July 18, 1939. K. FRITZ 2,166,210

MAGNETRON DISCHARGE TUBE FOR FREQUENCY MULTIPLICATION

Filed Nov. 16, 1937

Fig. 1

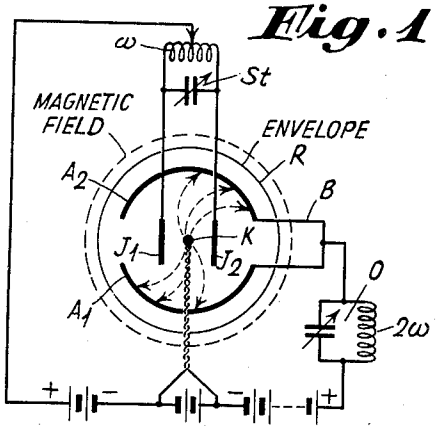


Fig. 2

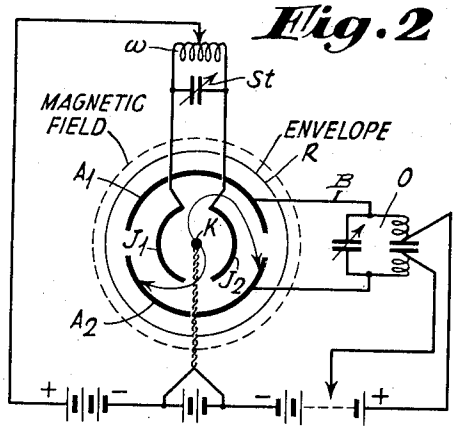


Fig. 3

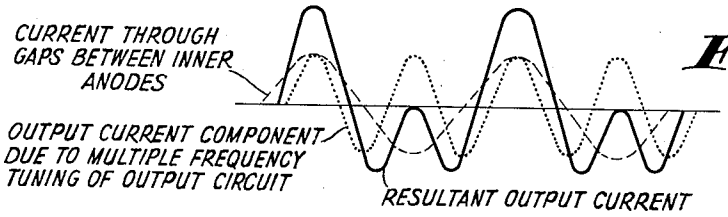


Fig. 4

SAME AS FIG. 3 BUT INPUT AND OUTPUT CIRCUITS TUNED TO SAME FREQUENCY

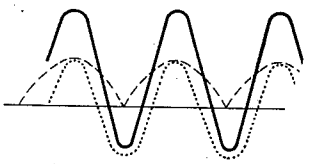


Fig. 6

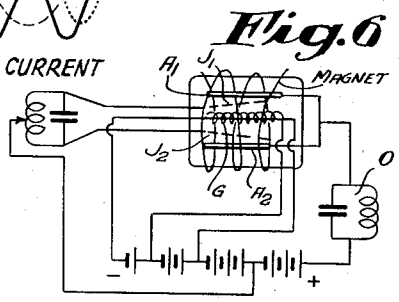
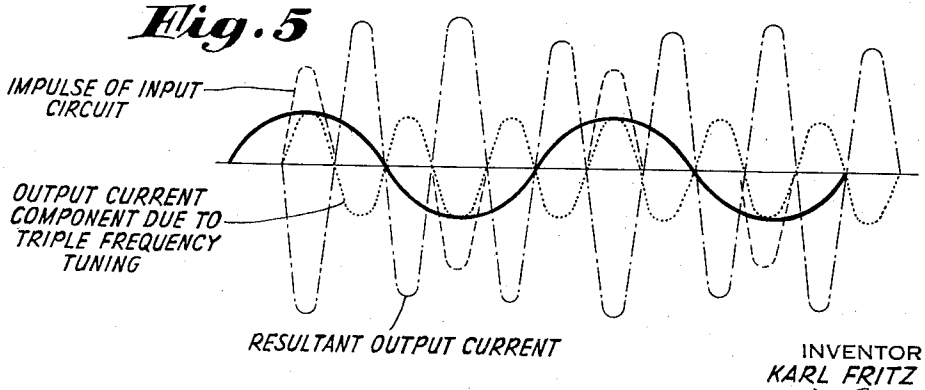


Fig. 5



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MAGNETRON DISCHARGE TUBE FOR FREQUENCY MULTIPLICATION

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In Germany October 30, 1936

6 Claims. (Cl. 250—36)

This invention relates to magnetron discharge tubes and circuit arrangements therefor. More particularly, it concerns a frequency multiplier including a magnetron discharge tube in which pairs of alternating current-carrying anodes are disposed at different distances from the cathode.

It has been suggested in the prior art that segmented anode magnetrons may be employed for frequency multiplication. It was usual in such cases to have two control segments and two power segments. I shall presently give a brief description of the prior art system in order to better explain my improvements thereover.

The accompanying drawing includes five figures, of which

Figure 1 is a diagram of a magnetron discharge tube designed substantially in accordance with conventional practice,

Fig. 2 is a corresponding diagram intended to show the improvements of this invention, and

Figs. 3, 4 and 5 are representations of wave formations obtainable under different conditions of operation of a magnetron discharge tube.

Referring first to Fig. 1, I show therein a magnetron discharge tube R having a cathode K, a pair of inner anodes J_1 and J_2, and a pair of outer anodes A_1 and A_2. The anodes of each pair are symmetrically disposed about the cathode. The outer electrodes A_1 and A_2 are electrically interconnected directly through a loop B. Between the two inner or control electrodes J_1 and J_2 is the control circuit St which normally is fed with an alternating potential having a frequency ω from an outside source of control or master potential.

The outer or energy electrodes A_1 and A_2, with the interposition of an oscillatory circuit tuned to control frequency, would operate in push-pull. Upon each alternation or half-cycle of the control oscillation a rush or pulse of current arises in the joint plate or anode lead of the two electrodes A_1 and A_2. These current pulses, inasmuch as they are of a frequency twice that of the control oscillations, may excite an oscillation circuit O inserted between the loop B and the cathode K, and the said oscillatory circuit must then be tuned to a wave twice the control frequency.

The arrangement just described has the shortcoming that the control of the oscillations generated is not symmetric because the output circuit is uni-laterally grounded through the comparatively high capacitances of the source of potential. Moreover, difficulties arise on account of the relatively long connecting leads.

My improved magnetron circuit organization is adapted for frequency multiplication by the aid of a specially designed magnetron in which the alternating current carrying electrodes are mounted at different distances from the cathode and comprise an even number of segments. It also has this outstanding characteristic feature that the control electrodes adjacent the cathode are fed through an oscillation circuit tuned to the fundamental frequency of the control potential, and that an output circuit is connected between the power segments which are located outwardly from the control segments. The oscillations after they have been multiplied in frequency are also preferably amplified. Moreover, the degree of saturation of the magnetic field and/or the biasing direct current voltages of the various segments are so chosen as to advantageously determine the shape of the generated wave. The current wave shape in the output circuit may also differ from that of the control current.

If the frequency multiplication is to be at an odd ratio, say, at the ratio of 1:3, then the various segments of the electrode systems are impressed with like biasing potentials. The magnetic field is then made so powerful that electrons will emerge from the control system only during the negative and the positive crest values of the control potential, while the length of flow of current to the power electrodes is less than ½ or more particularly equal to or less than ⅙ of the time T of a control oscillation. The current curves in this scheme need by no means be of rectangular shape, though they should substantially differ, say, from the sine shape of the control potential.

If frequency multiplication is to be at an even ratio, more particularly frequency doubling, then the intensity of the magnetic field is made roughly normal, while the various segments of one or of both systems, or more particularly only the segments of the power system, are impressed with positive biasing voltage of different values as compared with the cathode. The difference between these biasing voltages and also the absolute value of the biasing voltages must be so chosen that the electrons, during both alternations of the control oscillations, will flow over predominantly to the same segment, or to one and the same group of segments. Of course, this means that no uninterrupted direct current must arise, but that the size of the current which flows over to the impacted segment varies between a minimum and a finite maximum value.

The actions inside the tube and above all the

current intake or current passages to the various segments of the power system are shown in more detail in Figs. 3 to 5 inclusive. It should be noted that the output circuit, similarly as in simple amplifier arrangements, is interposed between the segments or segment groups of the power systems, and that radio frequency current is kept away from the cathode.

Fig. 2 shows a practical embodiment of the idea underlying the invention as incorporated in a twin-system master-control tube. The following description is not intended, however, to restrict the invention to this form of construction. The constant electric and magnetic fields are so chosen that electrons will fly through the slits or gaps between the electrodes J_1 and J_2 of the inner system, provided, however, that an electric cross field prevails between these inner electrodes, the latter being intended to exercise a control action. In such a case, as will be remembered, alternate control of the current is possible. These current flows, which for the time being may be assumed to be of sinuous form, will contribute to a reduction of damping in the outer power system only when they pass at the proper phase through the oscillatory cross-field which is set up between the outer segments A_1 and A_2. But, if the output circuit is tuned to a different frequency, then the flow of current through the gap or split-plane of the inner system (which plays the most essential part) is determined by the superposition of the two alternating potentials which arise in the inner and the outer systems.

As shown both in Fig. 1 and Fig. 2 the leads to the outer electrodes A_1 and A_2 are constituted by a twin conductor system B having distributed inductance and capacitance. Another twin conductor system having distributed inductance and capacitance forms part of the input circuit connected to the inner anode segments J_1 and J_2. The last mentioned twin conductor system is preferably arranged at right angles to the first mentioned twin conductor system.

Referring to Fig. 3, the dash line illustrates the flow of current through the split-plane of the control system *St*, if only the control alternating voltage is present. The output circuit O, for instance, for the object of doubling, is tuned to a frequency twice as high, and incidentally, as is usual, the system starts oscillating spontaneously. Under the influence of the alternating potentials of the outer system alone the wave shape of current flow should be represented in accordance with the known current distribution principle applying to multi-split anode magnetrons. Such a wave shape is as indicated by the dotted line. Upon the superposition of both alternating potentials there results the solid heavy line which reflects actual flow of current to the outer system. The phase between the two control potentials is so chosen as to obtain maximum efficiency. It is found that a distinct generation of the double frequency occurs side by side with an appreciable residue of the fundamental frequency. An essential improvement of this action is secured by suppressing the fundamental, for instance, by inverting an alternation. Fig. 2 shows that by raised or reduced biasing voltage upon one of the two outer segments A the flow of current which is controlled from the fundamental wave is practically or predominantly only in one and the same direction through the split-plane of the control system. The heavy solid line in Fig. 4 again illustrates the superposition of the other two graphs. In other words, as contrasted with Fig. 3, there is an increase in amplitude of the doubled frequency, while the control frequency or fundamental frequency practically disappears. A similar situation results also for multiplications of a higher order.

In case of odd multiplications, however, with a view to insuring high efficiency it is best to employ a non-sinuous and preferably an impulse wave in the control system. Referring to Fig. 5, the dotted line represents the control alternating potential for the inner system. By raising the intensity of the magnetic field, conditions may be made so that the emergence or outflow of current will occur only in the presence of a certain amplitude of the alternating potential. Accordingly, there result current pulses as indicated by the dash line. By superposition with the control effect or control potential (dotted line) of the excited output circuit, which, for instance, has been tuned to the triple frequency, there results an actual potential at the outer system such as shown by the dot-dash line. Upon energy absorption this wave seems to be slightly damped and then excited again. A similar situation holds good for the higher multiplications.

Experiments along these lines have shown that in odd-frequency generation there is a failure to maintain fixed phase relations between the control energy and the output energy. That is to say, the phase is constantly subject to change. And this exactly agrees with mathematical findings.

It was further ascertained by practical experiments with multiplications of a high order that a critical adjustment of the magnetic field was required as well as sharp tuning to the desired short wave. Otherwise the operation of the multiplier would become uncertain. There is either a tendency for the fundamental wave to become excited in the output circuit, or else several harmonic waves of a higher order are generated.

When comparatively large currents are dealt with, especially when working with brief current pulses only, the electrons will be held back between the segments of the control system for relatively long periods of time. The result is that an unduly large space charge is built up in the vicinity of the cathode. Among the electrons thus retained a great many return again to the cathode and cause additional heating of the same. In order to remedy this shortcoming and difficulty it is preferable to mount an apertured auxiliary electrode G in close proximity to the cathode. This auxiliary electrode may be a grid in coiled form upon which is impressed cathode potential or a slightly positive potential. The Faraday cage-like structure about the cathode collects the alternating components from the cathode so that additional heating is avoided.

It has been found expedient to place the electrodes of the control system in an inclined position in reference to the cathode in such a way that the electrodes which roughly have the form of segments of a prismatic hollow body or hollow cylinder present a slope similar to the lateral surfaces of a pyramid or a cone in reference to the corresponding axis. The result is that the electric field contains a slightly axial component in addition to the radial component. The electrons during their looped trajectories or paths of flow, move additionally to a slight degree in the direction of the axis of symmetry, that is, towards the base of an imagined pyramid. By this artifice the exit of the electrons from the control system is promoted. A similar effect is obtainable also by

providing some other dissymmetry either electrical or magnetic of the field pattern.

The circuit organization could also be used directly for the production of oscillations, say, in such a way that the inner system is operated in a self-oscillatory scheme. But in most instances the control or inside system will be fed with oscillations whose frequency is stabilized, especially when the frequency multiplier tube is to furnish the heterodyne oscillations for a high-quality receiver. For a multi-stage master-excited transmitter, of course, the same basic rules will apply.

What precedes does not apply, of course, merely to the actions observed in multi-split magnetrons, but holds good whenever the current is influenced both by the fundamental controlling system as well as by the output system.

I claim:

1. A circuit organization adapted for frequency multiplication having a magnetron discharge tube containing a cathode and a plurality of segmented anodes mounted at unequal distances from the cathode, the outer anode segments being equal to the inner segments in number, means including a direct current source for impressing suitable bias potentials on said electrodes, means for impressing control potentials upon the electrode system adjacent the cathode, an oscillation circuit connected to the control electrode system and tuned to the fundamental frequency, means for projecting periodic clouds of electrons between the inner segments and toward the outer electrode assembly, means including an output circuit connected between the outer electrodes and the cathode for deriving oscillations of multiplied frequency, and means for adjusting the strength of the magnetic field and the value of the direct current biasing potentials on the various segments to suitable values for obtaining frequency multiplication at optimum efficiency.

2. A circuit organization adapted for frequency multiplication as claimed in claim 1, with the characteristic feature that the various segments of the electrode systems are impressed with biasing potentials that are alike in reference to one another, and that the magnetic field is chosen so powerful that from the control system electrons are caused to emerge only during the negative and positive crest values of the control potential, and that the duration or length of current passage or electron flow to the outer anode segments is less than ½, and preferably equal to or less than one-sixth of the duration of a control oscillation, whereby an odd harmonic of the fundamental frequency is obtained.

3. A circuit organization adapted for frequency multiplication as claimed in claim 1 with the characteristic feature that the various pairs of segments are impressed with different positive biasing potentials in reefrence to the cathode, the said biasing potentials being of such values that the electrons, during both halves of a cycle of a control oscillation flow predominantly towards the same segment, whereby an even harmonic of the fundamental frequency is obtained.

4. A circuit organization as claimed in claim 1 and comprising a twin-conductor system with distributed inductance and capacity forming part of the output circuit, and having an additional twin-conductor system constituted by a reactive impedance to the multiplied wave disposed in the input circuit and perpendicular to the twin-conductor line of the output circuit, said reactance being adapted to stabilize the frequency of the fundamental wave.

5. A circuit organization as claimed in claim 1 and having a grid electrode disposed in close proximity to the cathode, and means for maintaining said grid electrode substantially at cathode potential.

6. A high frequency generating system comprising a magnetron discharge tube having a centrally disposed linear cathode and a plurality of cylindrically segmented anodes, said anodes being constituted by two systems one within another, and the axis of at least one of said systems being at a slight angle to the axis of said cathode.

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