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H. S. BLACK

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WAVE GENERATING AND MODULATING SYSTEM

Filed Sept. 6, 1927

FIG. 1.

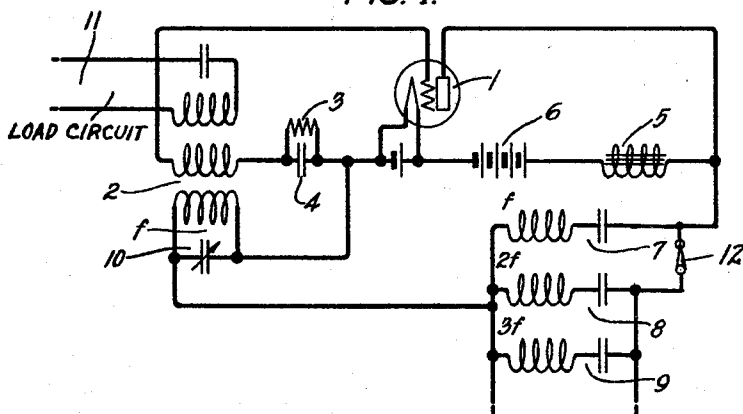


FIG. 2.

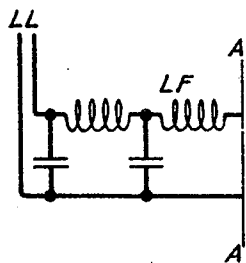
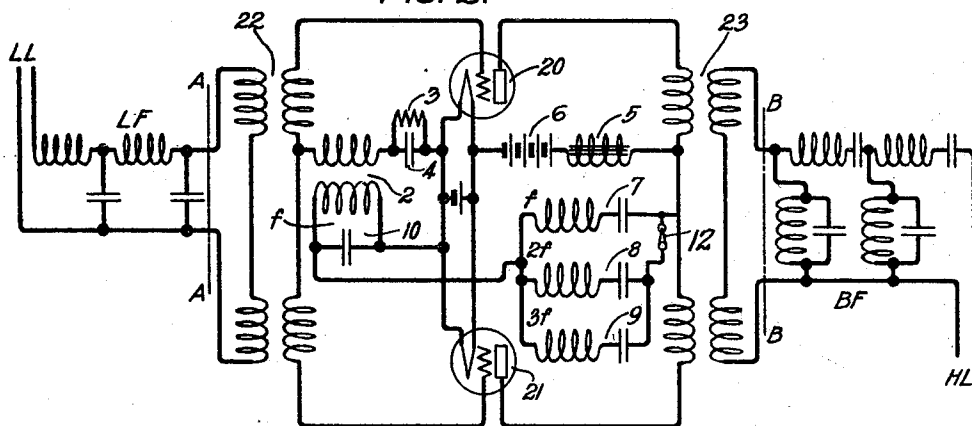


FIG. 2A.

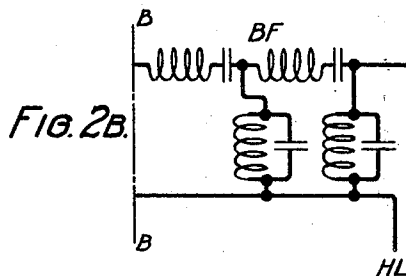


FIG. 2B.

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WAVE GENERATING AND MODULATING SYSTEM

Application filed September 6, 1927. Serial No. 217,679.

The present invention relates to systems employing, preferably, space discharge devices for producing oscillations, and also to systems for both producing and modulating oscillations. The invention is particularly applicable to systems in which the space current of the device or devices is permitted to flow for only a relatively small portion of each cycle of the wave that is being produced, or produced and modulated.

From the functional viewpoint, oscillation producing and modulating circuits may be looked upon as frequency-converting systems in which the purpose is to produce one or more frequency components. The invention increases the efficiency of production of desired components by space discharge devices of given power rating by minimizing the load put on the tubes by unnecessary frequency components, in other words, by confining the load on the tubes or devices to those components that are most effective in producing the desired final frequency components, thereby enabling the useful load obtainable with tubes of given power rating to be increased over prior art systems and methods of operation.

It has been found in the prior art that attempts to obtain increased output of desired frequency components by increasing the impressed voltages with prior art methods of operation, that is, "crowding" the tubes, have resulted in irregular operation amounting in extreme cases to the occurrence of the phenomenon of blocking. The invention enables the output of desired frequency components to be increased while keeping the operation perfectly stable and free from irregularities and blocking effects.

Objects of the invention are:

To increase the available output of desired frequency components in an oscillation producing system or in an oscillation producing and modulating system.

To increase the stability of operation of such systems; and

To control the tube impedance by external circuit adjustments in a novel manner to be more fully described hereinafter.

As a matter of convenience in the art a

distinction has customarily been drawn between modulators and demodulators. However, it will be simpler in the present case to describe the invention as applied to a modulator since so far as the invention is concerned its application to a modulator is essentially the same as its application to a demodulator. In the case of a modulator the applied waves are, in carrier telephony, for example, speech and the carrier waves while the desired output frequency components are side-band components and carrier, the latter of which may or may not be actually transmitted although it occurs in the output with, and is an accompaniment to, the side-band components. In a demodulator the applied waves are a side-band component (one or both side-bands) and the carrier wave while the output is speech waves, the carrier that occurs as an incidental not being used by the receiver. It is now well known that the interactions in the circuits are essentially the same in a modulator as those in a demodulator. Wherever in the following description and in the claims, therefore, the term "modulator" or the like is used it will be understood that this refers equally as well to a demodulator.

A better understanding of the invention will be had from the following detailed description in connection with the accompanying drawing in which:

Fig. 1 is a schematic representation of one form of oscillator embodying the invention,

Fig. 2 is a similar schematic diagram of an oscillator modulator embodying the invention, and

Figs. 2—A and 2—B represent alternative filter connections to give the desired terminating impedances in typical cases that will be described.

It is now well understood in the art that a vacuum tube oscillator can be made to operate at high efficiency if the grid is polarized negatively with respect to the cathode and particularly to such an extent that the space current through the tube is allowed to flow for only a small portion of each period of the oscillations. One manner of obtaining a negative biasing potential for the grid is by

the use of a parallel condenser-resistance combination, the resistance developing a drop of potential between its terminals due to the flow of grid current and the condenser serving to maintain the potential drop substantially constant by storing a charge between the instants of grid current flow.

When the space current flow is confined in this manner to a small portion of the cycle in order to raise the efficiency, the actual output power is reduced, other conditions remaining the same. Attempts to increase the output while still operating with the space current interrupted for the greater part of the cycle as by increasing the driving voltage have resulted in the prior art in irregular or unstable operation of the circuit extending in some instances to actual "blocking" of the circuit. As is well-known, when blocking occurs, the oscillations occur in successive trains or "spurts" rather than in a perfectly continuous manner.

In accordance with the invention the oscillator may be made to give a greatly increased oscillating power output and at the same time remain stable by properly controlling the external circuit impedances as will now be described.

Referring first to Fig. 1, the vacuum tube 1 has in its grid circuit the secondary of the feedback coupling 2, and the grid biasing resistance 3 shunted by condenser 4, and its plate or anode circuit comprises two branches. One branch extends through the large impedance 5 and space current source 6 and the other branch extends through a number of tuned circuits 7, 8 and 9 in parallel, and the resonant circuit 10, the latter being the circuit which exercises the principal frequency control over the oscillations produced. A load circuit 11 may also be coupled to the control circuit 10.

Instability in the operation of an oscillator, which in the extreme case takes the form of blocking, consists in a variation in the amplitude of the oscillations at a comparatively low frequency rate. It has been proposed heretofore to prevent blocking action by diminishing the average negative charge on the grid, the theory being that the grid periodically accumulates such a large negative charge as to choke off or greatly diminish the space current and thus prevent the continuance of production of sustained oscillations. However, in accordance with the invention it is desired to have the grid maintain its high negative charge in order that the space current may flow in short quick impulses at the oscillation frequency and thereby operate at high plate efficiency. At the same time the actual oscillatory output may be maintained high if the maximum amplitude of these space current impulses is sufficiently high, even if the length of the impulses is extremely short. Since the lack

of stability requires that the amplitude of the oscillations vary at a fairly low frequency rate the invention provides for forcibly preventing the occurrence of variations at a low frequency rate by making the impedance of the anode-cathode circuit practically infinite at all frequencies that must necessarily be present in the occurrence of blocking or other unstable actions.

In order to do this, the path 5-6 is made of substantially infinite impedance to all frequencies that are low in comparison with the oscillation frequency. The choke coil 5 is given an inductance of a different order of magnitude from that which has been common in the prior art. In a particular instance used by applicant the choke coil 5 had an inductance of the order of 200 henries with a very low ohmic resistance.

The output branch for the high frequency components in the ideal case would also be made to have infinite impedance at frequencies low compared to the fundamental frequency and particularly at any frequency at which the circuit would tend to exhibit blocking, and would be made to have a zero impedance at all of the harmonics of the fundamental. To realize these conditions in an ideal case would require an infinite number of tuned circuits 7, 8 and 9, etc., tuned in succession to the fundamental and each one of the harmonics. This would make the alternating current branch as a whole have substantially zero impedance at all of the harmonic frequencies. The circuit 10 or this circuit together with the circuit branch 7 should be adjusted to make the impedance at the fundamental frequency equal to that of the load circuit 11, in order to obtain maximum transfer of oscillatory power into the load circuit. With these impedance conditions the circuit is enabled to develop all of the harmonics that are necessary in order that the space current may flow in extremely short sharp impulses at the fundamental frequency.

In the practical case, of course, the effect of the infinite number of tuned circuits 7, 8 and 9 etc., which would be present in the ideal circuit can be approached by designing a single network to take the place of the large number of tuned circuits. If f represents the fundamental frequency the harmonics higher than $3f$ are of relatively small importance so that the ideal is closely approached by the use of three tuned circuits resonant at frequencies f , $2f$ and $3f$. A simpler combination of tuned elements than these three tuned circuits may, however, be used to approach the ideal and the limiting case would, of course, be a single condenser designed as a compromise to give the lowest impedance to the fundamental and its harmonics.

The grid bias resistance 3 and condenser 4 should be made sufficiently large to insure

that the tube in operating sweeps off from the static characteristic, that is, for the greater part of the time the grid is so far negative that there is no space current. As the grid potential varies farther and farther in the positive direction there will be an instant of time in each period when the tube conducts space current and a still smaller instant of time when grid current can flow. By the use of sufficiently large values for elements 3 and 4 the grid can be maintained at the requisite negative bias.

In Fig. 2 a pair of similar space discharge devices 20 and 21 are connected in balanced or push-pull relation and are provided with circuit elements 2 to 10 inclusive as in the case of Fig. 1 to make the tubes oscillate in parallel.

The grids of the tubes 20 and 21 are differentially connected to the incoming line LL and the plates are differentially connected to the outgoing line HL. Assuming that the incoming line transmits speech or other low frequencies, a low-pass filter LF is inserted in the line LL ahead of the input transformer 22. A band filter BF preferably designed to transmit a single sideband resulting from the modulating action of the circuit is inserted in the line HL following the output transformer 23.

As was explained heretofore the circuit may be used either as a modulator or a demodulator and it could just as well be assumed that the waves impressed through the input transformer 22 from the line LL represent an incoming sideband to be demodulated and that the waves impressed upon the line HL are demodulated signal waves such as speech. In the latter case the filters LF and BF would, of course, be suitably designed to pass the necessary frequency components.

It was pointed out in connection with Fig. 1 that the impedance of the anode-cathode circuit at the fundamental frequency should be made equal to the impedance of the load while at frequencies low with respect to the fundamental the impedance should be practically infinite and at harmonic frequencies the impedance should be zero. These same impedance relations hold for the modulator circuit of Fig. 2 except that in the case of the modulator it is desired that the oscillatory energy developed in the circuit be dissipated in the tubes 20 and 21 rather than in a load circuit such as 11 of Fig. 1 since this circuit is a modulator and the purpose is to produce as large a distortion as possible in the fundamental or carrier oscillators. The anode-to-cathode impedance at the carrier frequency will therefore depend upon the type of modulation that is used as will be explained hereinafter.

It was pointed out in U. S. Patent 1,448,702 to Carson dated March 13, 1923 that where modulation is effected by virtue

of the non-linear relation between the space current and the grid potential of a tube the efficiency of the circuit for modulation is a maximum when the anode-cathode impedance is made zero at the carrier frequency and at the frequency of the impressed modulating waves. It has been found that if this impedance is made zero, also at all frequencies higher than the carrier, and also including the unwanted side-band in case only one side-band is to be transmitted, the efficiency of the circuit as a modulator is increased to a pronounced degree. This type of modulator is conveniently termed in the art "a plate current modulator" since the distortion which produces modulation is produced by the control of the grid on the space current of the tube. A second type of modulation that is well known in the art is termed "grid current" modulation which means that current is permitted to flow in the grid circuits and modulation is effected by distorting this grid current. The grid potential varies corresponding to the modulated grid current and, preferably without further distortion, corresponding variations are set up in the plate current. It has been shown that the efficiency of a circuit in producing grid current modulation is a maximum when the impedance of the outgoing circuit is made equal to the total anode-to-cathode impedance at the frequency of the wanted side-band components, that is, the components which it is desired to produce and utilize, and is infinite at all other frequencies. In the case of both types of modulator, however, in order to obtain maximum transfer of desired components from the incoming circuit to the modulator and from the modulator to the outgoing circuit, it is desirable in practice to match the impedances for those components which are to be transferred. This means that in the case of a plate current modulator considering Fig. 2, in addition to the impedance requirements above stated, the impedance looking to the left of the tubes 20 and 21 should be made equal to the impedance of the incoming circuit for the impressed waves including both voice and carrier, and preferably zero for all other components. The impedance looking to the right of tubes 20 and 21 should be made equal to the outgoing circuit for the wanted sideband components. In the case of a grid current modulator, also considering Fig. 2, the impedance looking to the left of the tubes 20 and 21 should match the incoming circuit for the impressed waves including both voice and carrier, and should be zero for all other frequencies. Preferably, this impedance looking to the left should also be substantially infinite for the wanted sideband. The impedance looking to the right of the tubes 20 and 21 should match the outgoing circuit for the sideband.

for a large part of the cycle) if the two circuit branches 8 and 9 are omitted (as by opening switch 12) it has been observed that the internal anode-to-cathode impedance of the tube or tubes rises to a high value. The maximum amplitude of the oscillations of fundamental frequency also falls off but this can be compensated for by increasing the ratio of the feedback coupling 2. The tube thus takes up a new condition of oscillation with a different average tube impedance. This phenomenon is useful in certain situations such, for example, as measuring circuits where a given type of tube may be controlled to have different internal impedances with the same amplitude of oscillations.

Where two modulating devices are used as shown in Fig. 2, there are two incoming circuits, one through the transformer 22 for the speech or other modulating waves and the other through the transformer 2 for the carrier waves. Where reference is made in the claims to an incoming circuit it will be understood that this may relate to a common or to separate circuits, in fact to any circuit by which waves are impressed on the modulating system, including other types of connection than those shown, several of which are familiar in the modulator art.

The impedance relations disclosed are not limited to the modulator circuits disclosed but are general and the scope of the invention is to be limited only by the claims. Other modulating elements or devices than space discharge devices may be used in accordance with the broader aspects of the invention such, for example, as magnetic systems or asymmetrically conducting devices or rectifiers.

What is claimed is:—

1. The method of operating an oscillator of the type using a space discharge device having a grid or control element whose potential is varied at the oscillation frequency about a value so far negative with respect to the cathode that the anode current is interrupted for a large portion of each period of the oscillations, which method comprises making the total external impedance as measured between the anode and cathode very low and approaching zero for multiple frequencies of the oscillations produced, and very high and approaching infinity for all frequencies substantially lower than the oscillation frequency.

2. An oscillation producing circuit comprising a space discharge device having a cathode, a grid and an anode, grid and anode circuits, a tuned circuit relating the grid and anode circuits, means in the grid circuit for biasing the grid so far negative with respect to the cathode that the space current is zero for a large portion of each period of the oscillations, a path of practically infinite impedance to low frequencies

for supplying direct current to the anode, and impedance means interposed between the tuned circuit and one of the output terminals of the discharge device, said last means being substantially equivalent in impedance to as many tuned circuits in parallel as there are harmonics of the fundamental oscillations present, each tuned to a respective harmonic, whereby the total anode to cathode external impedance is of the order of infinity for all frequencies low in comparison with the fundamental and practically zero at the harmonic frequencies.

3. An oscillating modulating system comprising a pair of three-element discharge devices connected in balanced relation, a common anode-cathode circuit branch for said devices, differential circuit connections for applying input waves to the system and deriving modulation components from the system, a tuned feed-back circuit branch coupling the anode circuits in parallel to the grid circuits in parallel for enabling the system to produce oscillations of carrier frequency, and impedance means in said circuit branches for making the total external cathode-anode impedance of the system practically infinite at frequencies low in comparison with the carrier frequency, and practically zero at frequencies harmonic to the carrier.

4. A system in accordance with claim 3, in which the cathode-anode impedance at the carrier frequency and at the frequencies of the input modulating components is substantially zero, whereby said circuit acts efficiently as a self-oscillating plate current modulator.

5. A system according to claim 3, in which the cathode-anode impedance at the carrier frequency and at the frequencies of the input modulating components is very high and approaching infinity whereby said circuit acts efficiently as a self-oscillating grid current modulator.

6. A wave modifying system having an input and an output circuit, incoming and outgoing circuits, and means to apply to said system waves to be modulated and modulating waves, the impedance of the output circuit of said system being matched to that of the outgoing circuit for the modulated wave components to be transmitted, and approaching zero at the frequencies of the applied waves, and the impedance of the input circuit being matched to that of the incoming circuits for the applied waves, and being of the order of zero or negligibly small at all other frequencies.

7. A wave modifying system having an input and an output circuit, incoming and outgoing circuits, and means to apply to said system waves to be modulated and modulating waves, the impedance of the output circuit of said system being matched to that of

the outgoing circuit for the modulated wave components to be transmitted, and approaching infinite value at the frequencies of the applied waves, and the impedance of the input circuit being matched to that of the incoming circuits for the impressed waves and approaching infinity at all other frequencies.

8. A system according to claim 6 in which an output-to-input coupling is provided for making the system self-oscillatory at a fundamental frequency, the total anode-cathode impedance being substantially zero at the fundamental frequency, and its principal harmonics, and practically infinite at all frequencies low with respect to the fundamental, other than the sideband.

9. A system according to claim 7 in which an output-to-input coupling is provided for making the system self-oscillatory at a fundamental frequency, the total anode-cathode impedance being practically infinite at the fundamental frequency and at all other frequencies except the sideband.

10. In an oscillator employing a three-element discharge device in which the space current is zero for a large portion of each period of the oscillations, the method of controlling the internal tube impedance independent of conditions in the grid circuit comprising varying the total external anode-cathode impedance within a region approaching practically infinite value at all frequencies except the oscillation frequency and correspondingly varying the amplitude of the wave fed back to the grid.

11. The method of controlling the internal anode-cathode impedance of a space discharge device comprising applying to the grid a negative bias potential and waves such that the space current flows in only fractional parts of the fundamental oscillation cycles, and controlling the total external cathode-anode impedance at substantially all frequencies present except the fundamental, while at the same time controlling the amplitude of the said applied wave to maintain the amplitude of the fundamental space current impulses substantially unchanged.

12. The method of controlling the production of combination wave components of impressed waves in a wave repeater having an outgoing circuit therefor, comprising making the impedance looking into the outgoing circuit practically zero at the frequencies of all components which are produced but are not to be transmitted, practically infinite at the frequencies of all components which it is desired not to produce and matching the impedance looking into the outgoing circuit to that of the repeater for the frequency components that are to be transmitted.

In witness whereof, I hereunto subscribe my name this 1st day of September, A. D., 1927.