequency oscillations.

HANS ERICH HOLLMANN.