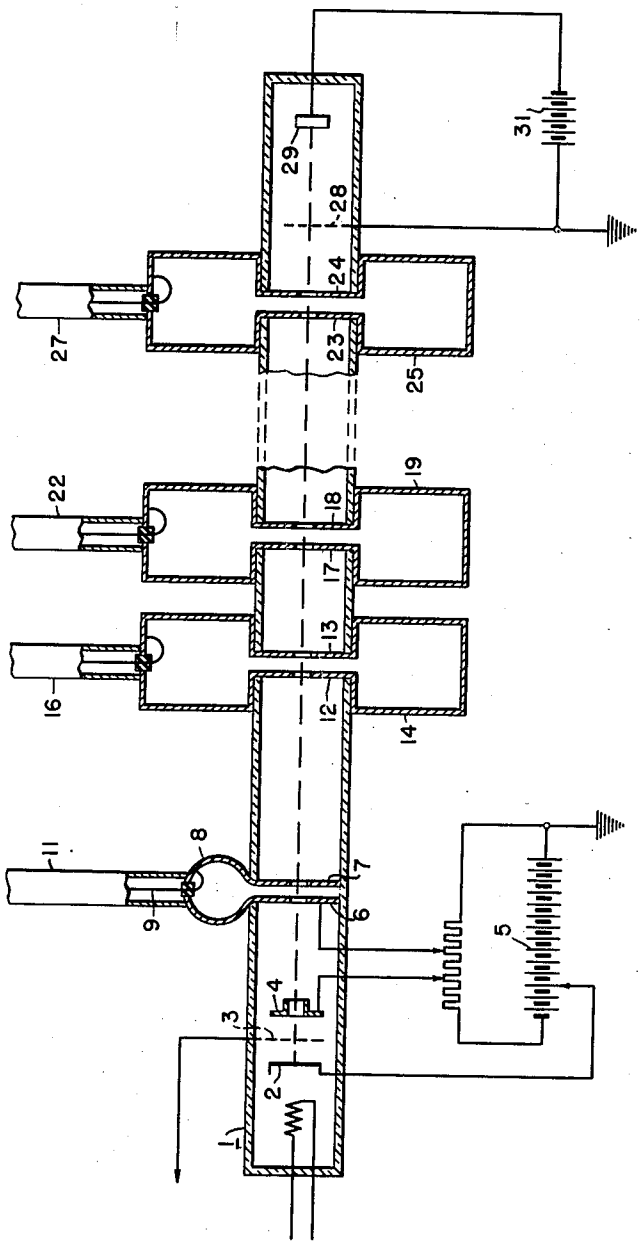
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MULTICHANNEL FREQUENCY SELECTOR AND AMPLIFIER

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WITNESSES:

Robert C. Baird

Mrs. L. Groome

INVENTOR

Max Garbuny.

BY F. W. Lyle.

ATTORNEY

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MULTICHANNEL FREQUENCY SELECTOR AND AMPLIFIER

Max Garbuny, Pittsburgh, Pa., assignor to Westinghouse Electric Corporation, East Pittsburgh, Pa., a corporation of Pennsylvania

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My invention relates to an improved arrangement for selectively amplifying high-frequency alternating voltages, and for rendering ancillary electric circuits responsive to any desired one among a number of specific frequencies derived from a control circuit.

Oscillation generators and amplifiers of a velocity-modulated type known as the Klystron are known in the art, and these function by projecting a beam of electrons through a first alternating electric field, then passing them through a substantially field-free space for some distance, and then passing them through a portion of a resonant chamber or cavity and then collecting them on a collecting electrode positioned beyond the confines of the latter. In passing through the first-mentioned alternating electric field, the electrons are subjected to a velocity modulation, retarding them when the alternating field is at one polarity and accelerating them on the subsequent half cycle when the alternating field is of the opposite polarity. The electrons, accordingly, pass into the field-free space with differing velocities which tend to separate them into a series of groups or "bunches" moving in spaced relation to each other. They, accordingly, pass into the resonant chamber in this "bunched" condition, and it can be shown that this tends to set the space within the chamber into electrical vibration. The first-mentioned cavity resonator is referred to as the "buncher" and frequently takes the form of a pair of spaced grids forming a portion of a resonant chamber which is usually tuned to the same frequency as the resonant chamber through which the bunched groups pass.

It can be shown that the electrons passing through the field-free space first tend to bunch themselves more completely as the faster moving electrons overcome the slower moving electrons; but this bunching can be shown to reach a maximum after a time which is a function of the velocity with which the electron stream is projected into the alternating-current field and of the intensity of that field. However, after the termination of the optimum bunching time just mentioned, it can be shown that the bunching tendency ceases and is even reversed. The effectiveness of the electron stream in exciting vibrations in the resonant cavity is generally greater when the bunching is most complete, and it will be evident, accordingly, that there is an optimum separation between the resonant cavity and the alternating exciting field which will generate vibrations in the resonant cavity most

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effectively. At distances either less or greater than this optimum separation, the effectiveness of the arrangement is lessened.

In accordance with the present invention, I cause the electron beam emerging from the exciting alternating field to enter, not the field-free space characteristic of the prior art, but a unidirectional electric field, as a result of which the electrons undergo continuous acceleration before they pass through the resonant cavity. I have discovered that it is possible, by properly relating the intensity of the alternating exciting field and unidirectional electric field to the velocity of the electrons in the beam entering it, to cause the electrons to form and maintain throughout their passage in the above-mentioned accelerating field a group or bunch formation in which the electrons constituting any one group move at equal velocities so that they maintain the group formation unchanged, while the distance between any one pair of groups continually increases as the groups move toward the resonant chamber or chambers. The required relationship to effect this result will be described below in connection with the detailed description of the drawing. Since the successive groups remain substantially intact throughout their subsequent travel to the collecting anode, there is no longer a single optimum distance by which a resonant cavity which the group is to efficiently excite into vibration need be spaced from the alternating exciting field, but a series of resonant chambers may, if desired, be located along the path traversed by the groups before striking the collecting electrode. A severe limitation, present in the prior art Klystron, to location of the resonant cavity at a fixed distance from the exciting field is, accordingly, obviated by my arrangement. It is, therefore, possible to position a series of resonant cavities, which may have different characteristic frequencies, at successive positions along the path of travel of the electron groups to the collecting anode.

One object of my invention is, accordingly, to provide a novel type of velocity modulated electrical discharge device in which a plurality of resonant chambers may be excited to vibration efficiently by a single velocity modulated electron beam.

Another object of my invention is to provide a novel type of velocity modulated amplifier in which a plurality of ultra-high frequency control voltages may be selectively caused to excite a plurality of separate resonant circuits of different characteristic frequencies into vibration.

Still another object of my invention is to provide an arrangement by which any one of a plurality of resonant chambers may be excited selectively into vibration by means of a single control voltage of proper frequency.

Still another object of my invention is to provide a relay device by which a plurality of different control circuits may be selectively energized by impressing a proper control frequency on a novel type of velocity modulated tube.

A still further object of my invention is to provide a novel type of velocity modulated electrical discharge tube in which an alternating control voltage is employed to excite vibrations through the agency of an electron beam in a resonant circuit.

A still further object of my invention is to provide an amplifier or relay device in which a plurality of control voltages of different frequencies may be caused to separately excite resonant circuits of their respective frequencies with high efficiency.

Other objects of my invention are to provide ultra-short wave amplifiers or relays capable of transmitting a broad range of different frequencies between their output and input circuits.

Such objectives as I describe have applications in relays and amplifiers useful in multi-telephony, television both ordinary and color, and in the ultra-high frequency electronic field generally.

Other objects of my invention will become apparent upon reading the following description, taken in connection with the drawing in which the single figure is a schematic showing of an electrical discharge tube suitable to embody the principles of my invention for certain purposes.

Referring in detail to the drawing, a vacuum-tight electrical discharge tube 1 which may have walls of insulating material is provided at one end with an electron gun capable of projecting a concentrated beam of electrons and comprising a cathode 2, a control electrode 3 and an anode 4 of conventional type for this purpose, and supplied from a suitable source of direct-current voltage 5 having its positive terminal grounded. The beam from the electron gun is projected through a pair of aligned openings in exciter electrodes 6, 7, one of which is supplied with suitable potential from the voltage source 5. The exciting electrodes 6, 7 are separated by a distance corresponding to an electrical transit angle for the crossing electrons of the desired value; this may preferably be 180°. The electrodes 6, 7 also form a portion of an input circuit preferably comprising an exciting coupling 8 which may be connected to an input circuit comprising a concentric line 9, 11.

After passing through the apertures in the exciter electrodes 6, 7, the electrons of the beam enter a unidirectional accelerating field, preferably constant and homogeneous which is adjusted and maintained by electrodes 7, 12, 13, 17, 18 and 24. Inside this field the beam first passes through a pair of aligned apertures in a first pair of work-circuit electrodes 12, 13 which constitute portions of a resonant output chamber 14 which may be connected to a load through a suitable concentric line or other output transmission circuit 16. After passing through the first work-circuit electrodes 12, 13, the electron beam passes through a similar pair of work-circuit electrodes 17, 18 which are connected to a second resonant output chamber 19 having an output transmission circuit 22. The resonant frequency of the resonant chamber 19 may be different from that of the resonator 14, if so desired.

Any desired number of output circuits similar except for their resonant frequency to the arrangement 12, 13, 14, 16 may be positioned along the path of the electron beam, the dotted portions of the walls of container 1 and the arrangement designated by the reference numerals 23 to 25 being intended to indicate such an arrangement. After passing through some or all of such a series of output chambers, the electron beam passes through an aperture in an electrode 28, which is preferably grounded, and is collected by a suitable electrode 29 on which a voltage source 31 impresses a suitable potential. It will usually be of advantage to make the voltage source 31 of such polarity that the collector electrode 29 is negative in potential relative to the electrode 28 by an amount sufficient to reduce losses and heating of the electrode 29.

It will be evident from the above arrangement that, if the exciting electrode 7 is made negative to ground, as shown in the drawing, the electrons, after passing through the aperture in this exciting electrode, will undergo continuous acceleration throughout the distance between the exciting electrode 7 and the electrode 28.

The mode of operation of the above-described arrangement I consider to be substantially as follows: Electrons from the cathode 2 pass through the aperture in the anode 4 with a velocity determined by the potential of the latter, their number being controllable by impressing suitable voltages as desired upon the control electrode 3 in a manner well known in the art. The electrons thus formed into a beam undergo further acceleration and pass through the space between the exciting electrodes 6, 7. An alternating control voltage is impressed on the latter through the member 8 and the input circuit 9, 11.

The electrons in the beam prior to passage through the aperture in electrode 6 will be, on the average, evenly spaced from each other. Let us now consider an electron passing through the field between the exciter electrodes 6, 7 at a time when the alternating voltage impressed on the electrode 7 relative to the electrode 6 is at its negative maximum. For simplicity let us assume the transit angle between 6 and 7 is very small. The case of larger transit angles does not change the principle discussed. In this latter case, the field found by the electron at the midpoint of the alternating current field is then the critical value. This electron will obviously be slowed down in passing through the field between the electrodes 6 and 7 and will emerge into the space beyond the electrode 7 with a lower velocity than it had in entering the aperture in electrode 6. On the other hand, an electron which passes through the space between electrodes 6 and 7 when the alternating voltage impressed therebetween is zero will enter the space beyond electrode 7 at the same velocity it had on passing electrode 6. Similarly, an electron which enters the space between the electrodes 6, 7 when the voltage impressed on electrode 7 relative to electrode 6 is at its positive maximum will undergo an acceleration and enter the space beyond electrode 7 at a higher velocity than that with which it entered the aperture in electrode 6.

However, a half period of the alternating voltage impressed by the input circuit 9, 11 has intervened between the time that the first-mentioned electron passed through electrode 7 and that at which the last-mentioned electron

passed through the aperture. During that time the first-mentioned electron has been undergoing further acceleration by the unidirectional electrical field which exists in the space between electrode 7 and electrode 28, and its velocity is, accordingly, higher than that at which it passed into that space. By properly relating the values of the electric field impressed between electrodes 7 and 28 to the alternating voltage on exciter electrodes 6 and 7, the increase in the velocity of the first-mentioned electron during said half period can be made such that it just cancels the decrease obtained in the alternating field. Hence, when the second electron enters the unidirectional field, it has the same speed as the first. The same consideration holds for the third electron which due to the boost in velocity will enter the space with the same speed as that reached at that instant by the first and second electron. In short, all three electrons considered here are moving with the same velocity at the time the last-mentioned electron passes the electrode 7. It may, in fact, be shown that most of the electrons entering the space during one cycle of the control voltage undergo substantially a similar experience so that they form a group all moving with nearly the same velocity at the time the last electron of the group passes the electrode 7.

Since all the electrons entering the unidirectional field undergo the same accelerating force due to the substantially constant unidirectional electric field impressed between the electrodes 7 and 28, they will all be accelerated at the same rate during their passage between said electrodes, and will subsequently maintain their spacings unchanged within their group. In short, the group traverses the space between the electrodes 7 and 28 as a unit; this group is, however, undergoing a continual acceleration to higher velocities as it moves along its path.

After the lapse of a cycle of the voltage impressed on electrodes 6, 7 by the input circuit 9, 11, the above-described action will be repeated in periodic fashion, with the result that a second bunch of electrons moving as a group with equal velocity will pass through the tube. By the time that happens, however, the first-mentioned group will have traversed a substantial distance along its path and will have been accelerated so that it is moving at a higher velocity than the second. The result of this is that the electron beam is modulated into a series of electron groups or bunches moving along the path toward the aperture in electrode 28 with constantly increasing velocities as they proceed along the path and with the spacing between any two groups continually increasing as time passes while the spacings of the electrons within one group remain essentially frozen.

After passing through the aperture in electrode 28, the electrons are, of course, collected by electrode 29 and returned to the cathode through the voltage supplies 5 and 31. The example of the three electrons traversing the electrodes 6, 7 at intervals 90° apart has only been cited for convenience of explanation. In case of sinusoidal alternating voltage, not all the electrons will attain exactly the same speed in the unidirectional field. It is therefore understood that the magnitude of the unidirectional field shall be so adjusted to that of the alternating field that optimum bunching is achieved; id est a time-current relation is produced at passage through the output chambers 14, 19, 25, etc., that power transfer to those cavities is a

maximum. I have found that for a sinusoidally alternating voltage the best bunching is achieved if electrons, not of ±90°, but of ±102.7 electrical degrees from the zero point of alternating current voltage are exactly focused with those of the zero point. This then will produce the most efficient bunching. In most cases a transit angle of 180° between electrodes 6 and 7 is most advantageous.

By reason of the fact that each electron group travels as a unit spaced at a substantially interval from other groups, it is capable of exciting such an output resonator as 14 efficiently into vibration regardless of the position along the path between electrodes 7 and 28 at which the latter is located. The limitation, mentioned above as characteristic of prior art Klystron tubes, of a single optimum position where the resonator must be located to attain efficient excitation from the electron stream is thus obviated in my arrangement. Consequently, it is possible to position any desired number of resonators at successive points along the path of the electron path between electrodes 7 and 28 and excite them successively into energetic vibration by a single velocity modulated electron beam.

The efficiency with which an electron group excites vibrations in a resonator is, of course, critically dependent upon the resonant frequency of the latter, and is greatest when the latter is equal to the frequency of the voltage impressed by the input circuit 9, 11 on the electrodes 6, 7. Thus by giving the successive resonators 14, 19, etc., different resonance frequencies and impressing only one of these from the input circuit 9, 11, any desired one of the resonators 14, 19 and their output circuits 16, 22, etc., may be efficiently energized, the other output circuits than that one being left undisturbed. My arrangement obviously makes possible a relay or amplifier in which any one of a number of output circuits may be energized selectively and at will by impressing the proper frequency on the input circuit 9, 11. This provides an arrangement which is an effective relay for enabling an input circuit to control at will any one of a number of output circuits. Such relays find application in multiplex telephony, television, and the alternating-current technology generally. It will usually be found advantageous to position the resonant chambers of highest frequency most distant from the exciter electrodes 6 and 7.

However, the use of the above-described arrangement is not confined to employment of a single modulating frequency impressed by the input circuit 9, 11. Any desired number of the frequencies to which the resonators 14, 19, etc., are tuned may be simultaneously impressed from the input circuit 9, 11 and the corresponding resonant chambers will all be excited to energetic vibration. By spacing the frequencies impressed by the input circuit 9, 11 over a band of any desired width, a similar broad band of frequencies may be excited in an output circuit which is coupled to all of the corresponding resonators 14, 19, etc. The arrangement thus provides a broad band amplifier which may be designed to transmit any predetermined band of frequencies efficiently. Such broad band amplifiers will find many applications in high frequency alternating-current techniques.

It is, in fact, possible to show that the effectiveness of the bunching action of the electrodes 6 and 7 is so little dependent on the frequency as well as on the distance by which they are separated from the resonant chambers 14, 19, etc.,

that the efficiency with which they excite vibrations in chambers resonating over the range 1500 megacycles to 4500 megacycles varies by only about 10%. In short, the outputs of resonators of a wide variety of frequencies may be efficiently controlled by impressing proper input frequencies on a single pair of exciting electrodes in structures such as I have described.

By arranging feedback circuits between the resonators 14, 19, etc., and the input circuit 9, 11 in a manner well known in the Klystron art, the arrangement I have described may be made to act as an oscillation generator capable of operating at any one of the frequencies to which the resonators 14, 19, etc., are designed, or even to generate any plurality of such frequencies simultaneously.

While I have described my arrangement as employing electrons to constitute the projected beam, it will be evident that the above-described principles are applicable to beams comprising any electrified particles. Also while I have described the resonant output chambers as positioned within the region traversed by the unidirectional accelerating field due to electrode 28, it is within my invention to position any of them in a field-free space beyond that electrode or even in a retarding field such as that in front of anode 29. It is also evident that, instead of using only one input coupling, several input couplings or resonators, preferably spaced closely to each other, may be used.

I claim as my invention:

1. An electron discharge device comprising an envelope having therein a source of charged particles and a collecting electrode forming a beam path therebetween, resonant input means along said path for subjecting said particles to an alternating electromagnetic field over a limited portion of their path, means including an electrode in said envelope adjacent said collecting electrode adapted to produce a homogeneous field for accelerating said particles after emerging from said portion of their path, and a plurality of output cavity resonators along said path intermediate said resonant input means and said field producing electrode.

2. An electron discharge device comprising an envelope having therein a source of charged particles and a collecting electrode forming a beam path therebetween, resonant input means along said path for subjecting said particles to an alternating electromagnetic field over a limited portion of their path, means including an electrode in said envelope between said collecting electrode and said resonant input means adapted to produce a homogeneous field for accelerating said particles after emerging from said portion of their path, and a plurality of output cavity resonators along said path intermediate said resonant input means and said field producing electrode.

MAX GARBUNY.

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