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CATHODE-RAY DEVICE FOR IMPROVING
SIGNAL-TO-NOISE RATIO IN RADAR
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This invention relates to cathode ray means for utilizing signals and, in an important specific aspect, to means for distinguishing between signals and noise in radio object-locator systems and in other systems using similar signals.

Considerable interest has been shown by various investigators in the problem of increasing the signal-to-noise ratio in radio object-locator systems (frequently called "Radar" systems). In such systems, ultra-short carrier waves modulated with spaced pulses are directly emitted, reflections thereof are received at the transmitting point from objects upon which the emitted pulses impinge, and the reflection times for particular reflections or echoes are determined to provide indications of the distances to the objects from which the respective reflected signals are received. It has been suggested to store a complete train of impulses, that is, impulses (including spurious ones due to noise) received at the receiving station of the locator system during a complete interval between adjacent transmitted pulses, by delay networks and combine the delayed train of impulses with an undelayed train of impulses in such a manner that the echo pulses add up in phase, the noise impulses, due to their nature, adding up in random phase. It is well known that noise peaks do not occur in the same place in each train and it is because of this characteristic that the contrast between true echo impulses and noise impulses is increased by the storage method. The delay network arrangement, however, becomes very cumbersome and costly if it is desired to store many complete trains of impulses and superimpose them.

It is an object of the present invention to provide means for storing trains of impulses in an object-locator system which does not have the above-mentioned disadvantages.

It is another object to provide cathode ray means for storing trains of impulses and for reproducing trains of impulses in which the true signal pulses or variations are accentuated with respect to the noise pulses or peaks.

It is still another object of this invention to provide novel cathode ray signal utilization means.

In accordance with a specific embodiment of the invention, shown by way of example for illustrative purposes, an electrostatic storage type of cathode ray tube is provided which can be incorporated in already existing radio object-locator systems with very little change therein. A suitable form of tube is shown in United States Patent 2,245,364, issued June 10, 1941 to R. R.

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Riesz and H. S. Wertz but the circuits therefor are considerably modified. The tube comprises an envelope having two chambers, there being an electron gun in each chamber. The two chambers are separated by a partition member containing a multiplicity of metal elements mounted in an insulating disc. A metal ring is mounted outside the insulating disc. The exposed surface of each metal element in one chamber is preferably treated with a suitable substance to discourage secondary emission while the other exposed surface is left untreated or treated so as to encourage secondary emission. The electron beam in the one chamber, because of this treatment of the target, produces a very low ratio of secondary electrons emitted to primary electrons in the beam while the beam in the other chamber produces a very high ratio. By means of two voltage sine waves in quadrature phase applied respectively to the two pairs of deflecting plates in the first chamber, the beam in that chamber is caused to move in a circle over each of the conducting elements in turn, leaving each of them negatively charged, the beam being modulated by a control element surrounding the cathode. Each of the sine waves has a frequency corresponding to the period between corresponding portions of successive trains of impulses. Similar sweep waves are applied to the two sets of deflecting plates in the second chamber, but the frequency of these waves is only a small fraction, as, for example, one twentieth, of the frequency of the waves applied to the deflecting plates in the first chamber. Each passage of the beam in the first chamber over the conducting elements increases the negative charge on each element and this continues until the charges are removed. The stored charges are removed by the beam in the second chamber due to the fact that an excess of secondary electrons is emitted in that chamber. These electrons are collected by a collector ring which is positively biased with respect to the ring mounted outside the insulating disc. Inasmuch as the beam in the first chamber produces only a small charge on a conducting element for each passage thereover compared with the total charge removed by the beam in the second chamber, it is possible for both beams to contact an element at the same time. Thus neither beam has to be blanked out. The reproduced signal train (in which the echo pulses add up in phase and the noise peaks in random phase, thus greatly increasing the signal-to-noise ratio) is applied to one set of deflecting plates in the oscilloscope of the radio object-locator system while a sweep

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wave is applied to the other set of plates. The frequency of this sweep wave is much lower than that of the sweep wave which would normally be used with the oscilloscope (the repetition frequency of the trains of impulses); in the example given it is one-twentieth of this normal sweep frequency. Thus if the trains of impulses are repeated 480 times per second the frequency of the sweep wave for deflecting the beam in the second chamber of the storage tube and of the sweep wave in the oscilloscope is 24 sweeps per second. The trace on the oscilloscope when used with a storage tube is characterized by a much greater contrast between the marks indicating echo pulses and those indicating noise peaks than in the case when the oscilloscope is used without such a tube.

The invention will be more readily understood by referring to the following description taken in connection with the accompanying drawing forming a part thereof in which:

Fig. 1 is a simplified schematic diagram of the receiving station of a radio object-locator system employing, in accordance with the invention, an electronic storage tube;

Fig. 2 is a schematic representation of an electronic storage tube and certain of its associated circuits;

Fig. 3 is an end view of the target in the tube shown in Fig. 2; and

Figs. 4 and 5 show typical traces on the screen of the cathode ray oscilloscope in the system of Fig. 1 when the electronic storage tube is not used and when it is used, respectively.

Referring more specifically to the drawing, Fig. 1 shows, by way of example to illustrate the principles of this invention, a simplified circuit diagram of a radio object-locator system. Any suitable transmitter 8 for the radio object-locator system may be utilized. For example, the transmitter 8 can comprise an oscillator for providing a sine wave having a suitable periodicity which can conveniently be 480 cycles per second but which may be as high as 4000 cycles per second, if desired. This oscillator energizes a pulse generator of any of several suitable types well known in the art. For example, see United States Patent 2,117,752, issued May 17, 1938, to L. R. Wrathall which provides an energy impulse at a particular point of each cycle of the input wave supplied to it. The pulses from the pulse generator are then applied to a carrier generator and modulator of any suitable type which may, for example, generate a carrier wave of approximately 3,300 megacycles per second and this carrier wave is modulated by the pulses from the pulse generator. The modulated wave is applied to the transmitting antenna 9.

Waves reflected from one or more objects within the range of the transmitting antenna 9 are received by a receiving antenna 10. The antennas 9 and 10 can be of any suitable type; for example, they can be of the polystyrene "polyrod" type disclosed in an application of G. E. Mueller, Serial No. 469,284, filed December 17, 1942. Connections to the transmitting antenna 9 and from the receiving antenna 10 are made by coaxial cable. The reflected waves (and also the transmitted waves) picked up by the receiving antenna 10 are applied to a receiver 11 of any suitable form wherein they are detected and amplified and applied to the electronic storage tube 12 to be more fully described below. The input of the electronic storage tube comprises trains of impulses each train comprising a transmitted pulse (if it is not

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blanked out) and one or more echo pulses separated by noise variations. In the specification and claims, the term "noise" will be used to include all types of spurious variations occurring at random times. The output signals from the electronic storage device 12 are applied to one set of plates 13, 13 in any suitable cathode ray oscilloscope 16, a linear sweep circuit 14 being applied to the other set of plates 15, 15. Sweep circuit 14 has only a fraction of the frequency of the repetition rate of the pulses at the transmitting station. The reasons for this will be pointed out below.

Reference will now be made to Fig. 2 which shows a cathode ray tube 20 of the electrostatic recording and reproducing type disclosed in Patent 2,245,364, issued June 10, 1941 to R. R. Riesz and H. S. Wertz. The tube is used in a different manner, however, than that described in this patent and the circuits therefor are different. The tube 20 comprises in general a recording tube or compartment 21 and a reproducing tube or compartment 22 separated by a target 23 which is common to both. The target 23 comprises a plate of insulating material 24 (see Fig. 3) through which is inserted a circle of metal plugs 25. A metal ring 26 surrounds the insulating plate 24. An input circuit is provided for the recording tube 21 which is connected to the receiver 11 and an output circuit is provided for the reproducing tube 22 which is connected to the plates 13, 13 of the cathode ray oscilloscope 16. Circuits are also provided to cause the beam in each tube or compartment to move in a circle over the target 23, the beam in the tube or compartment 22 being moved at a frequency which is only a fraction, as, for example, one-twentieth, of that of the beam in the tube or compartment 21.

The recording tube 21 includes an electron gun, comprising a cathode 27, an anode cylinder 28, an anode plate 29 and a conducting coating 30, for forming and accelerating a beam of electrons and for focussing it into a fine spot upon the target 23. The cathode 27 is heated by a filament 31 which is supplied with current from a source of potential 32. The anode 28 is positively biased with respect to the cathode 27 by means of a source of direct potential 33 while the anode plate 29 and the conducting coating 30 are positively biased with respect to the anode 28 by means of a source of direct potential 34. A source of direct potential 35 may be included in circuit between the coating 30 and the metallic ring 26, the purpose of which will be more fully described below. The intensity of the beam is modulated by means of incoming signals applied between a modulating or control element 41 and the cathode 27 by means of the coupling condenser 40. A leak resistor 42 and biasing source of potential 43 are also included in this input circuit.

The reproducing tube 22 includes an electron gun comprising a cathode 50, a cylindrical anode 51, a plate anode 52, and a conducting coating 53 for forming and accelerating a beam of electrons and for focusing it into a fine spot on the surface of the target or screen 23 remote from the recording tube or compartment 21. The cathode 50 is heated by a filament 54 which is supplied with current from a source of potential 55. The cylindrical anode 51 is positively biased with respect to the cathode 50 by means of a source of direct potential 56, while the apertured plate 52 and the conducting coating 53 are placed at a positive potential with respect to the anode 51 by means of a source of potential 57. Be-

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tween the metal ring 26 which surrounds the target 23 and a secondary electron collecting electrode 60 are connected an output resistance 58 and a source of direct potential 59. The resistance 58 is connected to an amplifying device 61. The output circuit of the amplifier 61 is connected to the deflecting plates 13, 13 of the oscilloscope 16.

The electron beams in the tubes 21 and 22 are preferably caused to trace circular paths over the metallic plugs 25 in the target 23, one beam acting to form charges on one side of the target and the other beam acting to remove these charges some time later after a number of traversals of the recording beam. While it should be understood that separate sources for the deflecting voltages may be provided to control the movements of the cathode ray beams in the respective tubes 21 and 22, it is preferred to supply the deflecting voltages from a single source of oscillations in order to interlock the movements of the two beams. The oscillator 70 preferably supplies waves of sinusoidal form which are applied to the pairs of deflecting plates 71, 71 and 72, 72 of the tube or compartment 21 through a resistance 73 and a condenser 74 which are in a series path connected to the output terminals of the oscillator 70. These impedance elements serve as a phase splitter for obtaining quadrature voltage components of the output of the oscillator 70 which components are applied to the respective pairs of deflector plates 71, 71 and 72, 72.

Also connected to the output of the oscillator 70 is a frequency divider 75 which may be of any one of a variety of well-known forms. For example, it may be a multivibrator such as that shown on page 53 of the Radio Amateur's Handbook, Special Defense Edition, 1942, or it may comprise two or more stages of such multivibrators. Thus, for example, the first multivibrator can have its circuit constants chosen to produce a frequency division of 5 and the second multivibrator have its constants chosen to produce a frequency division of 4, there being an over-all frequency division of 20 in the two multivibrators. A filter for selecting a sine wave of the desired frequency can be utilized in the output of the second multivibrator. By way of example, if the frequency of the oscillator 70 is 480 cycles per second, the filter is made to select a frequency of 24 cycles per second. As an alternative arrangement, the frequency divider 75 can be a rotary motor-generator set for converting 480 cycles to 24 cycles.

The output of the frequency divider 75 is connected to a resistance 76 and a capacity 77 connected in series. These impedance elements serve as a phase splitter for obtaining quadrature voltage components which are applied to the respective pairs of deflector plates 78, 78 and 79, 79. The value of the voltage delivered by the oscillator 70 and the values of the resistance and capacity elements 73, 74, 76 and 77 are preferably so adjusted that the beam in the tube 21 traverses a circular path over one end of each of the metallic elements 25 and the beam in the tube 22 traverses a similar circular path over the opposite end of each of these metallic elements but at only one-twentieth of the speed or, in other words, the beam in the tube 21 makes twenty passages, for example, over the circle of elements 25 while the beam in the tube 22 is making only one.

The operation of the system shown in Figs. 1 and 2 will now be described. Pulses are sent out

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from the transmitting antenna 9 and received by the receiving antenna 10. Between transmitted pulses, echo signals, produced by reflection of the transmitted pulses from one or more targets, are received by the receiving antenna and these with the transmitted pulse and the accompanying noise produce a train of signals or electrical variations. These trains, after being removed from the carrier and amplified in the receiver 11, are applied as a video signal to the control element 41 of the tube 21 to modulate the beam therein and to vary the intensity thereof in accordance with the variations in the video signal. These variations are shown in Fig. 4 which represents the trace which would be viewed on the screen of a cathode ray oscilloscope if the voltage applied to the control member 41 were applied instead to the deflecting plates of the oscilloscope.

A cathode ray beam in the tube 21 is formed and accelerated by the electron gun member and is focused into a fine spot on the target 24 by means of the electron lens action of the anodes. This beam is modulated in intensity by the incoming video signal which is applied between the modulating element 41 and the cathode 27. The modulated beam is caused to move in a circular path successively over one end of each of the metallic elements 25 to cause the formation of charges thereon which vary in accordance with the variations in the incoming signals. The charges will be held on the metallic elements 25 because of the condenser action between the elements 25 and the metallic ring 26 separated by a narrow ring of insulating material from the elements 25 (see Fig. 3). The ends of the metallic elements 25 in the tube 21 are preferably coated with a suitable substance such as, for example, carbon to prevent or decrease secondary emission. The electrons in the beam which are not laid down on the metallic elements 25 are collected by the conducting coating 30. In the cathode ray tube or compartment 22 an electron beam is formed and accelerated by the cathode 50 and the anodes 51, 52, and 53 and is focused into a fine spot on the target 23 by the electron lens action of the anodes. This beam is also caused to move in a circle over the ends of the metallic elements 25 remote from the tube 21 by the quadrature voltage components applied to the deflecting plates 78, 78 and 79, 79. Due to the difference in frequency of the waves applied to the deflecting plates in the tube 21 and to those in the tube 22, the charges build up on the elements 25 for 20 cycles or sweeps before they are removed by the action of the reproducing beam in the tube 22. The charges accumulate on those of the elements 25 corresponding to the transmitted pulse and the echoes (represented by the pulses 80, 81, 82 and 83 in Fig. 4) in direct manner. The charges accumulate, however, on those of the elements 25 corresponding to the portions of the train shown in Fig. 4 representing noise in random fashion rather than in a direct manner. This is due to the nature of the spurious variations (noise). It will be understood that if the train shown in Fig. 4 does not take up the entire period of time between successive transmitted pulses 80 (and as a practical matter it rarely does), some of the elements 25 will not be charged inasmuch as there will be no signals to modulate the beam during this period as it will be cut off by the bias produced by the source 43 on the control element 41. Due to the difference in the manner that the charges accumulate on those of the elements 25 corresponding to the transmitted

and echo pulses and to those corresponding to the noise variations, the voltage train produced in the output circuit of the tube 22 has the transmitted and echo pulses sharply accentuated with respect to the noise variations. This is shown in Fig. 5. The reproducing is accomplished by the removal of the negative charges applied to the metallic elements 25 by the beam in the tube 21, this removal being caused by the electron beam in the tube 22 by secondary emission action. The voltages applied to the anode members in the tube 22 and the material of the metallic elements 25 are chosen so that more secondary electrons are emitted than there are primary electrons in the beam. The elements 25, for example, may be made of nickel or they may be made of any good conducting metal coated with a suitable alkaline earth oxide layer to enhance the emission of secondary electrons. Secondary electrons are collected by the electrode member 60 thus removing the charges from each metallic member in turn. As the charges are removed from the metallic elements 25 which are successively contacted by the beam in the tube 22 at a rate which is, for example, one-twentieth of the rate at which they are laid down, a succession of voltage variations is set up across the resistance 58 which is generally representative of the video signal in the input circuit of the tube 21 but with the noise peaks greatly reduced in magnitude in comparison with the echo pulses and the transmitted pulse. The source of potential 59 which is connected in series with the resistance 58 between the ring 26 and the deflecting electrode 60 is preferably so poled that the collecting electrode 60 is at a positive potential with respect to that of the metallic elements 25 in order to encourage secondary emission from these elements to the electrode 60. Due to the fact that the surges produced when the beam in the tube 22 contacts the metallic elements 25 are large compared with the charges being laid down by the beam upon one passage over the other side of the element, no harm is caused when both beams contact an element at the same time. The image current in the resistance 58 produces a voltage which is amplified by the amplifier 61 and applied to the pair of plates 13, 13 in the oscilloscope 16, to the other pair of plates 15, 15 of which is applied the linear sweep circuit 14. This sweep circuit has a frequency which is equal to that of the sweep waves used in the reproducing tube 22 and this circuit is synchronized by any well-known means so that the sweep starts (approximately at least) with the reproduced version of the transmitted pulse. This trace viewed on the screen of the oscilloscope 16 is like that shown in Fig. 5. In this trace, the pulses 90, 91, 92 and 93 correspond to the pulses 80, 81, 82 and 83 of Fig. 4, but are greatly amplified with respect to the noise.

The above-described system has the advantage that the tube of the type shown in Fig. 2 and its associated circuits can be inserted in a radar system already in operation, it only being necessary to change the frequency of the sweep circuit for the oscilloscope from that of the frequency of repetition of the transmitted pulses to a fraction thereof, or in other words from a frequency of 480 cycles, for example, to one of 24 cycles. This change can be very readily made in most sweep circuits that are furnished with oscilloscopes of this type. While it is preferable that the frequency of reproduction be an integral fraction of the frequency of recording, it will be obvious that satisfactory, though somewhat less exact, results can be obtained if the ratio is not

an integer. For example, if the frequency of storage is $19\frac{1}{2}$ times that of the frequency of reproduction, part of each reproduced train would represent storage for 19 incoming trains and part for 20 incoming trains. This difference is hardly noticeable.

While the invention in its primary aspects is concerned with the improvement of the signal-to-noise ratio in radio object-location systems, it will be apparent that in other aspects the invention is not so limited as the apparatus of this invention may be utilized in any other system transmitting pulses or waves of substantially even spacing accompanied by spurious current or voltage variations of a random distribution and character.

Various changes may be made in the embodiments above disclosed without departing from the spirit of the invention, the scope of which is indicated in the appended claims.

What is claimed is:

1. Means for differentiating between cyclically repeated pulse signals and spurious variations of a random distribution and character, comprising means for producing a space-current beam modulated with said pulse signals and said spurious variations, target means for said beam, means for repeatedly sweeping said beam across a predetermined path on said target so that different distinctive parts of said target are impacted in turn by said beam and each of said parts repeatedly at instants respectively when said beam is being modulated with successive ones of a distinctive set of said pulse signals to accumulate charges on said parts each of which charges is dependent upon the number of beam impacts on the corresponding target part and also upon the beam energy at time of impact, means separated from said space-current beam generating means for generating a second space-current beam, and means for successively impacting said target parts with said second beam in the same order as, and at a slower rate than, with said first beam for producing voltages the magnitude of which depends upon said accumulated charges respectively.
2. The combination of elements as in claim 1 in further combination with means for utilizing said voltages in the production of corresponding visual indications.
3. Means for differentiating between cyclically repeated pulse signals and spurious variation peaks of a random distribution and character, comprising means for producing a space-current beam modulated with said pulse signals and said spurious variations, target means for said beam, means for sweeping said beam over said target means, means for generating a second space-current beam, means for sweeping said second beam over said target means at a periodicity which is an integral fraction of that of the sweeping of said first beam over said target to remove charges accumulated by said first beam, whereby an output voltage is produced in which portions thereof corresponding to the repeated pulse signals are accentuated with respect to portions thereof corresponding to the spurious variation peaks inasmuch as electrical charges representative of the pulse signals are added up in phase on portions of said target means for a number of cycles, and other charges representative of the spurious variation peaks are added up in random phase on other portions of said target means for the same number of cycles.
4. The combination of elements as in claim 3

in further combination with means for utilizing the output variations in production of corresponding visual indications.

5. The combination with a cathode beam target comprising an array of alternate conducting and insulating segments, all of the conducting segments being of substantially the same size, of means for producing a space-current beam, means for producing two waves capable of jointly causing the beam to be deflected repeatedly over the same closed path and confined to said path, the path including only the conducting segments of substantially the same size and the insulating segments adjacent thereto, two deflecting means to which said waves are respectively applied, means including means for modulating said beam with signals to cause electric charges to be accumulated on said conducting segments, and means for discharging said accumulated charges one at a time at a rate lower than that at which said beam impinges on said conducting segments.

6. The combination of elements as in claim 5 in which the rate of discharging each of said accumulated charges is of the order of one-twentieth that of the rate at which said beam impinges on each of said conducting segments.

7. The combination of elements as in claim 5 in which said last-mentioned means include means for generating a second space-current beam, and means for causing said beam to sweep over said conducting segments.

8. The combination with a cathode beam target comprising an array of alternate conducting and insulating segments, all of the conducting segments being of substantially the same size, of means for producing a cathode beam, means for producing two waves capable of jointly causing the beam to be deflected repeatedly over the same closed path and confined to said path, the path including only the conducting segments of substantially the same size and the insulating segments adjacent thereto, two deflecting means to which said waves are respectively applied, means including means for modulating said beam with signals to cause electric charges to be accumulated on said conducting segments, means for discharging said accumulated charges one at a time at a rate less than that at which said beam impinges on said conducting segments, and means for utilizing voltages produced by said discharges in the production of corresponding visual indications.

9. The combination as in claim 8 in which said last-mentioned means comprises a cathode ray oscillograph comprising means for generating a beam of electrons and two sets of deflecting elements, means for applying said voltages to one set of said deflecting elements, and means for applying a sweep wave to the other set of deflecting elements.

10. Means for differentiating between time-spaced variations occurring at a definite periodicity and non-periodic variations intermixed therewith comprising means for producing a space-current beam, means for modulating said beam with both said variations, a target for said beam, means for repeatedly sweeping said beam over a predetermined path on said target so that different distinctive parts of said target are impacted in turn by said beam and each of said parts repeatedly at instants respectively when said beam is being modulated with successive ones of a distinctive set of said periodic variations, whereby charges are accumulated on said parts each of which charges is dependent upon the

number of beam impacts on the corresponding target parts and also upon the beam energy at time of impact, means for producing a second space-current beam, and means for successively impacting said target parts with said second beam in the same order as, and at a slower rate than, with said first beam for producing voltages the magnitude of which depends upon said accumulated charges respectively.

11. Means for differentiating between time-spaced variations occurring at a definite periodicity and non-periodic variations intermixed therewith comprising means for producing a space-current beam, means for modulating said beam with both said variations, a target for said beam, means for repeatedly sweeping said beam over a predetermined path on said target so that different distinctive parts of said target are impacted in turn by said beam and each of said parts repeatedly at instants respectively when said beam is being modulated with successive ones of a distinctive set of said periodic variations, whereby charges are accumulated on said parts each of which charges is dependent upon the number of beam impacts on the corresponding target parts and also upon the beam energy at time of impact, means for producing a second space-current beam, means for successively impacting said target parts with said second beam in the same order as, and at a slower rate than, with said first beam for producing voltages the magnitude of which depends upon said accumulated charges respectively, and means for utilizing said voltages in the production of corresponding visual indications.

12. Means for differentiating between time-spaced variations occurring at a definite periodicity and non-periodic variations intermixed therewith comprising means for producing a space-current beam, means for modulating said beam with both said variations, a target for said beam, means for repeatedly sweeping said beam over a predetermined path on said target so that different distinctive parts of said target are impacted in turn by said beam and each of said parts repeatedly at instants respectively when said beam is being modulated with successive ones of a distinctive set of said periodic variations, whereby charges are accumulated on said parts each of which charges is dependent upon the number of beam impacts on the corresponding target parts and also upon the beam energy at time of impact, means for producing a second space-current beam, means for successively impacting said target parts with said second beam in the same order as, and at a slower rate than, with said first beam for producing voltages the magnitude of which depends upon said accumulated charges respectively, a cathode ray oscillogoscope comprising means for generating a beam of electrons, and two sets of deflecting elements for said beam, means for applying said voltages to one set of deflecting elements, a sweep wave generator, and means for connecting said sweep wave generator to said second set of deflecting elements.

13. In combination, means for generating a space-current beam, a target for said beam comprising a plurality of conducting elements of substantially the same size and a plurality of insulating segments adjacent thereto, means on the side of said target remote from said first-mentioned means for generating a second space-current beam, means for producing two waves capable of jointly causing the first beam to be

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deflected repeatedly over the same closed path and confined to said path, the path including only the conducting segments of substantially the same size and the insulating segments adjacent thereto, two deflecting means to which said waves are respectively applied, and means for deflecting said second beam over a similar path on said target to contact in order the same conducting elements but at a different periodicity.

14. The combination as in claim 13 in which the speed of deflection of said second beam is less than that of said first beam.

15. The combination as in claim 13 in which the speed of deflection of said second beam is an integral fraction of that of said first beam.

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