

Aug. 17, 1948.

M. G. CROSBY

2,447,057

DIVERSITY RECEIVING SYSTEM

Filed May 6, 1943

2 Sheets-Sheet 1

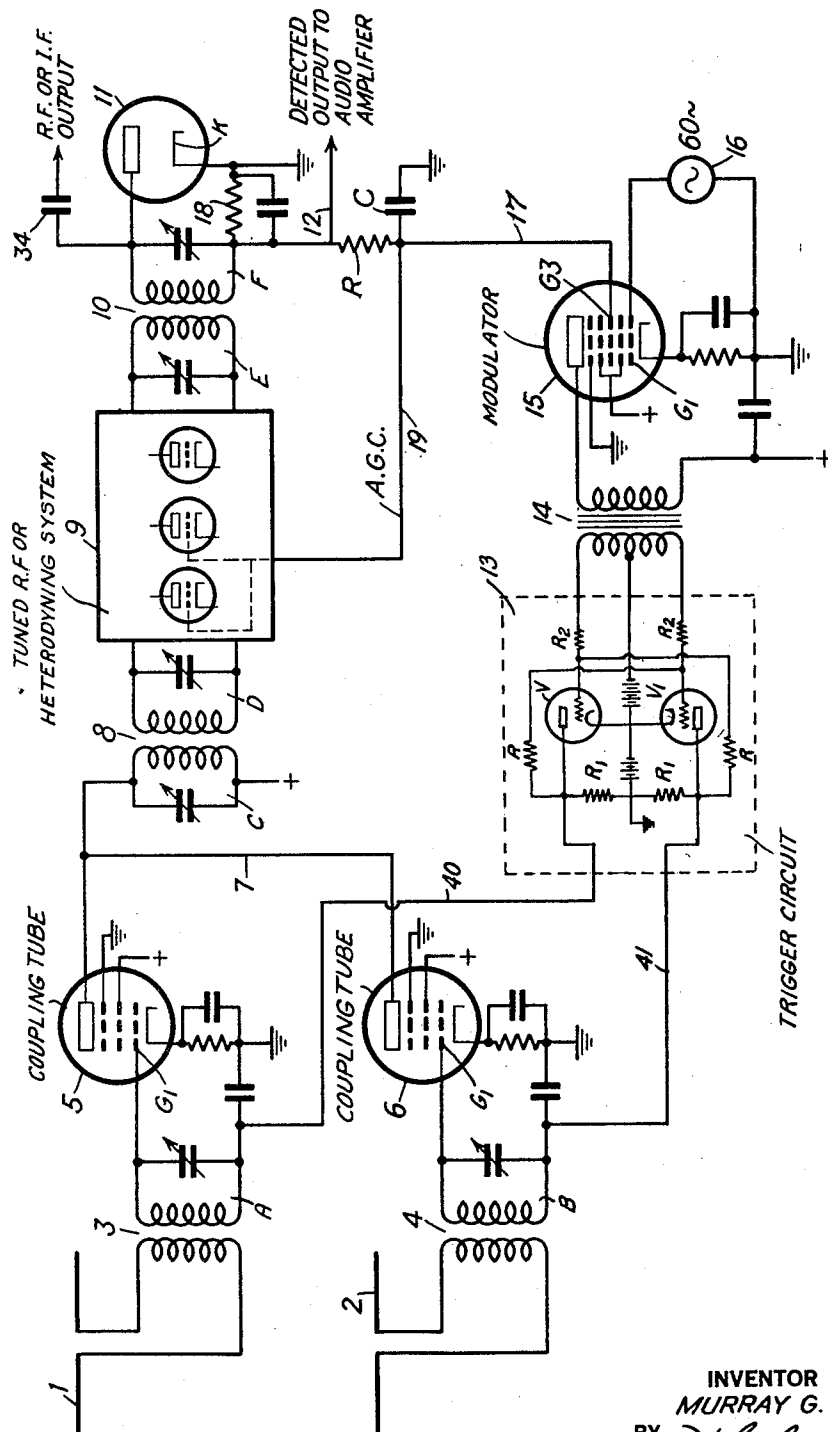


Fig. 1

INVENTOR
MURRAY G. CROSBY
BY *H. B. Brover*
ATTORNEY

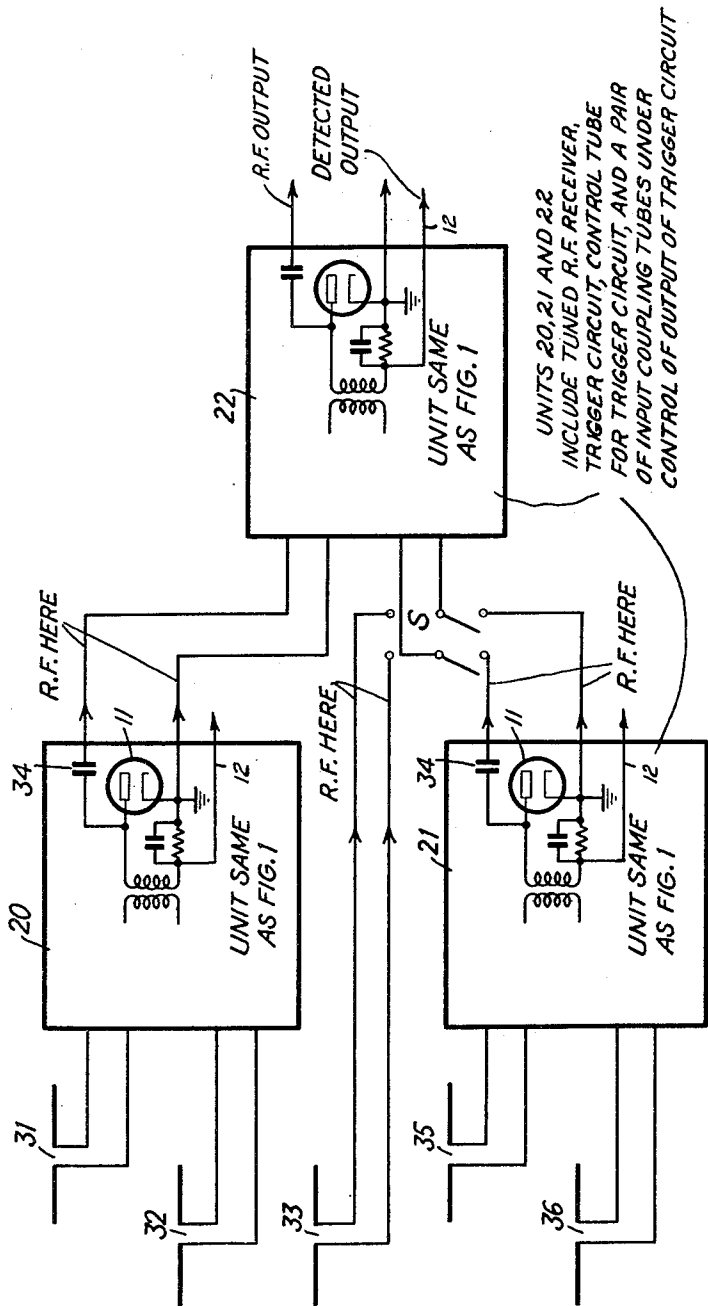
Aug. 17, 1948.

M. G. CROSBY
DIVERSITY RECEIVING SYSTEM

2,447,057

Filed May 6, 1943

2 Sheets-Sheet 2



UNIT SAME
AS FIG. 1

UNIT SAME
AS FIG. 1

UNIT SAME
AS FIG. 1

UNITS 20, 21 AND 22
INCLUDE TUNED R.F. RECEIVER,
TRIGGER CIRCUIT, CONTROL TUBE
FOR TRIGGER CIRCUIT, AND A PAIR
OF INPUT COUPLING TUBES UNDER
CONTROL OF OUTPUT OF TRIGGER CIRCUIT

Fig. 2

INVENTOR
MURRAY G. CROSBY
BY *H. G. Swover*
ATTORNEY

UNITED STATES PATENT OFFICE

2,447,057

DIVERSITY RECEIVING SYSTEM

Murray G. Crosby, Riverhead, N. Y., assignor to
Radio Corporation of America, a corporation of
Delaware

Application May 6, 1943, Serial No. 485,821

14 Claims. (Cl. 250—20)

1

This invention comprises a simplified diversity receiver for switching a common receiving system to that one of a pair of spaced antennas in which the strongest signals appears.

Diversity receiving systems are employed to overcome the effect of fading. Such diversity systems include a plurality of geographically spaced antennas so separated that the signal fades differently at the different antennas. In using diversity systems, it is known to switch a common receiving circuit from one antenna to another in order to receive the signal of strongest intensity. One such arrangement is described in Peterson United States Patent 2,243,118, granted May 27, 1941, which describes an arrangement employing a pair of grid-controlled gas tubes to effect the switching action. Other arrangements for achieving the same result have employed mechanical relays. The mechanical switcher has the disadvantage of introducing clicks into the receiving circuit.

The present invention provides a simplified and improved electronic switching arrangement for a diversity receiver which is completely electronic and fast in operation.

A more detailed description of the invention follows in conjunction with a drawing, in which Figs. 1 and 2 illustrate two embodiments of a diversity receiver in accordance with the present invention.

Referring to Fig. 1 of the drawing in more detail, there is shown a pair of antennas 1 and 2 which are separately coupled through radio frequency transformers 3 and 4, respectively, to coupling tubes 5 and 6. Antennas 1 and 2 may be geographically spaced from one another as in commonly employed diversity receiving systems, or, alternatively, these antennas may have the same space location but have different polarizations or different vertical angles of reception. The output electrodes of both coupling tubes 5 and 6 are connected in parallel by means of a connection 7. Energy from both of these coupling tubes is fed to a tuned transformer 8 in circuit with a suitable radio frequency apparatus 9. This apparatus 9 may be a tuned radio frequency system for supplying amplified radio frequency output, or, if desired, an amplifying and heterodyning system for beating the incoming energy in transformer 8 down to an intermediate frequency and supplying output of this intermediate frequency. The output from apparatus 9 is fed to a transformer 10 and rectified by diode 11. The detected output is available in lead 12 for utilization by a suitable device, such as a loudspeaker,

2

headset, or recorder through the intermediary of an audio amplifier (not shown). The condenser 34 is provided for enabling the system to supply a radio frequency output if apparatus 9 is of the tuned radio frequency type, or to supply an intermediate frequency output if apparatus 9 is of the heterodyning type, and this condenser 34 is employed only in the event the system of Fig. 1 is utilized in an embodiment of the type shown in Fig. 2 to be described later.

The parallel tuned input circuits A and B for tubes 5 and 6, and the parallel tuned circuits C and D, respectively, associated with the primary and secondary windings of transformer 8 are all tuned to the same radio frequency which is the frequency of the incoming signal. The parallel tuned circuits E and F, respectively, associated with transformer 10, however, are tuned to a lower intermediate frequency when apparatus 9 is of the heterodyning type, but tuned to the same radio frequency as the input circuits when apparatus 9 is a tuned radio frequency system.

Coupling vacuum tubes 5 and 6 receive their bias potentials from the output of an electronic trigger circuit 13, which in turn is controlled by a pentagrid control or modulator tube 15 through an audio transformer 14. The control grid G1 of modulator tube 15 is connected to a suitable source of low frequency energy 16 which, for example, may be 60 cycles and obtainable from the ordinary house power supply. The conductivity of the modulator tube 15 is controlled by means of negative automatic gain control potentials supplied to the grid G3 of tube 15 by means of lead 17 from a time-constant circuit R, C connected to the output resistance 18 of the diode detector 11. Resistor 18 is connected between the cathode K of tube 11 and the cathode end of tuned circuit F. A lead 19 supplies automatic gain control potentials to the grids of the radio frequency or intermediate frequency amplifier stages of the receiver 9. The electronic trigger circuit 13 is of a well known type and comprises a pair of vacuum tubes whose anodes and grids are interconnected to have two degrees of stability. These tubes are unstable when both are drawing current but stable when one tube is passing current and the other blocking. The change from one position of stable equilibrium of the electronic trigger circuit, such as when one tube is blocking and the other tube passing, to the other condition when the first tube is passing and the other tube blocking, is caused by the presence of a predetermined potential on the leads extending to the secondary winding of the trans-

former 14. Such an electronic trigger circuit is more adequately described in United States Patent 1,844,950, granted to Finch on February 16, 1932, to which reference is made for a more detailed explanation of the operation thereof.

The time-constant of the R, C circuit connected to leads 17 and 18 is such as to remove fast variations of potentials and pass slow variations representative of relatively slow fading of the incoming signal. These fast variations include the applied modulation frequency.

In the operation of the system, source 16 will normally permit the pentagrid modulator tube 15 to pass current at the frequency of the source 16. These low audio frequency currents appearing in transformer 14 will cause the electronic trigger circuit 13 to change its condition of stable equilibrium at a rate equal to the frequency of source 16. The output of the electronic trigger circuit 13 is connected via leads 40 and 41 and tuned circuits A and B, respectively, to the first grids G1 of the tubes 5 and 6, and thus biases the coupling vacuum tubes 5 and 6 so as to enable them to alternately amplify the incoming signals. Coupling tubes 5 and 6 are so arranged that either one or the other will pass current, depending upon which one has its control grid G1 more positive than the other, a condition controlled by the electronic trigger circuit 13. Thus, when tube 5 is conductive it will pass the signals received from antenna 1, and when tube 6 is conductive it will pass the signals received on antenna 2. The apparatus 9 will thus have impressed on its input the signal from only one of the antennas 1 or 2 at any one time, and this signal, which is detected by diode 11, will be impressed on automatic gain control lead 17 to the time-constant circuit R, C for controlling the pentagrid modulator tube 15.

The manner in which the system functions to switch the input of the radio frequency apparatus 9 to only that antenna which at the moment has the strongest incoming signal will now be described: Let it be assumed that antenna 1 has a strong signal. This will be amplified by tube 5 and apparatus 9 and detected by diode 11. This detected output will be fed as a negative potential to the grid G3 of modulator tube 15. This negative potential will cut off the flow of current through modulator tube 15, thereby removing the control of the electronic trigger circuit 13 from source 16. It is assumed, of course, that the intensity of the signal is sufficient to produce a negative potential in the output of the rectifier of sufficient magnitude to cut off the flow of current through tube 15. The electronic trigger circuit 13 will thus remain in its last condition of stable equilibrium, which is the condition for enabling coupling tube 5 to amplify and for preventing coupling tube 6 from amplifying. If at this time the signal collected by antenna 1 should fade, the negative bias fed to the grid G3 by lead 17 will be reduced to such an extent as to permit the modulator tube 15 to pass current and permit the low frequency source 16 to again control the electronic trigger circuit 13 to change its state of equilibrium. This change in the state of the electronic trigger circuit will now permit vacuum tube 6 to amplify and will bias tube 5 to cut-off. If a strong signal now appears on antenna 2, it will be amplified in tube 6 and be passed on to receiver 9, and will serve to control the modulator tube 15 to prevent any change in the state of equilibrium of the electronic trigger

circuit. It will thus be seen that the electronic trigger circuit 13, under control of the modulator tube and the output of the receiver 9, functions to render only that coupling tube 5 or 6 conductive to which is applied the stronger signal, assuming that there is occasional fading on the signals collected by the two antennas, so that the switching action will be set into operation.

It will be noted that, if both signals fade at the same time, tube 15 becomes conductive and low frequency source 16 is continuously applied to electronic trigger circuit 13. This causes a continual alternation of the amplifications of tubes 5 and 6. As soon as a signal of sufficient strength appears on either antenna, the alternation is stopped by the application of the rectified signal to electronic G3 of tube 15 and the particular antenna furnishing the stronger signal remains in control. The electronic trigger circuit 13 and its controlling amplifier 15 thus act as a device which tests the strength of the signal from each antenna and leaves the receiving apparatus connected to the antenna having the strongest signal.

A more detailed description of the operation of the electronic trigger circuit 13 will now be given. Let it be assumed that anode current is being drawn by tube V1. This causes a drop in potential in resistor R1 in the anode circuit of tube V1. The drop in potential is such as to make the anode of tube V1 more negative so that a negative potential is fed through feed back resistor R to the grid of tube V. This negative potential forms a drop on grid resistor R2 which biases tube V to cut-off. With tube V at cut-off, there is no anode current through resistor R1 in its anode circuit so that the feed back to the grid of tube V1 is at its maximum positive value. All of these conditions are such as to maintain an equilibrium that will not be upset unless there is an opposing force applied by transformer 14. If this transformer applies sufficient positive voltage to the grid of tube V and sufficient negative voltage to the grid of tube V1, tube V1 will be cut off so that the grid of tube V will be swung positive. This swings the equilibrium to a condition such that tube V1 is cut off and tube V draws current. This equilibrium will be maintained until the opposite opposing voltage from 14 is sufficient to overcome it. Thus, it will be seen that the circuit "triggers" from a first condition in which one tube draws current and the other is cut off, to a second condition in which the one tube is cut off and the other draws current. The drop across the anode resistor R1 in one of the tubes throws a negative voltage on the grid of one of the radio frequency amplifier tubes 5 or 6 so as to cut it off. The other amplifier tube 6 or 5 is biased to its operating point since there is no current in the anode resistor feeding the grid of the amplifier. If the triggering force is removed, the circuit remains in the condition which existed just before the force is removed. This type of action allows the electronic trigger circuit 13 to "hunt" between the two diversity antennas 1 and 2 until one of the antennas obtains a strong enough signal to switch off the triggering force and leave the apparatus 9 connected to that antenna collecting this strong signal.

Fig. 2 shows how units of Fig. 1 may be utilized in a system employing more than two antennas. Units 20, 21 and 22 each include the two coupling tubes, the common amplifying and/or heterodyning apparatus, the rectifier, the modulator tube, and the trigger circuit as illustrated and described in connection with Fig. 1. The ap-

paratus 9 of units 20 and 21 should be of the tuned radio frequency type supplying radio frequency output. The condensers 34 in circuit with the detectors of units 20 and 21 enable the radio frequency outputs to be supplied to the unit 22. In unit 22, however, the apparatus 9 is preferably of the heterodyning type. With switch S on the upper contacts, three antennas 31, 32 and 33 are in use. With switch S on the lower contacts, four antennas 31, 32, 35 and 36 are utilized with the use of three of the units 20, 21 and 22, as described above in connection with Fig. 1. This principle could, of course, be carried further to utilize any number of antennas. The operation of the system of Fig. 2 will be obvious to one skilled in the art from what has been described above in connection with Fig. 1.

What is claimed is:

1. A fading control system comprising a pair of antennas having relatively different fading characteristics, common receiving apparatus therefor including a detector, a coupling tube between each antenna and the input of said receiving apparatus, a trigger circuit for supplying bias potentials to said coupling tubes to render them alternatively conductive, a control tube having an electrode, means coupling the output of said control tube to said trigger circuit for controlling said trigger circuit, a source of low frequency currents coupled to said electrode of said control tube to enable said control tube to pass current at the frequency of said source, and means coupled between said control tube and the detected output of said common receiving apparatus for controlling the conductivity of said control tube.

2. In a diversity receiving system, a pair of antennas having relatively different fading characteristics, common radio frequency amplifying apparatus therefor, separate tubes coupling said antennas to the input of said amplifying apparatus, and means for rendering only that coupling tube conductive upon which is impressed a strong incoming signal, said means including a trigger circuit biasing said coupling tubes such that only one of them is conductive at any one time, a detector coupled to the output of said radio frequency amplifying apparatus, a modulator tube having its output circuit coupled to said trigger circuit and its input circuit coupled to a source of low frequency currents, a lead for supplying bias potentials to said modulator tube from said detector, and a time-constant circuit connected between said lead and said detector for removing signal modulations from said lead.

3. A diversity receiving system comprising a pair of antennas having relatively different fading characteristics, separate coupling tubes for said antennas, said coupling tubes each having input and output electrodes, a radio frequency transformer between each antenna and the input electrode of its associated coupling tube, a connection between the output electrodes of said coupling tubes to provide a common output circuit, radio frequency electron discharge device apparatus having its input coupled to the common output of said coupling tubes, a rectifier in the output of said radio frequency electron discharge device apparatus, a modulator tube having a control electrode, means for supplying negative bias potentials to said modulator tube from said rectifier to thereby control the conductivity of said modulator tube, a source of low frequency current coupled to said control electrode of said modulator tube, an electronic trig-

ger circuit having two degrees of electrical stability coupled to the output of said modulator tube, and connections from the output of said trigger circuit for supplying bias potentials to said coupling tubes to enable only that coupling tube to pass current which has the strongest signal impressed thereon.

4. A diversity receiving system comprising a pair of antennas having relatively different fading characteristics, radio receiving apparatus including a rectifier, separate tubes coupling said antennas to said receiving apparatus, said coupling tubes having a common output circuit, and means for rendering that coupling tube conductive upon which is impressed a strong signal, said means including a modulator tube having a control grid, a source of low frequency currents coupled to the control grid of said modulator tube, a circuit for controlling the conductivity of said modulator tube from the rectified output of said receiving apparatus, and a circuit from the output of said modulator tube for supplying different bias potentials to said coupling tubes.

5. A diversity receiving system comprising a pair of antennas having relatively different fading characteristics, radio receiving apparatus including a rectifier, separate tubes coupling said antennas to said receiving apparatus through separate radio frequency transformers, said coupling tubes having a common output circuit, and means for rendering that coupling tube conductive upon which is impressed a strong signal, said means including a modulator tube having a control grid, a source of low frequency currents coupled to the control grid of said modulator tube, a circuit for controlling the conductivity of said modulator tube from the rectified output of said receiving apparatus, and an electronic trigger circuit under control of the output of said modulator tube for supplying different bias potentials to said coupling tubes.

6. A diversity receiving system comprising a pair of antennas having relatively different fading characteristics, a radio frequency transformer for each antenna, a coupling vacuum tube in the output of each transformer, a common output circuit for said coupling tubes, heterodyning apparatus having its input coupled to said common output circuit, a rectifier for said heterodyning apparatus, a multi-grid tube, a connection including a time-constant circuit for supplying said multi-grid tube with bias potentials from said rectifier, whereby the conductivity of said multi-grid tube is controlled by the resultant rectified currents, a source of sixty-cycle current coupled to a grid of said multi-grid tube, an electron trigger circuit having two degrees of electrical stability controlled by the output of said multi-grid tube, and connections from said trigger circuit for supplying bias potentials to said coupling tubes, whereby only that coupling tube is rendered conductive which has a strong signal impressed thereon by its associated antenna in the presence of fading of the signal at the other antenna.

7. A high frequency system comprising a common transmission medium for signals, radio receiving apparatus including a rectifier, separate paths coupling said medium to the input of said receiving apparatus, a coupling electron discharge device in each of said paths, and means for rendering only that path conductive upon which is impressed a strong signal, said means including a multi-grid vacuum tube, a circuit for controlling the conductivity of said multi-grid

7

tube from the rectified output of said receiving apparatus, a source of low frequency currents coupled to a grid of said multi-grid tube, and an electronic trigger circuit under control of the output of said multi-grid tube for supplying different bias potentials to said coupling devices.

8. The combination with a first fading control system comprising a pair of antennas having relatively different fading characteristics, radio receiving apparatus therefor, a coupling tube between each antenna and the input of said receiving apparatus, a trigger circuit for supplying bias potentials to said coupling tubes to render them alternately conductive, a control tube for controlling said trigger circuit, said control tube having an electrode structure, a source of low frequency currents coupled to an electrode of said control tube to enable said control tube to pass current at the frequency of said source, and means for controlling the conductivity of said control tube from the output of said receiving apparatus, of a second fading control system and associated apparatus same in construction to said first system, and means for supplying the alternating current outputs of said first and second fading control systems to the inputs of still a third fading control system having the same construction as said first systems, said third fading control system differing from said first and second systems solely in lacking antennas.

9. The combination with a first fading control system comprising a pair of antennas having relatively different fading characteristics, radio receiving apparatus therefor including a detector, a coupling tube between each antenna and the input of said radio receiving apparatus, a trigger circuit for supplying bias potentials to said coupling tubes to render them alternately conductive, a control tube for controlling said trigger circuit, said control tube having an electrode structure, a source of low frequency currents coupled to an electrode of said control tube to enable said control tube to pass current at the frequency of said source, and means for controlling the conductivity of said control tube from the detected output of said radio receiving apparatus, of a third antenna, and means for supplying the output of said first system and energy from said third antenna to a selecting system, said selecting system having apparatus for selecting signals from either said first system or from said third antenna.

10. A fading control system comprising a pair of wave receiving structures having relatively different fading characteristics, radio receiving apparatus therefor, a coupling tube between each wave receiving structures and the input of said receiving apparatus, an electronic control circuit having two degrees of electrical stability for supplying bias potentials to said coupling tubes to render them alternatively conductive, a control tube for controlling said electronic control circuit, said control tube including a control electrode, a source of low frequency currents of the order of sixty cycles per second coupled to said electrode of said control tube and supplying voltage thereto of such magnitude and polarity as to enable said control tube to pass current at the frequency of said source, and rectifier means coupled to the output of said radio receiving apparatus and to said control tube for producing a negative voltage of such value as to cut off the flow of current through said control tube in the presence of a strong incoming signal, said source of low frequency currents exercising control of

8

said control tube whenever the negative voltage produced by said rectifier falls below a predetermined value as a result of reduced intensity of incoming signal.

11. A high frequency system comprising a common transmission medium for signals, radio receiving apparatus including a rectifier, separate paths coupling said medium to the input of said radio receiving apparatus, a coupling electron discharge device in each of said paths, and means for rendering only that path conductive upon which is impressed a strong signal, said means including a multi-grid vacuum tube, a circuit for controlling the conductivity of said multi-grid tube from the rectified output of said radio receiving apparatus, said circuit being coupled to a grid of said multi-grid tube other than said first grid, a source of low frequency current coupled to the first grid of said multi-grid tube and an electronic trigger circuit having two degrees of electrical stability under the control of the output of said multi-grid tube for supplying different bias potentials to said coupling devices, said trigger circuit comprising a pair of interconnected electrode structures.

12. A fading control system comprising a pair of wave receiving structures having relatively different fading characteristics, radio frequency receiving apparatus therefor including a rectifier, a coupling tube between each wave receiving structure and the input of said receiving apparatus, an electronic control circuit having two degrees of electrical stability for supplying bias potentials to said coupling tubes to render them alternatively conductive, a control tube for controlling said electronic control circuit, said control tube having an electrode structure, a source of low frequency currents of the order of 60 cycles per second coupled to an electrode of said control tube to enable said control tube to pass current at the frequency of said source, a connection from said rectifier to said control tube, said rectifier producing a negative voltage on said connection to cut off the flow of current through said control tube in the presence of a strong incoming signal, said source of low frequency currents exercising control of said control tube whenever the negative voltage produced by said rectifier falls below a predetermined value as a result of reduced intensity of incoming signal.

13. A receiving system comprising radio frequency receiving apparatus including a detector and having a pair of input circuits each having an electron discharge device therein, means including a source of low audio frequency alternating current for rendering said devices alternately conductive, and means responsive to the detected output voltage from said receiving apparatus exceeding a predetermined value for removing the control of said source over said devices from said first means.

14. A receiving system comprising radio frequency receiving apparatus having a plurality of input circuits, each of said input circuits including an evacuated electron discharge device, an electronic circuit of two degrees of electrical stability and having a pair of outputs coupled to said devices for rendering them alternately conductive, said receiving apparatus including a rectifier, means coupled between the output of said rectifier and the input of said electronic circuit and responsive to a predetermined magnitude of rectified voltage for controlling the stable position of said electronic circuit and hence the

conductive condition of said devices, and a source of low audio frequency alternating current coupled to the input of said electronic circuit for controlling the stable position thereof in the absence of said predetermined magnitude of rectified voltage.

MURRAY G. CROSBY.

REFERENCES CITED

The following references are of record in the 10 file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,913,428	Bruce -----	June 13, 1933
1,959,281	Willoughby -----	May 15, 1934
2,189,317	Koch -----	Feb. 6, 1940
2,243,118	Peterson -----	May 27, 1941
2,282,526	Moore -----	May 12, 1942
2,290,992	Peterson -----	July 28, 1942