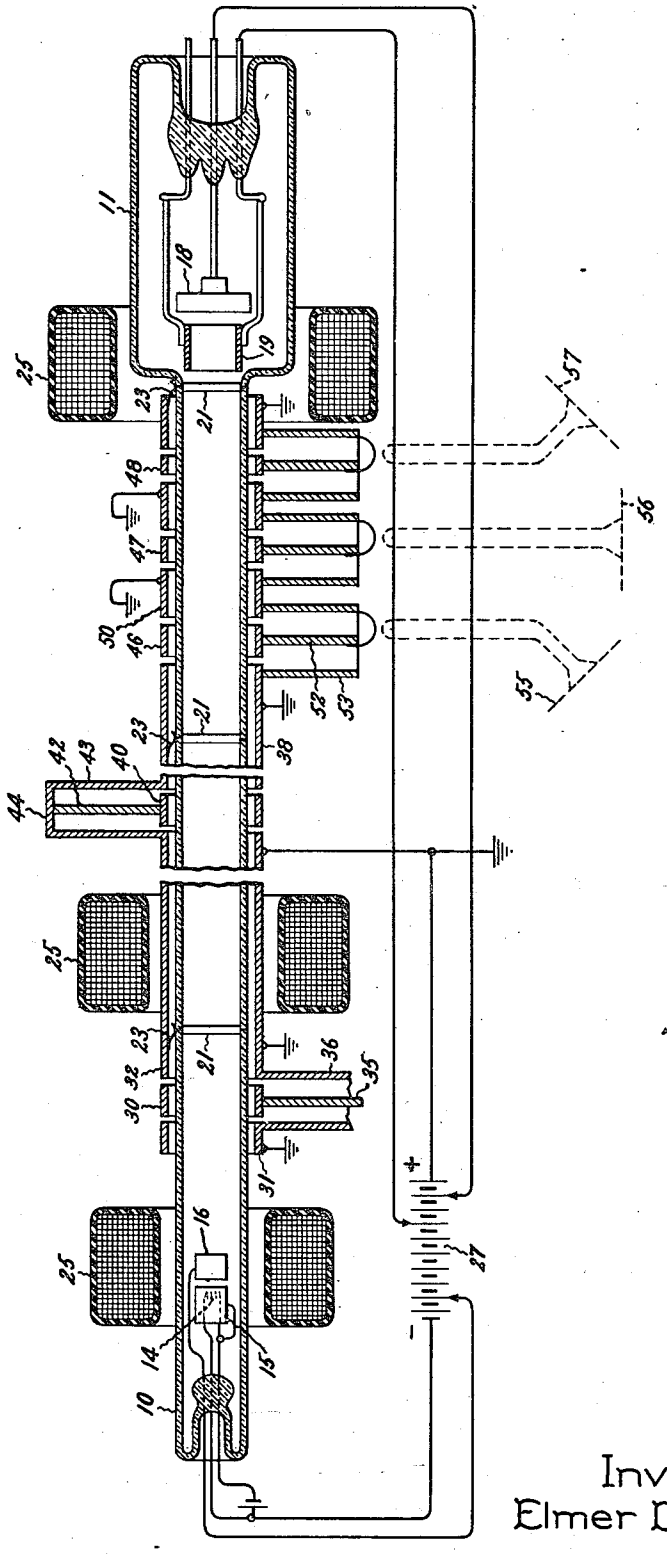
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POLYPHASE GENERATOR FOR ULTRA SHORT WAVE LENGTHS

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POLYPHASE GENERATOR FOR ULTRA SHORT WAVE LENGTHS

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3 Claims. (Cl. 250—11)

The present invention relates to means for generating polyphase currents at ultra-short wave lengths.

It is known that directional signaling effects can be accomplished by the use of an antenna array wherein the separate antenna elements are energized with voltages of the same frequency but of different time phase. The use of this system is limited, however, especially at ultra-high frequencies, by the difficulty of obtaining polyphase high frequency voltages. It is an object of my present invention to provide means whereby polyphase voltages of desired phase relationship may be easily obtained at ultra-short wave lengths, even down to 5 centimeters or less.

This is accomplished by utilizing a beam tube of the cathode-ray type in combination with means for varying the beam current at a desired frequency. Polyphase voltages are then obtained from the modulated beam by causing it successively to excite a plurality of separate electrode structures which are sequentially coupled to the beam at various points along its path.

The features which I desire to protect herein are pointed out with particularity in the appended claims. The invention itself, together with further objects and advantages thereof may best be understood by reference to the following description taken in connection with the drawing, in which the single figure represents a sectional view of a discharge device suitably embodying the invention.

Inasmuch as the invention is considered to be primarily applicable to discharge devices of the character described and claimed in W. C. Hahn application Serial No. 153,602, filed July 14, 1937, it will be helpful to refer briefly to some of the principles utilized in such devices.

An electron stream such as flows between the electrodes of a vacuum tube may be modulated either as to "electron velocity" or as to "charge density." The first type of modulation involves the production of systematic irregularities in electron velocity from point to point along the beam. The second involves the production of charge density variations, such variations being manifested as systematic irregularities in the electron grouping.

In the conventional design of electronic discharge devices no distinction is made between these two types of modulation. In connection with ultra-short wave devices, however, it is advantageous to utilize modulating electrodes which are capable of producing velocity modulation without simultaneously causing appreciable charge density variations. For reasons which need not be elaborated here this expedient avoids the large input losses which are observed with conventional prior art devices when they are operated at extremely high frequencies. By additional means, also described in the aforesaid Hahn application, velocity modulation produced as above specified may be subsequently converted into charge density modulation of a higher order of magnitude so as to produce amplification effects.

It is found that the velocity modulation principle may be most readily utilized in a discharge device of the cathode ray type, wherein the elongated stream of electrons is susceptible of being variously influenced at different points along its length. I have, therefore, chosen a device of this kind to illustrate my present invention.

Referring to the drawing, there is shown an electron beam tube which comprises an evacuated envelope having an elongated shaft portion 10 and an enlarged anode-containing portion 11. This envelope may be suitably constituted of glass, quartz, or any equivalent insulating material.

The shaft portion 10 encloses means for producing an electron beam, such as a known type of electron gun. The combination shown comprises a cathode 14, which is indicated in dotted outline, and a focusing cylinder 15 for confining the electrons from the cathode to a concentrated beam. This cylinder may be either connected directly to the cathode or maintained at a few volts negative with respect to it. In order to accelerate the electrons to a desired extent, there is provided an accelerating electrode 16 which is spaced from the cathode and which may be biased to a suitable positive potential, say several hundred volts.

In order that the intermediate portion of the beam path may be maintained at a desired potential level there are provided a number of intermediate electrodes 21 which suitably comprise rings of conducting material applied to the inner wall surface of the envelope. These are provided with external contact-making terminals 23. A number of magnetic focusing coils 25 distributed along the envelope serve to prevent dispersion of the electrons and to maintain the beam in focus during its passage through the discharge space. In some cases these coils may be advantageously replaced by electrostatc beam focusing means.

After traversing the envelope, the electron beam is collected by an anode 18 which consists of graphite or other suitable material. A tubular electrode 19 in the nature of a suppressor grid serves to prevent secondary electrons emitted by the anode from returning to the discharge space.

In the operation of the device the intermediate electrodes 21 may be maintained at ground potential, the cathode 14 at one thousand to several thousand volts below ground, and the anode 18 at one thousand to several thousand volts above the cathode. The suppressor grid 19 should be biased fifty to several hundred volts negative with respect to the anode 18. These potential relationships may be established by means of a suitable source of potential, conventionally represented as a battery 27 connected as shown.

The combination of elements so far described comprises means for producing a unidirectional electron beam of substantially constant average intensity and velocity. As pointed out in the aforesaid Hahn application, Serial No. 153,602, an electron beam of this type may be velocity modulated by applying to the beam longitudinal potential gradients which vary cyclically at a desired frequency. One suitable velocity modulating structure is shown in the drawing.

This comprises a modulating chamber or space provided between the extremities of two conducting tubular members 31 and 32 which are arranged to surround the beam path. Within this space there is provided a tubular control electrode 30 which also surrounds the beam path. The tubular members 31 and 32 are both shown as being grounded so that the boundaries of the modulating space may be regarded as definitely fixed. By alternately raising and lowering the potential of the electrode 30 with respect to these boundaries, variable potential gradients are produced which act longitudinally on the electron beam as it traverses the approach spaces between the electrode 30 and the extremities of the members 31 and 32. The modulating effect thus produced will be most pronounced if the length of the tubular electrode 30 is so correlated to the velocity of the beam that the electron transit time therethrough corresponds at least approximately to a half cycle of the control potential (or to an odd number of such half cycles). If this condition is fulfilled, an electron which enters the modulating space when the potential of the control electrode 30 is a maximum is accelerated first by the gradient existing between the tube 31 and the electrode and again as it leaves the electrode a half cycle later when the electrode potential is at a minimum with respect to the tube 32. Similarly, an electron which enters the modulating space in such time phase as to be retarded by the effect of the control electrode is also retarded as it leaves the electrode. As a result of these effects, the electron beam leaving the modulating chamber is made up of alternate elements, some of which have a velocity above the average of the beam and others a velocity below such average.

Modulating potential may be supplied to the control electrode 30 from any desired source such, for example, as a high frequency oscillation generator (not shown). As a means for connecting this potential to the control electrode structure there is provided a concentric conductor transmission line comprising an inner conductor 35 and an outer conductor 36 which concentrically surrounds the conductor.

If only weak control potentials are available, the velocity modulation produced may be relatively slight. However, it may be converted into charge density modulation of a higher order of magnitude by a mechanism now to be described.

It will be understood that as the beam issues from the modulating space it comprises alternate groups of slow and fast electrons. At the exit boundary of the modulating chamber the beam is still substantially uniform so far as charge density or electron grouping is concerned. At a slightly later time, however, the more rapidly moving electrons will have caught up with the slower electrons, and electron bunches will exist from point to point along the beam. The resultant succession of charge density maxima and minima corresponds to charge density modulation as hereinbefore defined.

The conversion of velocity modulation as produced by the electrode 30 into charge density modulation is a matter which in its very nature requires only the elapse of time and the absence of extraneous influences which might tend adversely to affect conditions within the beam. These requirements may be fulfilled by the provision of an electrostatically shielded drift space in which sorting of the electrons can take place. This drift space may comprise, for example, the section of the discharge envelope which is enclosed within the conducting tube 32.

If this tube, which is shown partly broken away in order to economize space on the drawing, is made sufficiently long, a relatively slight degree of velocity modulation may be converted into a much higher order of charge density modulation so that an amplification effect is obtained. However, if the initial control voltage or signal is very small, a single stage of such amplification may still yield an insufficient output. It is, therefore, advantageous to provide additional means by which multistage amplification can be accomplished. In the embodiment shown, this means comprises a second or "modulation intensifying" chamber formed between the opposed extremities of the tube 32 and of another conducting tube 38. Within this chamber there is provided a tubular electrode 40 generally similar to the electrode 30 which has already been described.

It will be readily understood that the current variations in the charge density modulated beam traversing the approach spaces which exist between the extremities of the electrode 40 and of the tubes 32 and 38 will induce in the electrode a cyclically varying current of frequency corresponding to the modulation frequency. The magnitude of this induced current will be greatest if the length of the electrode 40 corresponds approximately to the spacing between adjacent charge density maxima and minima in the beam so that the approach of a charge density maximum corresponds with the recession of a charge density minimum and vice versa.

In order that the induced current may be caused to produce the effects desired in the present connection, the electrode 40 and the tubes 32 and 38 (which are both at ground potential) should be connected through a high impedance circuit. In the arrangement illustrated, such a circuit is provided by a resonant transmission line of the parallel conductor type. This may comprise, for example, an inner conductor 42, connnected with the electrode 40, and an outer tubular conductor 43 which concentrically surrounds the inner conductor. The inner and outer conductors are directly connected to one an-

other at one end, as indicated at 44, so that the point of connection is approximately a quarter wave length from the open-circuited end of the transmission line; that is, the end to which the electrode 40 is connected.

With an arrangement such as that indicated, the current induced in the electrode 40 will produce sustained oscillation of the transmission line and will cause a voltage maximum or antinode to exist at the open-circuited end; i. e., between the electrode 40 and the adjacent extremities of the tubes 32 and 38. This voltage will be of cyclically varying character and will have a frequency determined by the rate of approach and recession of charge density maxima in the beam; that is to say, by the frequency of the initial velocity modulating potential.

By analogy with the operation of the electrode 30 it will be seen that the potential gradients produced by the electrode 40 will necessarily act to cause additional velocity modulation of the electron beam. Furthermore, since the voltage swing of the electrode 40 may be very much greater than that of the input electrode 30, the magnitude of the new velocity modulation is correspondingly larger than that of the initial modulation. Consequently, the future action of the beam may be controlled almost entirely by the modulation produced by the electrode 40.

This modulation, at its inception, involves only velocity variations in the beam. However, by providing within the tube 38 a further drift space, the velocity modulation may be converted into charge density modulation in accordance with the principles already described. The tube 38 may be of any length required to accomplish the conversion effectively.

My present invention consists in the provision of means for abstracting energy from the charge density modulated beam in such a way as to provide a plurality of separate voltages or currents having a desired phase relationship. To this end there is provided along the beam path a series of successively arranged output electrodes numbered 46, 47, and 48 respectively. These are in the form of conducting tubes which closely surround the beam so as to be effectively coupled thereto. The manner of their functioning may be understood by a consideration of the electrode 46.

As in the case of the electrodes 30 and 40 previously described, the electrode 46 is positioned in a chamber provided between the extremities of two conducting tubes, namely, the conducting tube 38 and a tube 50 somewhat spaced therefrom. As explained in connection with the electrode 40, the action of the modulated beam in traversing the electrode 46 is to induce in that electrode currents which correspond in frequency to the modulation frequency of the beam. In order that this effect may be a maximum, it is desired that the axial length of the electrode shall be approximately equal to the spacing between adjacent charge density maxima and minima in the beam. If it be assumed that the velocity of the beam traversing the electrode 46 is the same as that of the portion of the beam traversing the electrode 40, then the dimensions of the electrodes 40 and 46 should be equal.

In order that the current variations induced in the electrode 46 shall be effectively utilized, the electrode must be connected to the adjacent tubular conductors 38 and 50 through a high impedance circuit. This may be a resonant concentric transmission line provided by a pair of concentric conductors 52 and 53. Assuming that these conductors are approximately a quarter wave length long, they will comprise an oscillating circuit having a voltage maximum at the end nearest the electrode 46 and a current maximum at the opposite end. The power extracted from the beam by the electrode 46 may be utilized by inductively coupling the remote end of the transmission line 52, 53 to an appropriate utilization device, illustrated diagrammatically in the present case as a half wave antenna 55.

The functioning of the electrode 47 will be similar to that of the electrode 46 except for the fact that the currents induced in it by the beam will necessarily be displaced in phase from those induced in the electrode 46. This is due to the fact that a given charge maximum traveling along the beam path approaches the electrode 47 at a somewhat later time than it approaches the electrode 46. Consequently, its effect on the former electrode will lag behind its effect on the electrode 46. In other words, the two currents developed in the electrodes 46 and 47, considered conjointly, may be said to be of polyphase character. The exact nature of their phase relationship is determined by the physical spacing of the electrodes themselves. Thus, if it is desired to have a phase displacement of 120 electrical degrees between the current induced in the electrode 46 and that induced in the electrode 47, the distance between them should be such that a charge density maximum approaches the electrode 47 a third of a cycle later than its approach to the electrode 46.

It will be noted that the axial dimension of the electrode 47 is somewhat less than that of the electrode 46. This is due to the fact that the reaction of the electrode 46 in abstracting energy from the passing beam is to reduce its average velocity. Consequently, the velocity of the beam portion which traverses the electrode 47 is somewhat reduced, and the spacing between adjacent charge density maxima and minima is less when the beam traverses the electrode 46. This fact is taken into consideration by shortening the electrode 47 as shown.

A third current having a still different phase may be obtained by the use of the electrode 48. This electrode may be assumed to be positioned 120 electrical degrees beyond the electrode 47. It will be noted also that it is shortened in length even beyond the electrode 47 in order to take into account the additional velocity diminution caused by that electrode.

The currents developed by the electrodes 47 and 48 are employed to energize additional antenna elements 56 and 57 which bear an appropriate positional relationship to the antenna 55. The antenna arrangement thus formed, when energized by polyphase high frequency currents obtained as described in the foregoing, will project a signal pattern having a definite directional character. If it is desired to change the directional effects produced, this may be done by changing the phase relation of the various exciting currents as by changing the spacing of the electrodes 46, 47, and 48.

It will be understood that my invention is applicable to other uses than the excitation of a polyphase antenna system. Indeed, it may be applied in any connection where polyphase currents of extremely high frequencies are desired. I aim in the appended claims to cover all such variations of structure and use as fall within the true spirit and scope of the foregoing disclosure.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. In combination, a discharge device of the cathode-ray type for producing an electron beam, means for modulating the beam at high frequency so as to produce periodic variations in the beam current, a plurality of output electrodes successively coupled to the modulated beam so as to be sequentially affected thereby, and a plurality of circuit means respectively connecting with the various electrodes, the said electrodes being so dimensionally and spatially related that as a result of the electron transit time between them the currents generated in the various circuit means by the action of the beam on the electrodes have desired phase displacements which differ materially from one hundred eighty degrees.

2. In combination, a utilization system which includes a number of operating circuit components and which functions in its intended manner only when the said circuit components are excited by currents having a particular phase displacement different from one hundred eighty degrees, means for producing a beam of electrons, means for modulating the beam at high frequency so as to produce periodic variations in the beam current, a plurality of output electrodes successively coupled to the modulated beam so as to be sequentially affected thereby, the said electrodes being so dimensionally and spatially related that as a result of the electron transit time between them the currents generated in the various electrodes have a phase displacement corresponding to the said particular phase displacement, and means for separately coupling the various electrodes to the various circuit components of the said utilization system.

3. In combination, a directional antenna array which has a number of separate components and which functions in its intended manner only when the said components are excited by currents having a particular phase displacement different from one hundred eighty degrees, means for producing a beam of electrons, means for modulating the beam at high frequency so as to produce periodic variations in the beam current, a plurality of output electrodes successively coupled to the modulated beam so as to be sequentially affected thereby, the said electrodes being so dimensionally and spatially related that as a result of the electron transit time between them the currents generated in the various electrodes by the action of the electron beam have a phase displacement corresponding to the said particular phase displacement, and means for separately coupling the said electrodes to the various components of the antenna array for exciting the same.

ELMER D. McARTHUR.

CERTIFICATE OF CORRECTION.

Patent No. 2,235,527. March 18, 1941.

ELMER D. McARTHUR.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 1, second column, line 55, for "electrostatc" read --electrostatic--; page 3, second column, line 42, before "when" insert --than--; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 29th day of April, A. D. 1941.

(Seal)

Henry Van Arsdale,
Acting Commissioner of Patents.

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