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VELOCITY VARIATION TRANSMITTER-RECEIVER

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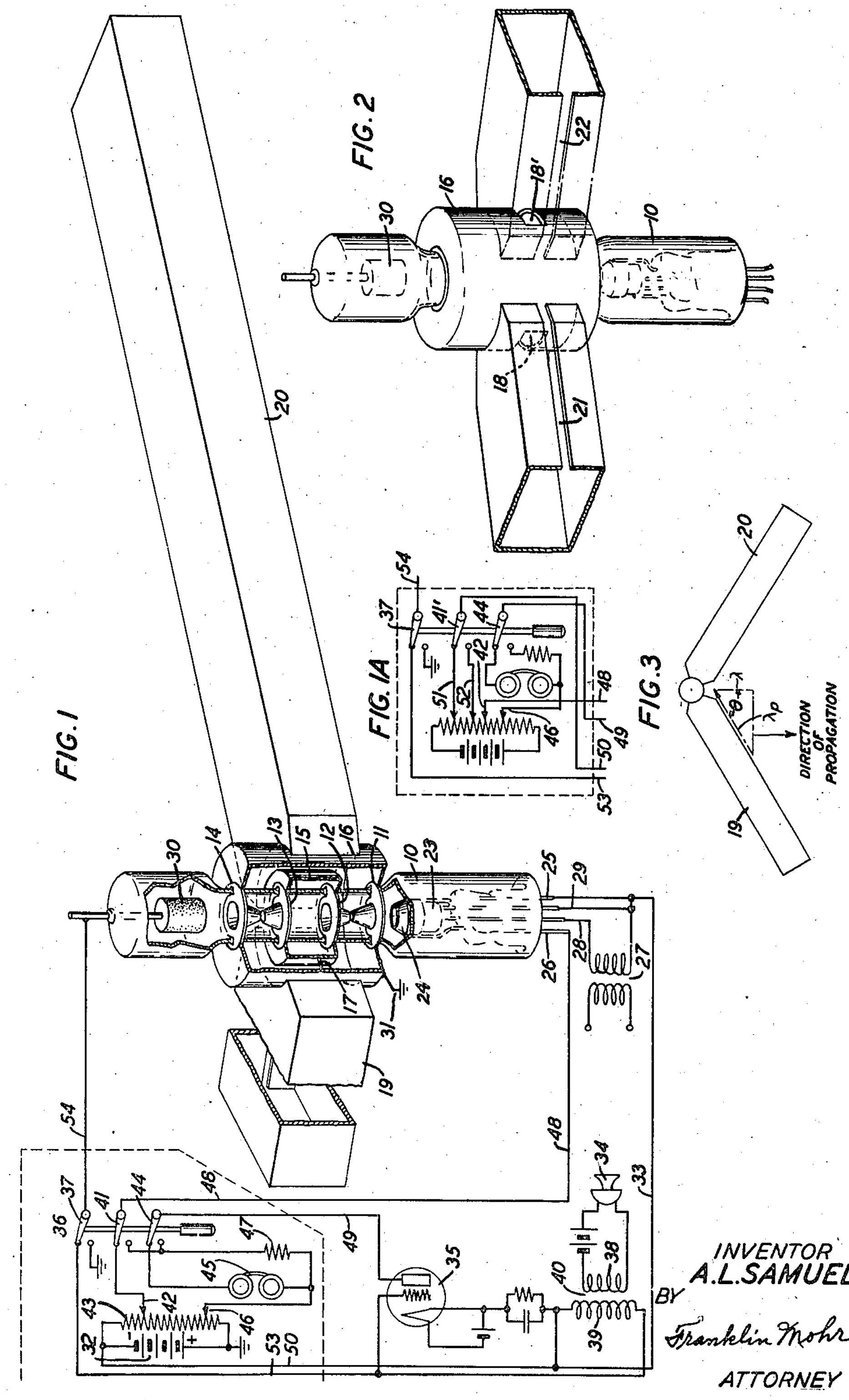

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VELOCITY VARIATION TRANSMITTER-RECEIVER

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4 Claims. (Cl. 250—13)

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This invention relates to apparatus for communication by means of ultra-high frequency electromagnetic waves, and more particularly to a combined transmitter and receiver for duplex operation.

The invention further relates to equipment for line-of-sight communication. It employs a vacuum tube utilizing electron velocity variations in conjunction with a hollow resonating chamber and a radiating wave guide.

Among the objects of the invention are to make the apparatus compact, readily portable and simple to operate and maintain.

A specific object is to employ the same vacuum tube both in transmitting and receiving. Other specific objects are to avoid the necessity for employing a quenching oscillator to disable the transmitter while receiving and at the same time to avoid switching of high frequency connections between the transmitter and receiving conditions.

A feature is a direct coupling between a resonant cavity and a directive antenna of the slotted wave guide type.

Another feature lies in varying the feedback in a velocity variation system by varying the transit time of the electrons in the drift space.

The invention is more fully described hereinafter by an illustrative example with reference to the accompanying drawing in which:

Fig. 1 is a perspective view of a combined transmitter and receiver, shown partly broken away, and partly diagrammatically;

Fig. 1A is an alternative circuit diagram for substitution in Fig. 1;

Fig. 2 is a fragmentary view of the apparatus showing certain structural details; and

Fig. 3 is a plan view on a reduced scale.

Referring to the figures, 10 represents a vacuum tube containing a series of electrodes 11, 12, 13 and 14 to two of which, 12 and 13, is conductively attached an inner cylindrical casing 15 and to the other two, 11 and 14, an outer cylindrical casing 16, the two casings being conductively joined by a rod or wire 17. The outer casing 16 is provided with a pair of slots 18 and 18′, shown in Fig. 2. A pair of rectangular wave guides 19 and 20 are mounted at the sides of the casing 16 and, if desired, may be arranged to permit a certain amount of rotation about the axis of the tube 10. The guides 19 and 20 are each open at the end adjacent the casing 16 so that the interiors of the guides communicate with the interior of the casing 16 through the respective slots 18 and 18′. The other end of each of the guides is shown open but it may be closed if desired. The guide 19 is

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provided with a longitudinal slot 21 and the guide 20 with a similar longitudinal slot 22. The guides 19 and 20 are preferably set apart at a wide angle 2θ as shown in Fig. 3, the value of θ being dependent upon the physical dimensions of the wave guide to give the best efficiency of radiation from the device as a directive antenna.

The vacuum tube 10 may be of the type shown in Fig. 3 of my application Serial No. 375,114, filed January 21, 1941, and assigned to the assignee of the present application, issued as Patent No. 2,281,717, May 5, 1942. A suitable electron gun is mounted at the lower end of the tube 10 and comprises a cathode 23 and an accelerating electrode 24 brought out through leads 25 and 26, respectively. The cathode may be heated in any suitable manner as, for example, by alternating current applied through a transformer 27 and leads 28 and 29, of which lead 29 may be connected to lead 25. The electrodes 11, 12, 13 and 14 may be of the type disclosed in my above-mentioned application, electrodes 12 and 13 being conductively connected with the inner casing 15 and electrodes 11 and 14 with the outer casing 16. An electron collecting electrode or collector 30 is provided at the upper end of the tube.

The casings 15 and 16 may be grounded by means of a lead 31 or otherwise connected with the grounded positive terminal of a source 32 of electromotive force. The negative terminal of the source 32 is connected to the cathode by means of leads 33 and 50.

Other auxiliaries include a telephone transmitter 34 connected in conventional manner to the grid of a low frequency amplifier 35. A multipole switch 36, shown designed for manual operation but which may be electrically operated, if desired, is provided for switching the low frequency connections of the system between the transmitting and receiving conditions. The switch is shown in the receiving condition. In this position, the upper arm 37 of the switch connects the collector 30 with the cathode 23 by way of the secondary winding of the transformer 40. The middle arm 41 of the switch 36 connects the accelerating electrode 24 by an obvious path to the more negative contact 42 of a potentiometer 43 across the source 32. The lower arm 44 of the switch 36 connects the plate of the amplifier 35 with one terminal of a telephone receiver 45 or other translating device. The remaining terminal of the receiver 45 is connected to the more positive contact 46 of the potentiometer 43.

In the transmitting or lower position of the switch 36 the switch arm 37 connects the collector

30 to ground potential, the arm 41 connects the accelerating electrode to the potentiometer contact 46 through a series resistor 47, and the lower arm 44 connects the plate of the tube 35 to the accelerating electrode.

In the operation of the system for transmitting, with the switch 36 in the lower position, the full potential difference of the source 32 is applied between the cathode 23 and the collector 30 of the tube 10. In this position of the switch the accelerating electrode 24 is placed at an intermediate potential and coupled to the plate of the low frequency amplifier 35. The collector 30 is at the same potential as the walls of the resonating chamber and the electrodes 11, 12, 13 and 14. The tube 10 operates as an ultra-high frequency oscillator employing the electron velocity variation principle. A beam of electrons projected by the electron gun is subjected to a velocity variation in passing through the gap between the electrodes 11 and 12 due to reaction with electromagnetic oscillations in the interior of the resonating chamber. The velocity variations of the beam are converted into electron charge density variations during the time required for the electrons to drift to the gap between the electrodes 13 and 14. The charge density-varied electron beam yields part of its kinetic energy to the electromagnetic field at this point, provided the electron transit time has been properly adjusted with respect to the resonant frequency of the chamber. The electromagnetic field in the chamber is maintained in sustained oscillations by the energy so contributed by the electron beam, in well-known manner. After passing the gap between electrodes 13 and 14 the electron beam is intercepted by the collector 30. A portion of the energy of the oscillating electromagnetic field escapes from the resonating chamber through the slots 18 and 18′ and produces traveling waves in the guides 19 and 20. Radiation from the slots 21 and 22 occurs primarily in the plane of the slots and is directed in the direction of the bisector of the angle between the guides 19 and 20. The ultra-high frequency output of the system is amplitude-modulated by signals from the telephone transmitter 34 impressed upon the accelerating electrode 24 in amplified form from the plate circuit of the tube 35. The signal-varied plate potential of the tube 35 impresses corresponding potential variations upon the accelerating electrode 24, thus varying the beam current and consequently varying the power output of the oscillator. Additional audio amplification may be employed if necessary by adding additional stages.

In the operation of the system of Fig. 1 as a receiver the switch 36 is placed in the upper position. Three changes are effected by the switching. The middle switch arm 41 transfers the accelerating electrode 24 to a reduced voltage, thereby reducing the beam current, preferably to a value insufficient to produce sustained oscillations but providing a controllable amount of regeneration, if desired. The upper switch arm 37 transfers the collector 30 to a reduced voltage in the neighborhood of the cathode potential, thereby setting up an electron retarding or reflecting field between the electrode 14 and the collector 30. The lower switch arm 44 transfers the plate of the low frequency amplifier 35 to the telephone receiver 45 with a somewhat increased plate potential due to elimination of the series resistor 47 from the circuit.

The incoming ultra-high frequency wave in-

tercepted by the slotted guides 19 and 20 is directed into the resonating chamber through the slots 18 and 18′, setting up standing waves in the chamber. The waves in the chamber serve to effect velocity variation of the electron beam at both gaps within the cavity of the chamber. The velocity variation at the first gap is converted into an electron current density variation by transit time grouping in the drift space in the usual manner so that the drift electrons are enabled to deliver power to the electromagnetic field in the chamber by reaction at the second gap. Because of the reduced beam current the power supplied to the field by the beam will be insufficient to produce sustained oscillations when properly adjusted for receiving. As above mentioned, a controllable amount of regeneration may be employed by adjusting the strength of the beam current. Detection will occur in the collector circuit due to the action of the retarding field which is set up by having the collector at a potential in the neighborhood of the cathode potential. The electrons after passing the gap between the electrodes 13 and 14 will still have sufficient velocity variations so that electron sorting takes place in the retarding field in accordance with the velocities of the individual electrons. The slower electrons are turned back before reaching the collector. The number of electrons which gain sufficient momentum to reach the collector depends upon the amount of velocity variation which has been imparted to the beam by the incoming signal. Accordingly, the stronger the signal the more electrons will reach the collector per unit of time and the greater the detected current delivered to the translator 45.

An alternative method of controlling the regeneration in the receiving condition consists in changing the electron transit time in the drift space by an adustment of the direct current potential difference between the cathode and the resonating chamber so that the current variation at the second gap is nearly in quadrature with respect to the electromagnetic field effective across this gap. The quadrature relationship may be secured by changing the voltage a small amount so that the transit time is equal to an integral number of cycles of the field oscillations. The velocity variation effects produced at the two gaps by the incoming signal will in this case be additive and hence detection is possible in the same manner as before. A slight increase in the voltage with respect to the condition of quadrature will produce regeneration whereas a decrease will produce degeneration. The condition for sustained oscillations requires a transit time of $(n+3/4)$ cycles as explained in connection with an oscillator disclosed in U. S. patent application Serial No. 386,794, filed April 4, 1941, by A. E. Anderson and A. L. Samuel, issued as Patent No. 2,405,175, August 6, 1946, and assigned to the same assignee. In accordance with the explanation given in the Anderson-Samuel application it will be evident that the condition for degeneration requires a transit time of $(n+1/4)$ cycles and a transit time of n cycles corresponds to a condition in which the electron beam neither contributes energy to the field nor abstracts energy therefrom.

The alternative method of operation above referred to may be incorporated into the switching arrangements by a slight modification of the connections to the switch 36 as shown in Fig. 1A. In this method of operation no change in the beam current is required, hence the accelerator potential need not be changed and lead **48** may be permanently connected to the slider **42**. The connections to the middle switch arm **41** are changed as indicated in Fig. 1A where the designation of the switch arm has been changed to **41'**. The cathode lead **50** is connected to the switch arm **41'** so that the cathode potential may be changed by a small amount in switching between the transmitting and receiving conditions. For this purpose the additional potentiometer sliders **51** and **52** are provided and connected to the terminals associated with the switch arm **41'**. The contacts **51** and **52** may be adjusted to give regeneration, degeneration or a neutral condition as explained above.

If desired, the two methods of reaction control shown respectively in Fig. 1 and Fig. 1A may be used simultaneously. Which of the methods, or what sort of a combination of the two, will be preferable in a given case may best be determined by experiment.

The directional antenna array illustrated comprises two rectangular wave guides mounted at an angle with respect to each other. The guides are provided with radiating slots **21** and **22** on their opposing faces. Other suitable guides having circular or various other cross sections may be employed, if desired, in place of rectangular guides. Radiating slots of a variety of forms might be used. With the optimum adjustment of the size of the radiating slot, and of the angle between the wave guides, the system provides a high degree of directivity, the transmission being principally confined to the plane of the slots and distributed about equally well in all directions in this plane within the angle between the guides. The antenna array is particularly adapted for use with the plane vertical in which case there is selective transmission in a desired azimuthal direction broadly scattered over a considerable range of elevations. At the receiving point the plane of the receiving antenna may be adjusted in the proper direction for best reception without imposing stringent requirements on the adjustment of the elevation.

The resonating chamber may be coupled to the antenna array in various suitable ways as, for example, by means of a slot, iris, coupling loop, etc., all of which are well known per se. For operation at a predetermined single frequency the angle between the two guides as well as the size of the coupling aperture may be fixed with an adjustment for tuning the resonant cavity as by means of a micrometer screw or the like, if desired.

What is claimed is:

1. Combined transmitting and receiving apparatus comprising: a resonating chamber for ultra-high frequency waves; an electron discharge device including a cathode for supplying an electron stream, and, in succession along the path of said electron stream, an accelerating electrode, a plurality of electrodes integral with said resonating chamber, defining input and output gaps separated by a substantially field-free drift space, and a collecting electrode; means operative while transmitting to maintain said accelerating and collecting electrodes respectively at relatively high positive potentials with respect to said cathode, whereby electromagnetic oscillations are sustained in said resonating chamber; means operative while receiving to maintain said accelerating electrode at a reduced positive potential, whereby the tube and chamber are enabled to function as a regenerative amplifier, and to maintain said collecting electrode at substantially cathode potential, whereby the tube is enabled to function as a detector of velocity variations in the electron stream.

2. The combination of claim 1 with the addition of means for switching the system to either the transmitting or the receiving condition.

3. Combined transmitting and receiving apparatus comprising an electron beam tube including a cathode, an accelerating electrode, and a collecting electrode, an associated resonating chamber, means within said chamber defining an input gap and an output gap traversed by the electron beam of said tube, means defining a substantially field-free drift space between said input and output gaps, means operative while transmitting to maintain said accelerating and collecting electrodes respectively at relatively high positive potentials with respect to said cathode, whereby electromagnetic oscillations are sustained in said resonating chamber, and means operative while receiving to maintain said accelerating electrode at a reduced positive potential, whereby the tube and chamber are enabled to function as a regenerative amplifier, and to maintain said collecting electrode at substantially cathode potential, whereby the tube is enabled to function as a detector of velocity variations in the electron stream.

4. The combination of claim 3 with the addition of means for switching the system to either the transmitting or the receiving condition.

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