

Sept. 13, 1938.

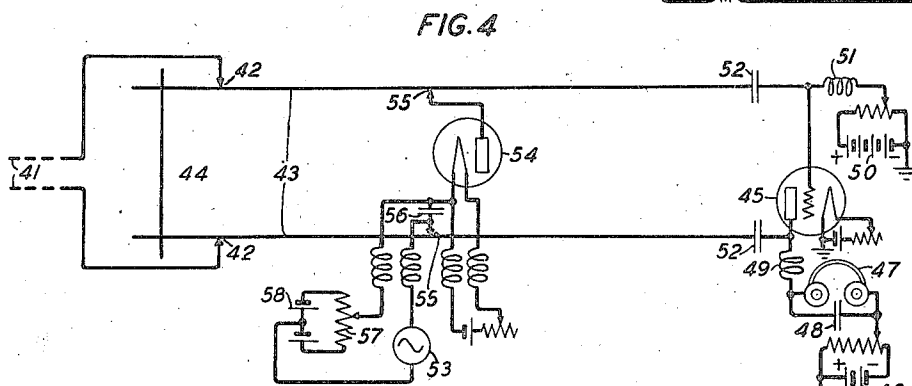
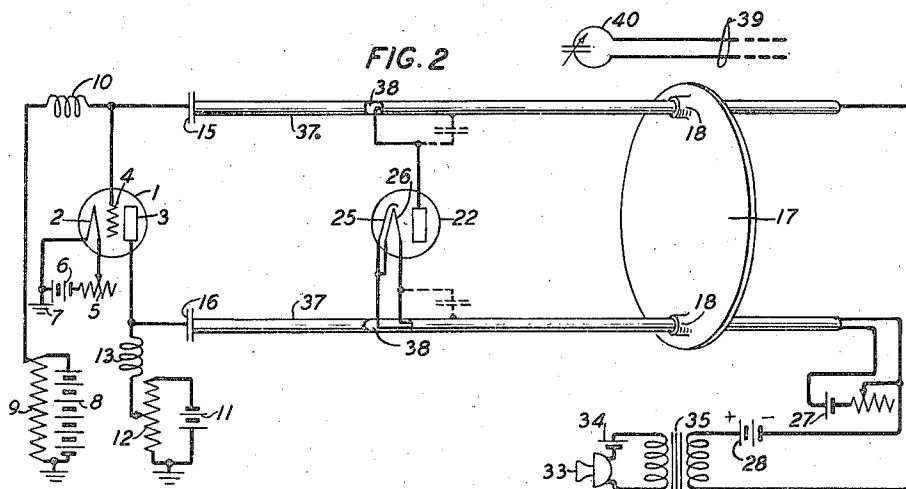
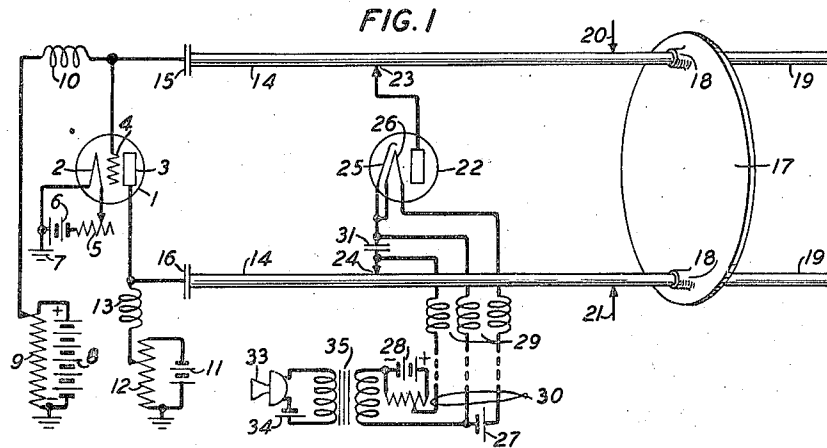
J. G. CHAFFEE

2,129,820

MODULATION SYSTEM FOR ULTRA-SHORT WAVES

Filed July 23, 1936

2 Sheets-Sheet 1



INVENTOR
J. G. CHAFFEE
BY
E. V. Briggs
ATTORNEY

Sept. 13, 1938.

J. G. CHAFFEE

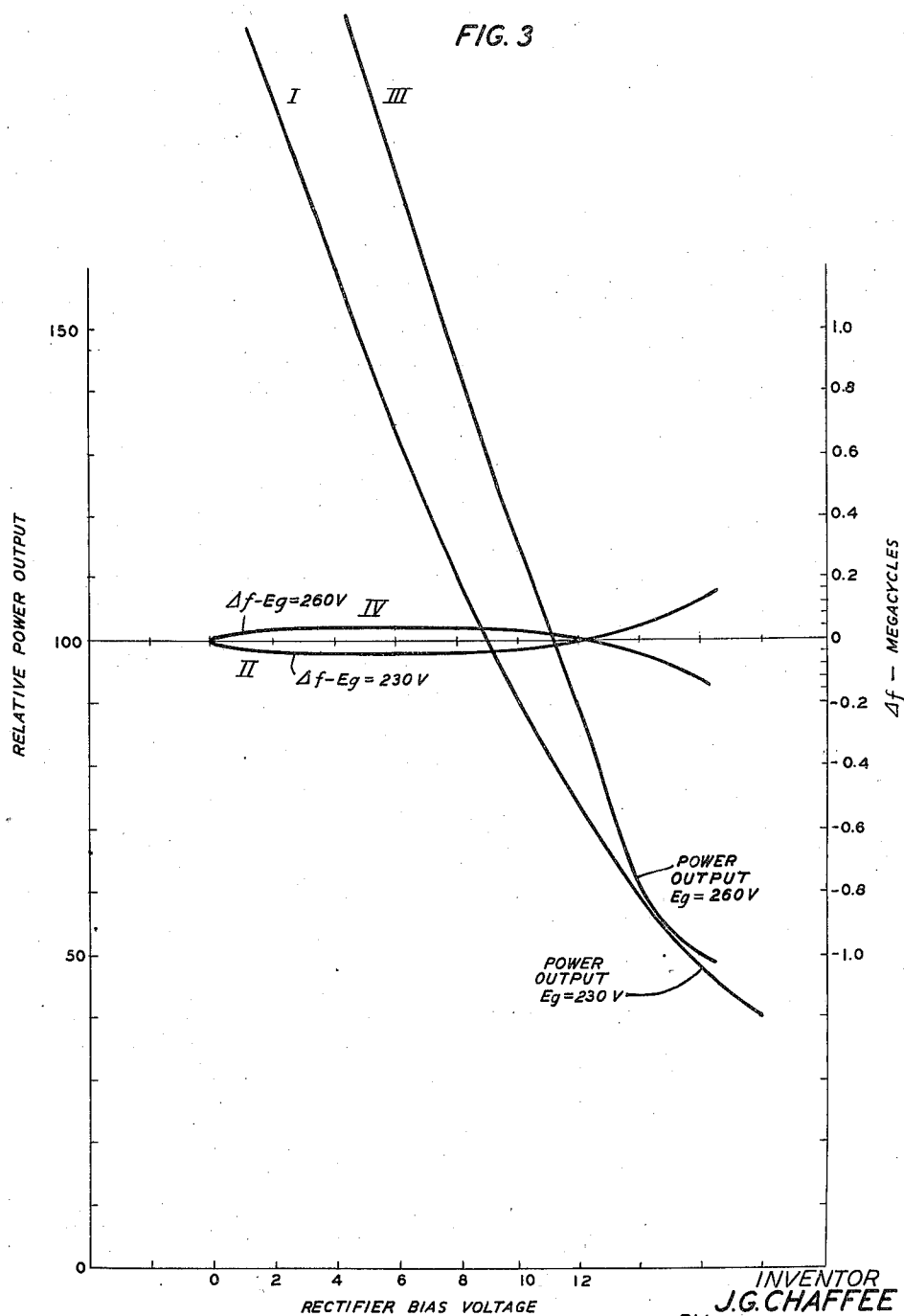
2,129,820

MODULATION SYSTEM FOR ULTRA-SHORT WAVES

Filed July 23, 1936

2 Sheets-Sheet 2

FIG. 3



INVENTOR
J. G. CHAFFEE
BY
E. V. Briggs
ATTORNEY

UNITED STATES PATENT OFFICE

2,129,820

MODULATION SYSTEM FOR ULTRA-SHORT WAVES

Joseph G. Chaffee, Hackensack, N. J., assignor to
Bell Telephone Laboratories, Incorporated,
New York, N. Y., a corporation of New York

Application July 23, 1936, Serial No. 92,116

3 Claims. (Cl. 179—171)

This invention relates to modulation systems for ultra-short waves and more particularly to absorption modulation systems for Barkhausen oscillators.

One of the most important and difficult problems arising in connection with the use of Barkhausen oscillators as sources of ultra-short waves for radio telephony and similar purposes is that of modulation. One of the principal difficulties arises from the fact that the frequency of this type of oscillator is dependent to a comparatively large degree upon the operating voltages so that any attempt to vary the amplitude of oscillation by superimposing the speech or other modulating electromotive force upon either the grid or plate electromotive force is accompanied by a comparatively large degree of frequency modulation. In fact, it is possible to produce a considerable degree of substantially pure frequency modulation in this fashion.

The extent of the frequency shift which takes place when the output of a Barkhausen oscillator is altered by varying its plate voltage, for example, depends to some extent upon the design of the electron discharge device which is used as the oscillation generator. However, when amplitude modulation is applied to a Barkhausen oscillator it is desirable to reduce considerably the extent of the frequency modulation which occurs with discharge devices even of the most favorable design. Particularly when a receiving circuit of the superheterodyne type is to be employed at the remote receiving station, it is expedient to restrict the frequency shift as much as possible so as to reduce the band width necessary in the intermediate frequency amplifier and selector.

A principal object of this invention is to modulate the amplitude of oscillations produced by an electron discharge oscillator operating at wavelengths of less than a meter with as little change in the frequency as possible.

In accordance with the present invention, the frequency shift which occurs during modulation of a Barkhausen oscillator is substantially reduced by an absorption system operating effectively as a pure resistance and introduced into the load circuit of the oscillator in such a manner that the amplitude of oscillation is varied or modulated as desired without altering the reactance of the system. To accomplish this in the case of a Lecher system the absorption device is preferably made of high resistance and is connected in shunt at a quarter wave-length point measured from the short-circuited end of the

system in order that the reactance presented by the circuit at the tube shall remain unaltered.

At lower frequencies a thermionic rectifier constitutes an ideal variable resistance of a few thousand ohms average value. However, at frequencies such that the time of transit of the electrons becomes comparable with the period of the applied electromotive force, the rectifier impedance is no longer a pure resistance and varies in a complicated manner with variations in applied electromotive force. For this reason and also for the reason that its resistance is not extremely high, it might be expected that such a rectifier would not be at all satisfactory as an absorption modulator at wave-lengths of the order of 60 centimeters. However, experience has demonstrated that with care in making the necessary adjustments good results can be obtained.

Important features of absorption modulating systems in accordance with the invention are the location of the connections of the absorption device to the Lecher system and the provisions for associating the polarizing and modulating circuits with the modulating rectifier in such manner as not to introduce unnecessary energy dissipation into the system.

In the drawings:

Fig. 1 shows a schematic of an absorption modulating circuit for a Barkhausen oscillator;

Fig. 2 illustrates a modification of the circuit of Fig. 1 according to which the circuit connections of the modulating rectifier are brought out through Lecher conductors of the Barkhausen oscillator;

Fig. 3 shows graphs illustrating the performance of the circuit of Fig. 1, and

Fig. 4 illustrates the circuit of a super-regenerative receiver employing a Barkhausen oscillator in conjunction with a source of quenching oscillations.

Referring to Fig. 1, the electron discharge device 1 is shown with a cathode 2, anode 3 and impedance control grid 4. Heating current is supplied to the cathode through regulating potentiometer resistance 5 by a source 6, one terminal of which is connected to earth at 7. A high potential source 8 associated with a grounded potentiometer resistance 9 serves to polarize the grid positively over a path extending from earth through the source and high frequency choke coil 10. The anode is biased to a low potential, in general slightly negative with respect to the cathode, by a source 11 associated with a potentiometer resistance 12 one end of which is con-

nected to earth and the other of which is connected through high frequency choke coil 13 to the anode.

A Lecher circuit consisting of parallel conductors 14 respectively connected to the grid and anode through stopping condensers 15 and 16 is provided with a short-circuiting tuning disc 17 of well-known type provided with contacting sleeves 18 so that the Lecher circuit may be tuned by movement of the disc 17. The projecting ends 19 of the rods 14 are effectively shielded by the disc to isolate them from the tuned Lecher circuit. It is accordingly possible to tune the Lecher circuit to an optimum wave-length for the Barkhausen oscillator. Energy may, therefore, be transferred from the Barkhausen oscillator to a dipole radiator 20, 21 connected to the Lecher circuit 14 at such points on the Lecher circuit conductors as will effect optimum coupling between the radiator and the Lecher circuit.

Modulation of the Barkhausen system is effected by a rectifier or thermionic resistance element 22 connected by sliding or other variable contacts between points 23 and 24 on the Lecher circuit conductors at approximately one-quarter wave-length from short-circuiting disc 17. If the resistance of the rectifier be varied the amplitude of the oscillations may be varied since the potential differences between points 23 and 24 are normally high. Assuming the impedance of the rectifier to be a pure, variable resistance, the connection of this device between points 23, 24 located exactly one-quarter wave-length from disc 17 would not alter the reactance of the Lecher circuit as viewed from the tube terminals, and consequently the amplitude of oscillation could be modified or modulated without frequency shift. However, at frequencies sufficiently high so that the time of transit of the electrons within the rectifier becomes appreciable compared with the period of oscillation, the impedance of the rectifier may include an appreciable reactive component which will vary with the bias impressed upon the rectifier anode. Hence the location of the connecting points 23, 24 which will yield a minimum of frequency shift during modulation will differ from a true quarter-wave point on the Lecher system. Since the existence of an appreciable reactive component in the impedance of the rectifier limits the extent to which the frequency shift can be made to approach a zero value, the rectifier should have as small a transit time as possible. It is thus desirable to employ a rectifier having very small spacing between anode and cathode.

The exact location of the points 23, 24 at which the frequency modulation is a minimum may best be determined experimentally. The rectifier 22 is preferably provided with an indirectly heated cathode 25, a heater 26 and a heater current supply source 27. The rectifier is biased so that its anode is normally positive and its cathode negative by means of a biasing source 28 connected between the cathode and one of the Lecher conductors. The proper value of bias voltage to be applied to the rectifier is best determined in the following manner. Observation is made of the amplitude of oscillations in the Lecher system or radiating element as the bias applied to the rectifier is varied. The region over which the amplitude of oscillation is approximately a linear function of the bias voltage is then determined. A fixed bias corresponding to the middle point of this region is then applied from source 28. The four leads to the heater source and biasing

current source each preferably include high frequency choke coils 29 and are cabled together as indicated at 30 and extended at right angles to the Lecher circuit for a distance of a foot or more from the Lecher circuit conductors. The choke coils 29 are very carefully adjusted and are placed as near the rectifier as possible. A high frequency by-pass condenser 31 for the high frequency oscillations but of too small capacity to appreciably transmit modulating signal frequency waves directly connects the cathode to one of the Lecher conductors.

A microphone 33 or other source of signals in series with current source 34 and the primary winding of modulating signal frequency transformer 35 is coupled by the transformer to the biasing circuit of the rectifier to vary the effective bias potential thereacross in accordance with modulating signal electromotive forces. In consequence of the varying bias the rectifier resistance likewise varies, so that the rectifier absorbs varying amounts of power and causes the amplitude of the oscillations supplied to the dipole radiator to be modulated in accordance with the signals impressed upon the microphone.

The circuit of Fig. 2 includes a Barkhausen oscillator in all respects similar to that of the circuit of Fig. 1 except that the Lecher conductors 37 are tubular whereas the particular form of the conductors 14 is not of great consequence. At the approximate points for connecting the rectifier 22 the conductors 37 are slotted for a short distance as indicated at 38. The various biasing and heating current leads are taken from the tube terminals through the slots 38 and pass out through the tubular Lecher conductors 37 at their ends beyond the tuning disc 17. In lieu of the direct connection of the anode to the Lecher conductor 14 of Fig. 1, a capacitive connection is employed, this capacity being that between the tubular conductor 37 and the anode conductor which passes through conductor 37. A similar capacitive connection between the cathode leads and the other tubular conductor 37 replaces condenser 31 of Fig. 1. Should the capacity between the tubular conductor and the wires within be inadequate it may be supplemented by additional physical condensers as indicated in dotted lines.

The load circuit 39 which may lead to a high frequency line or an antenna is coupled to conductors 37 by a coupling coil 40 provided with a variable tuning condenser. The operation of this circuit is similar to that of Fig. 1 and will accordingly be understood without further explanation.

Fig. 3 indicates graphically the performance of a Barkhausen oscillator in the circuit of Fig. 1 under different operating conditions. Curve I illustrates the variation in output power of an oscillating system according to the circuit of Fig. 1 with an applied bias potential of -9 volts on anode 3 and with a bias of +230 volts applied to grid 4. The normal bias potential applied to the anode of the rectifier tube 22 is +9 volts. The abscissae are in terms of net bias voltage applied to the rectifier. It appears from curve I that a modulating electromotive force of 7 volts peak value derived from secondary winding of transformer 35 together with 9 volts bias from source 28 will swing the net rectifier bias between the limits of 2 to 16 volts. This will vary the output power of the oscillations from 190 units down to 49 units as indicated by the ordinates at the left of the curve showing relative power output.

The form of this curve indicates an approximately linear relationship between instantaneous modulating electromotive force and oscillation amplitude. Consequently, a very effective amplitude modulation is attained. At the same time as indicated by curve II which shows variations in carrier frequency indicated by the ordinates to the right of the curve as related to variations in modulator bias, the carrier frequency having a normal magnitude of 500 megacycles remains within .13 megacycle of the normal magnitude. In other words, the carrier frequency varies by about one part in 4,000 throughout this range.

Curve III illustrates the performance of the same electron discharge device with a grid bias of +260 volts and an anode bias of -10 volts applied to the oscillator electrodes. It will be apparent that in this instance also the power output varies approximately as the square of the modulating electromotive force and that the variation in carrier frequency is very low.

In order to realize a large improvement in frequency stability during modulation it is necessary that circuit adjustments be made with considerable care. It is first of all necessary that the modulating rectifier be connected to the Lecher system at the proper point. It has been observed that if the actual point of connection departs from the optimum point by a rather small amount, variation of the rectifier bias will have relatively little effect upon the amplitude of oscillation. Furthermore, the point yielding the minimum frequency change tends to produce the most desirable relationship between rectifier bias and oscillator output. The performance of the system is also rather critically dependent upon the bias applied to the anode 3 of the Barkhausen oscillator.

Fig. 4 illustrates a super-regenerative radio receiver circuit in which an oscillator of the Barkhausen oscillation generator type is employed in accordance with the principles of the invention. As shown, an input circuit 41 which may either be the terminal of a long transmission line or may represent a circuit leading from a receiving antenna is connected by variable position taps 42 to the conductors 43 of a Lecher circuit. Associated with the Lecher conductors in order to tune the Lecher circuit is a slider element 44 which is preferably identical in character with element 17 of Figs. 1 and 2. Connected to the other terminals of the Lecher circuit conductors are the grid or impedance control element and the anode of an electron discharge device 45 which also includes a thermionic cathode. The anode is polarized by source 46 and its associated potentiometer over a path extending from ground and including audio frequency telephone or other signal indicating device 47 with its bypass condenser 48 and radio frequency choke coil 49. The biasing potential impressed on the anode is preferably made slightly negative with respect to that of the cathode but in any event it does not differ from that of the cathode by more than a few volts. The grid or impedance control element is polarized to a high positive potential by means of a source 50 and its associated potentiometer in series with a high frequency choke coil 51. The grid and the anode are each connected to one of the Lecher conductors 43 through stopping condensers 52. The thermionic cathode is heated in any well known manner. The various biasing potentials are preferably so adjusted that the device 45 with its associated Lecher

circuit oscillates with moderate intensity at the frequency which it is desired to receive when the rectifier 54 is made inoperative by the application of a large negative bias to its anode. Conditions should be such that when the anode of tube 54 is now biased somewhat positive with respect to the rectifier cathode, sufficient loss is introduced into the Lecher system to bring about a cessation of oscillations. Under these conditions the application of a suitable high frequency alternating potential from source 53, as well as a possible readjustment of bias voltage derived from potentiometer 57, will bring the device 45 and its associated Lecher system into alternate conditions of oscillation and non-oscillation. Source 53 therefore performs the same function as the so-called quenching oscillator in the well-known super-regenerative receiver. While it is equally possible to bring about a condition of super-regeneration by applying the quenching voltage from source 53 to the anode of the Barkhausen oscillator, there would result a rather large variation in the frequency at which the system tends to oscillate, with a consequent detuning of the receiver during the quenching cycle. With the rectifier 54 in Fig. 4 positioned with respect to the Lecher system so as to produce a minimum effect upon the frequency of the oscillator, quenching can be performed with very little disturbance of the oscillator frequency. In fact, Figs. 1 and 4 differ fundamentally only in that the oscillator of Fig. 4 is very considerably overmodulated at a super-audible frequency, and in addition contains telephone receivers 47.

For the reception of wave-lengths of about half a meter, the frequency of source 53 should be several megacycles. The most suitable value will depend upon the characteristics of the tube 45, the losses in the Lecher system 43, and the received frequency. The relative lengths of the periods of oscillation and non-oscillation, or more accurately the periods during which the decrement of the oscillatory circuit is negative or positive, can be controlled to some extent by adjustment of the biasing potentiometer 57 associated with the biasing source 58 in series with the source 53 of quenching voltage.

Capacity element 56 is preferably connected between the cathode of rectifier 44 and one of the Lecher conductors to afford a low impedance path for the incoming high frequency oscillations but is of too small capacity to appreciably shunt the sensitizing pulses from source 53.

According to the diagrams the Lecher systems have a length of about one-half wave-length. This is for the reason that practically all modern tubes operating at wave-lengths of the order of 60 centimeters have an equivalent of about one-quarter wave-length between the tube terminals and the actual elements. It is quite possible in many cases to place the tuning slider at or very near the tube terminals. However, this leaves practically no external circuit upon which to operate. Hence it is desirable to construct high frequency circuits involving such tubes so that the equivalent electrical length of the system between slider and actual tube elements is about three-quarters of a wave-length, leaving an external circuit of about one-half wave-length.

What is claimed is:

1. In combination, an electron discharge device having a cathode, an anode and an impedance control element, means for heating the cathode, means for polarizing the impedance control ele-

ment to a highly positive potential with respect to the cathode, means for polarizing the anode to a potential relatively near to that of the cathode, a Lecher circuit, stopping capacity elements
5 connecting the impedance control element and anode respectively to the two conductors of the Lecher circuit at one end, means for short-circuiting the Lecher circuit at its other end, a
10 second electron discharge device having an anode and a thermionic cathode connected in shunt to the Lecher circuit at a point approximately one-quarter wave-length from the short-circuited end of the Lecher circuit, and means for
15 controlling the impedance between the cathode and anode of the second electron discharge device in accordance with signals.

2. In combination, an electron discharge device having a cathode, an anode and an impedance control element, means for heating the
20 cathode, means for polarizing the impedance control element to a highly positive potential with respect to the cathode, means for polarizing the anode to a potential relatively near to that of the cathode, a Lecher circuit, stopping capacity
25 elements connecting the impedance control element and anode respectively to the two conductors of the Lecher circuit at one end, means for short-circuiting the Lecher circuit at its other end, a two-terminal rectifier connected in shunt
30 to the Lecher circuit at a point approximately

one-quarter wave-length from the short-circuited end of the Lecher circuit, and means for controlling the impedance of the rectifier in accordance with signals.

3. In combination, a carrier frequency generator comprising an electron discharge device having a cathode, an anode and an impedance control element, means for heating the cathode, means for polarizing the impedance control element to a highly positive potential with respect to the cathode, means for polarizing the anode to a potential relatively near to that of the cathode, a Lecher circuit, stopping capacity elements connected to the impedance control element and anode respectively to the two conductors of the Lecher circuit at one end, means for short-circuiting the Lecher circuit at its other end, a variable impedance device connected in shunt to the Lecher circuit at a point approximately one-quarter wave-length from the short-circuited end of the Lecher circuit, and means for controlling the impedance of the variable impedance device in accordance with signals whereby the potentials of the impedance control element and the anode are left substantially unchanged by the operation of the variable impedance device so that the carrier frequency of oscillations produced by the electron discharge device remains substantially constant.

JOSEPH G. CHAFFEE. 30