

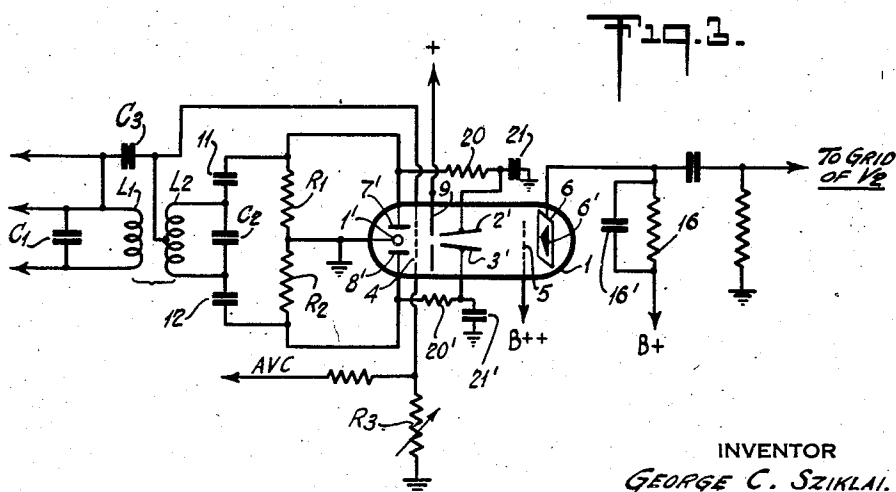
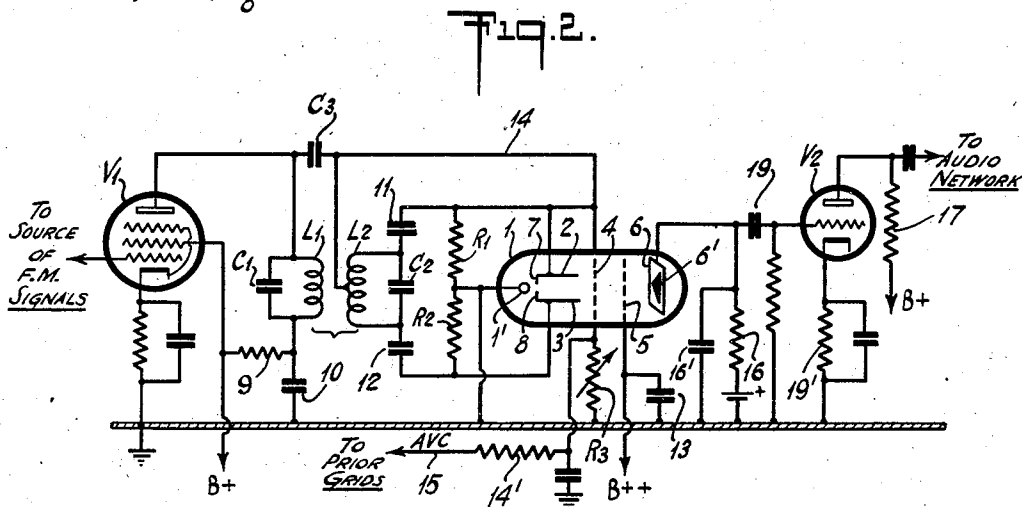
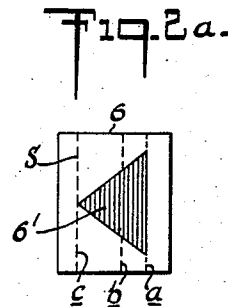
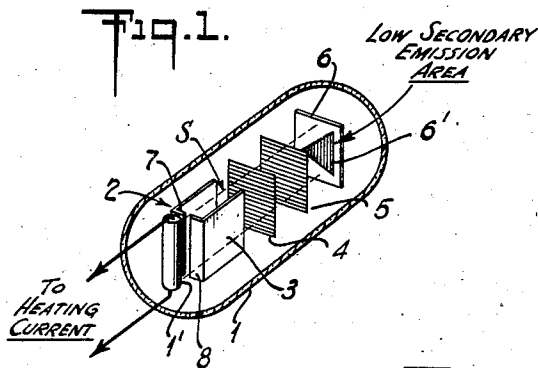
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2,408,702

ANGLE MODULATED WAVE DETECTOR

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ANGLE MODULATED WAVE DETECTOR

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My present invention relates generally to detectors of angle modulated carrier waves, and more particularly to novel circuits for detecting frequency modulated carrier waves.

As is well known, in the absence of special precautions the conventional frequency modulation (FM) detector not only has an output dependent on frequency variation, but also on intensity variation of the signal. Even in the case of a balanced FM detector circuit, which has zero output at carrier frequency, cross-modulation effects are obtained if the carrier intensity changes during production of output energy in response to frequency deviation, i. e. simultaneously with reception of frequency-modulated signals. In the past an amplitude limiter stage has been used prior to the FM detector to minimize such carrier intensity changes. Limiters are, in general, clipper tubes which require a minimum signal to operate, and this minimum signal (threshold improvement level) determines the sensitivity of the detector and of the receiver. While a limiter normally has a high gain when it is not clipping, a comparatively large portion of the gain is diverted into amplifying carrier harmonics during actual limiting. For this reason the stability of the preamplifier is diminished for the weak signal, or no-signal, state, and the receiver generally requires a noise muting circuit to suppress reproduction of inter-station noises which appear during the normal tuning process.

It is an important object of my invention to provide a detector for FM waves which is substantially non-responsive to carrier intensity variation without the use of a special limiter stage prior to the FM detector.

In the conventional and prior FM detectors of the type employing opposed rectifiers, usually one electron emitter cannot be connected to ground, and, therefore, a tube with indirectly heated cathode must be used thereby requiring increased filament power. This latter fact is particularly objectionable in battery-operated receivers. Another important object of my invention, therefore, is to improve the construction and gain of FM detector tubes by employing a beam type of tube permitting the use of a grounded primary electron emitter.

It is a further object of my present invention to provide a beam tube employing a target element having portions capable of emitting secondary electrons, and means for controlling the electron beam of the tube so as to minimize the effects of intensity variations of the received energy on the output current of the tube.

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Another object of my invention is to provide deflection electrodes in a beam tube which are additionally adapted to function as anodes of diode rectifiers.

Another object of this invention is to provide a beam tube detector for FM waves, wherein frequency variable waves cause relatively different emission variations from a pair of secondary emission surfaces thereby to provide a resultant useful output voltage.

Still another object of this invention is to improve reception of angle modulated carrier waves by producing variable secondary electron emission from an output electrode in response to phase departures of a pair of signal voltages from a normal phase relation, variations in amplitude of the signal voltages being automatically compensated for by control of said variable emission.

Still other objects of my invention are to improve generally the efficiency and stability of FM receivers, and to provide an amplitude limiter-free FM receiver system which is economical to manufacture and assemble.

The novel features which I believe to be characteristic of my invention are set forth with particularity in the appended claims; the invention itself, however, as to both its organization and method of operation will best be understood by reference to the following description, taken in connection with the drawing, in which I have indicated diagrammatically several circuit organizations whereby my invention may be carried into effect.

In the drawing:

Fig. 1 shows the electrodes of a beam tube of the type employed in my invention,

Fig. 2 shows FM detector circuits employing the tube of Fig. 1,

Fig. 2a shows different positions of the electron beam on the target,

Fig. 3 shows a modified tube and circuit.

Referring now to the accompanying drawing, wherein like reference numerals in the different figures designate similar circuit elements, there is shown in Fig. 1 a tube envelope 1 of any desired configuration. The electron emitter of the tube is an indirectly heated cathode 1' which is laterally arranged relative to the axis of the tube. The emitter 1' may be of the filament type, if desired. The emitter 1' provides a beam or sheet of electrons S which passes through a narrow space or slit between the forward wings or flanges 7 and 8 of respective deflection plates 2 and 3. The plates 2 and 3 are spaced in parallel rela-

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tion, and the flanges 7 and 8 are each bent normally to the planes of the plates. As will be explained in further detail at a later point, flanges 7 and 8 function as respective spaced diode anodes relative to common cathode 1'. The beam or sheet of electrons S passes through spaced control grids 4 and 5 and falls on target plate 6. The latter, as shown, is provided with a central triangular area 6'.

The target 6 is of conducting material, and one portion of its inner face is a high secondary electron emission surface, i. e. it emits a copious flow of secondary electrons upon bombardment by the beam of primary electrons S. However, the dark area 6' of the target 6 has a relatively low secondary emission characteristic, so that upon bombardment of area 6' by the beam of electrons S relatively less secondary electrons are emitted therefrom. The area 6' may be provided by a coating of carbon for poor secondary electron emission, while the high secondary electron emission may be provided by a caesium oxide coating. Further, the target 6 could be made of silver-magnesium alloys, or caesium on silver. In either of the latter cases there would be formed on the target the low emission area 6'. If desired, the area 6' of the target may be the smaller portion of the entire area of target 6.

When the beam S is deflected in such a way that the major portion of the electrons thereof land on the high secondary emission surface of target 6, a large number of negative secondary electrons leave the latter. Hence, the target assumes a relatively positive potential. On the other hand, when the beam is deflected so that the major portion of the electrons hits the low emission surface 6', less electrons leave the target 6 than are collected. Hence, the target becomes relatively negative in potential. The tube shown in Fig. 1, therefore, provides a device for varying the effective potential of an electrode by sweeping a beam of electrons across secondary emission surfaces of different emissivity in accordance with the relative potentials of a pair of beam control electrodes.

In Fig. 2 I have shown tube 1 connected in an FM receiver to function as an FM detector. The FM receiver is assumed to be a superheterodyne receiver employed in the 42-50 megacycle (mc.) band, the presently-assigned FM broadcast band. In that band each carrier frequency is deviated in accordance with modulation signals. The extent of frequency deviation is a function of modulation signal amplitude, while the rate of deviation is dependent upon the modulation frequencies per se. The permissible frequency deviation or swing, in accordance with present broadcast transmitting standards, is a maximum of 75 kilocycles (kc.) to each side of the carrier frequency. The invention is not restricted to the FM frequency range of 42-50 mc., nor to FM wave reception, nor to the specific over-all deviation range of 150 kc. The term "angle modulated carrier wave" used in this specification includes phase modulated (PM) carrier waves or FM carrier waves, or hybrid modulations of PM and FM possessing characteristics of each.

The tube V₁ is an amplifier preceding the usual discriminator network feeding the tube 1. Amplifier V₁ may be a non-limiting intermediate frequency (I. F.) amplifier whose input electrodes are coupled to a prior I. F. amplifier, or to a converter. The networks which precede I. F. amplifier tube V₁ are of suitable and usual construction. They may comprise a signal collector and

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one or more selective high frequency amplifiers followed, if the receiving circuits are of the superheterodyne type, by a converter which functions to produce the intermediate frequency (I. F.) signal energy.

The I. F. signal energy may be of a mean frequency chosen from a range of 2 to 15 mc., for example 4.3 mc. My invention is not limited to the specific I. F. band, as values up to 100 mc. can be used. The amplifier V₁ amplifies the I. F. signal energy at the selected 4.3 mc. value. In the plate circuit of amplifier V₁ there is arranged a resonant circuit C₁-L₁ tuned to the operating I. F. value. The low potential side of circuit C₁-L₁ is connected to the B+ terminal of the direct current energizing source through resistor 9, while condenser 10 bypasses all I. F. currents to ground. Resonant circuit L₂-C₂ is tuned to the operating I. F. value. Coils L₁ and L₂ are magnetically coupled, while direct current blocking condenser C₃ connects the midpoint of coil L₂ to the high alternating potential side of circuit C₁-L₁. The network C₁-L₁ and C₂-L₂ and its associated elements provide a form of frequency discriminator disclosed and claimed by S. W. Seeley in his U. S. Patent No. 2,121,103, granted June 21, 1938. My invention is not restricted, however, to this specific form of discriminator, as any other form of suitable frequency discriminator circuit may be used prior to the tube 1.

The output terminals of circuit C₂-L₂ are connected to the control electrodes of tube 1. Electron emitter 1' of tube 1 (the latter is schematically represented in Fig. 2) is connected to ground, and also to the junction of resistors R₁ and R₂. The latter two elements are connected in series across the tuned circuit C₂-L₂. The direct current blocking condenser 11 connects one side of secondary circuit C₂-L₂ to the upper end of resistor R₁, whereas the blocking condenser 12 connects the opposite side of circuit C₂-L₂ to the lower end of resistor R₂.

Deflection plate 2 is connected to resistor R₁, and deflection plate 3 is connected to resistor R₂. It will be seen that each of diodes 1'-7 and 1'-8 is connected in shunt with a respective one of resistors R₁ and R₂, the junction of the latter being at ground potential. The grid 5 is established at a suitable positive potential B++, the voltage supply lead being properly bypassed to ground for I. F. currents by condenser 13. The grid 5 acts, therefore, as a positive screen grid. Grid 4 is connected by lead 14 to condenser C₃ so that the I. F. voltage across primary circuit C₁-L₁ is applied to grid 4. A resistor R₃ is connected from grid 4 to ground thereby to develop across the resistor, in a manner further described hereinafter, a rectified voltage which, after filtering at 14' in the usual manner, is used for A. V. C. bias. The A. V. C. (automatic volume control) bias may be applied by lead 15 to the signal control grids of prior signal transmission tubes for the customary A. V. C. action.

The target or secondary emitter 6 may be connected directly to ground. However, it is preferred rather to connect target 6 to a potential point which is positive relative to ground, but which is kept substantially less positive than the potential of screen 5. In Figs. 2 and 3 the lower positive potential of electrode 6 is denoted by one plus sign, in place of the two plus signs of screen 5. This positive potential of target 6 will permit the landing of an increased number of primary electrons, and thereby augments the emission of secondary electrons. While it is

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true that the target 6 would assume a positive potential due to the net loss of electrons anyway, target voltages of higher gain can be obtained if the target is started at a positive potential. The screen 5, of course, functions as an electron collector, since it collects all secondary electrons emitted by the target 6. The target 6 is connected to its B+ terminal by resistor 16 bypassed to ground by condenser 16' for I. F. currents.

The voltage developed across resistor 16 is modulation signal voltage. It corresponds to, and is representative of, the modulation signals employed to modulate the carrier at the FM transmitter. The modulation amplifier V₂ has its input grid electrode coupled to the resistor 16 by blocking condenser 19 to amplify the modulation signal voltage across the latter. The resistor 16 is a high impedance element and provides high gain for amplifier V₂. The amplified modulation signal voltage is developed across the resistor 17 arranged in the plate circuit of tube V₂. Bypassed cathode bias resistor 19' provides normal negative bias of amplifier V₂. The amplified voltage, when of audio frequency, will be further amplified and finally reproduced in any desired manner.

There will now be explained the manner in which the present circuit functions to derive the modulation voltage from the FM waves. The I. F. or other high frequency signal energy at primary circuit C₁—L₁ is induced in the secondary circuit C₂—L₂ by the magnetic coupling therebetween. The induced voltage undergoes a phase shift of substantially 90° when the I. F. energy mean frequency is equal to the predetermined resonant frequency of the coupled tuned circuits. The phase-shifted voltage is applied to plates 2 and 3 in push-pull relation due to the midtap on coil L₂. The primary voltage is also applied to the midpoint of coil L₂ through condenser C₃. This voltage is applied in parallel relation to plates 2 and 3, and suffers no phase shift since blocking condenser C₃ is too large in capacity value to cause a phase shift in the voltage applied therethrough.

Hence, at each of deflection plates 2 and 3 there exists a resultant voltage which is produced by the vectorial combination of one of the parallel voltages and one of the phase-shifted voltages. The resultant voltages at the deflection plates are in phase quadrature and of equal magnitude for the condition of resonance between the mean frequency of the I. F. energy and the predetermined resonant frequency of the discriminator circuit. Should the mean frequency of applied I. F. energy instantaneously depart from the resonance condition, the phase relations will depart from the quadrature relation, and the resultant voltages will be unequal. It will, therefore, be seen that the resultant voltages on diode anodes 7 and 8 and the respective deflection plates 2 and 3 vary in relative magnitude in response to the frequency deviations of the applied I. F. energy.

The beam or sheet of electrons S, whose plane is normal to the plane of target 6, is shifted or deviated in response to the variations of the magnitudes of the resultant voltages provided at the deflection plates 2 and 3. It will be recalled that tube V₁ is a non-limiting amplifier, and applies both frequency and amplitude variations of the carrier to the circuit C₁—L₁. The resultant voltages at each end of L₂—C₂ are rectified by respective diodes 1'—7 and 1'—8. Thus, there is developed across each of resistors R₁ and R₂ rec-

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tified voltages derived from the respective resultant voltages. These rectified voltages will be equal at resonance, and be unequal in response to inequality of the resultant vector voltages at the ends of L₂—C₂. The effect of the rectified voltages across R₁ and R₂, impressed on deflection plates 2 and 3 respectively, on the sheet of electrons S will be to deviate the latter relative to its normal median position and in accordance with frequency modulation of the received signal.

Fig. 2a shows the manner in which the target is swept by the beam or sheet of electrons S. When the deflection plate 2 is more negative than the deflection plate 3 the electrons will be deflected towards the plate 3. The dotted line *a* of Fig. 2a shows the vertical line of bombardment of target 6 at the instant when deflection plate 2 is most negative relative to deflection plate 3. Since few secondary electrons are emitted from the high emission surface of the output electrode or target 6 because such surface is not impacted by the electron beam, and the area 6' struck by the electron beam is of low secondary electron emissivity, so that negative electrons collect on the target, the target 6 is at its least positive potential.

When the plates 2 and 3 are instantaneously of the same negative potential, as when the center frequency of applied signal energy is equal to the resonant frequency of the discriminator circuit, the sheet of electrons S will be in the median position. The dotted line *b* in Fig. 2a represents the line of bombardment of target 6 in such case. In this case the electron beam may be divided substantially equally between the high secondary emission area and the low emission area 6' of the target 6, and the output electrode 6 assumes a median potential which is positive relative to its biasing potential B+. The potential of output electrode 6 under this condition is more positive than in the case when the electrons fall at line *a*. If the deflection plate 3 should assume its most negative potential, for which the circuits are designed relative to plate 2, then the dotted line *c* in Fig. 2a would represent the deflection of electrons towards plate 2. Here the electron beam impacts substantially entirely on the high secondary electron emission area of the target electrode 6, and the maximum number of negative recording electrons leaves the target. Hence, the electrode 6 attains its most positive potential which most closely approaches the potential of screen grid 5. It will accordingly be understood that the potential of output electrode 6 varies from a more positive to a less positive value as the electron beam sweeps from line *c* to line *a*, and from a less positive to a more positive value as the electron beam moves in the opposite direction. This develops a corresponding potential across high impedance 16, which is amplified with high gain at modulation amplifier V₂. The secondary emission is collected by screen 5. When this emission is large the target 6 appears to be connected to screen 5 through the resistance of the secondary emission. In other words, the secondary electron stream from target 6 to collector 5 functions somewhat in the manner of a connector of variable resistance. The magnitude of the effective resistance depends on the position of beam S on the target 6. When the emission from target 6 to screen 5 is high, then target 6 is effectively closer to B++ in potential.

When beam 5 is at line *b* of Fig. 2*a*, the applied FM waves are at mean frequency.

As heretofore indicated, the constants of the tube 1 and its circuits are preferably so adjusted that the sheet of electrons *S* is swept between lines *c* and *a* of Fig. 2 as limits. The purpose of this is to keep the beam from sweeping to the right of line *a*, and rendering the electrode 6 highly positive thereby producing a false impression that the beam is really at line *c*. Of course, cutting the target at line *a* will, also, prevent over-swinging of the beam. In order to eliminate the effect of any change in the amplitude of the carrier, the primary voltage at C_1-L_1 is applied through condenser C_3 without phase shift. The electrode 4 acts in the manner of an anode of a diode rectifier consisting of electrodes 1' and 4. Resistor R_3 is the load resistor, and direct current voltages thereacross are proportional to carrier amplitude variations. The direct current voltage across resistor R_3 will bias control grid 4 negatively with respect to ground. This negative bias will affect the intensity of the beam current and the consequent secondary electron emission from target 6.

Accordingly, the potential variation of target 6 will be reduced when the carrier amplitude is increased, and the reverse will be true when the carrier amplitude is decreased. This will prevent any increase in the slope of the typical discriminator characteristic if carrier amplitude increases. By the proper adjustment of the magnitude of resistor R_3 the gain control by virtue of the action of grid 4 or the intensity of the electron beam can fully compensate for the varying deflection due to carrier amplitude changes, simultaneously with the reception of frequency modulated signals. In other words, the variable-bias grid 4 functions to minimize the effect of carrier amplitude variation on the electron stream *S* which flows to the target 6. Amplitude variations which occur at times of no signal reception balance out by having equal effects on the potentials of the deflection plates. For these reasons the amplifier V_1 may be a non-limiter device. Furthermore, as heretofore stated, the voltage across resistor R_3 may be used for biasing previous signal transmission tubes thereby functioning as a usual A. V. C. circuit.

In Fig. 3 I have shown a modified form of circuit, wherein the deflecting plates of tube 1 do not function as diode anodes. In this modification special electrodes 7' and 8' are employed on either side of the cathode 1', the electrodes 7' and 8' functioning as the anodes of diodes 1'-7' and 1'-8'. The deflection plates are divergent, and are indicated by numerals 2' and 3'. The resistors R_1 and R_2 in this case are connected as before between the anodes and the common cathodes of the respective diodes. The compensating grid 4 is located in this modification closely adjacent to emitter 1' in order to provide better control action. Furthermore, a beam-forming electrode 9 is utilized between grid 4 and the input end of the deflection plates to provide a well-defined beam on the target 6.

In the modified embodiment of Fig. 3 the resultant vector voltages at the opposite sides of secondary circuit C_2-L_2 are applied to diodes 1'-7' and 1'-8' for rectification. The load resistors R_1 and R_2 , respectively in circuit with the last mentioned diodes, develop across each of them the required direct current voltages for variable biasing of deflection plates 2' and 3'. The filters 20-21 and 20'-21' prevent any I. F.

voltages from affecting the deflection plates. Since each of plates 2' and 3' are connected to the respective anode ends of resistors R_1 and R_2 , they will function in the same manner as explained in connection with Fig. 2. The control grid 4, being adjacent the electron emission surface of cathode 1', will exercise a rigid control over the primary electron emission. As in the case of Fig. 1, the primary circuit (C_1-L_1) voltage is applied to grid 4, and the rectified voltage across adjustable resistor R_3 is used to vary the intensity of the beam of electrons sweeping the target 6. The rectified voltage across resistor R_3 , after proper filtering, may be used for A. V. C. bias. The embodiment of Fig. 3 functions otherwise in the manner described in connection with the preferred circuit of Fig. 2.

The area 6' of target 6 need not be restricted to a triangular configuration. If the beam of electrons is sufficiently thick, the target could have one path of its active face provided with a carbon coating and the other half could be a caesium surface. In this way according to the area of the beam landing on either surface, the potential of target 6 would vary. It is preferred to employ a triangular low emission area 6', since it is a simple configuration and is particularly suitable for the practice of my invention.

While I have indicated and described several systems for carrying my invention into effect, it will be apparent to one skilled in the art that my invention is by no means limited to the particular organizations shown and described, but that many modifications may be made without departing from the scope of my invention.

What I claim is:

1. In combination with a beam tube of the type having an output electrode provided with a secondary emission area of predetermined non-uniform configuration, means, adapted to be responsive to phase displacements of a pair of alternating current voltages from a predetermined normal phase relation, for sweeping the electron beam of said tube over said area thereby to vary the potential of said output electrode and means responsive to amplitude variations of said voltages for automatically controlling the intensity of said beam.

2. In an angle modulated carrier wave receiver, a demodulator of the beam tube type provided with an output electrode having at least two secondary electron emission areas of different predetermined non-uniform configurations and of different emissivities, one of said areas completely surrounding the other area means for translating received waves into a pair of modulated wave voltages of equal magnitude for the condition where the mean frequency of the received waves is equal to that of a predetermined reference frequency, means responsive to instantaneous inequalities of said pair of voltages for variably deflecting the electron beam of the demodulator tube in such a manner as to variably sweep the beam across said two areas, and means for deriving from said output electrode a voltage representative of the modulation of the received waves.

3. In an angle modulated carrier wave receiver, a demodulator of the beam tube type provided with an output electrode having at least two secondary electron emission areas of different non-uniform configurations and of different emissivities, means for translating received waves into a pair of modulated wave voltages of equal magnitude for the condition where the mean fre-

quency of the received waves is equal to that of a predetermined reference frequency, means responsive to instantaneous inequalities of said pair of voltages for variably deflecting the electron beam of the demodulator tube in such a manner as to variably sweep the beam across said two areas, means for deriving from said output electrode a voltage representative of the modulation of the received waves, and means, responsive to carrier amplitude variation, for controlling the intensity of said beam in a sense to render said output electrode voltage independent of said carrier amplitude variation.

4. In combination with a beam tube of the type having an output electrode provided with a secondary emission area of predetermined non-uniform configuration, means, adapted to be responsive to phase displacements of a pair of alternating current voltages from a predetermined normal phase relation, for sweeping the electron beam of said tube over said area thereby to vary the potential of said output electrode, and means, responsive to amplitude variation of said alternating current voltages, for controlling the intensity of said beam in a sense to render the output electrode potential independent of said amplitude variation.

5. In a receiver of frequency modulated carrier waves, a discriminator network for deriving from received waves a pair of voltages whose relative magnitudes are a function of frequency deviations of the mean frequency of the received waves with respect to a predetermined reference frequency, means providing a beam of electrons, an output electrode provided with a non-uniform secondary emission surface adapted to be traversed by said beam thereby to vary the effective potential of the output electrode, a pair of beam control elements, and means responsive to variations in the relative magnitudes of said pair of voltages, for differentially biasing said beam control elements to control the secondary emission from said surface.

6. In combination with a beam tube of the type having a target provided with a secondary emission area of predetermined non-uniform configuration, means, adapted to be responsive to phase displacements of a pair of alternating current voltages from a predetermined normal phase relation, for sweeping the electron beam of said tube over said area thereby to vary the potential of said output electrode, and means responsive to the amplitude of at least one of said alternating current voltages for controlling the intensity of the electron beam.

7. In an angle modulated carrier wave receiver, a demodulator of the beam tube type provided with an output electrode having at least two secondary electron emission areas of different emissivities and different non-uniform shapes, one of

said areas completely surrounding the other area, means for translating received waves into a pair of modulated wave voltages of equal magnitude for the condition where the mean frequency of the received waves is equal to that of a predetermined reference frequency, and means responsive to instantaneous inequalities of said pair of voltages for variably deflecting the electron beam of the demodulator tube in such a manner as to variably sweep the beam across said two areas.

8. In an angle modulated carrier wave receiver, a demodulator of the beam type provided with an output electrode having at least two secondary electron emission areas of different predetermined non-uniform configurations and of different emissivities, means for translating received waves into a pair of modulated wave voltages of equal magnitude for the condition where the mean frequency of the received waves is equal to that of a predetermined reference frequency, means responsive to instantaneous inequalities of said pair of voltages for variably deflecting the electron beam of the demodulator tube in such a manner as to variably sweep the beam across said two areas; and means, responsive to carrier amplitude variation, for controlling the intensity of said beam in a sense to render output electrode voltage independent of said carrier amplitude variation.

9. In combination with a beam tube of the type having an output electrode provided with a secondary emission area of predetermined non-uniform configuration, means, adapted to be responsive to phase displacements of a pair of alternating current voltages from a predetermined normal phase relation, for sweeping the electron beam of said tube over said area thereby to vary the potential of said output electrode, and a grid in said beam, responsive to amplitude variation of said alternating current voltages, for controlling the intensity of said beam in a sense to render the output electrode potential independent of said amplitude variation.

10. In a receiver of frequency modulated carrier waves, a discriminator network for deriving from received waves a pair of voltages whose relative magnitudes are a function of frequency deviations of the mean frequency of the received waves with respect to a predetermined reference frequency, means providing a beam of electrons, an output electrode provided with a non-uniform secondary emission surface adapted to be traversed by said beam thereby to vary the effective potential of the output electrode, and a pair of beam control elements, responsive to variations in the relative magnitudes of said pair of voltages, to control the secondary emission from said surface.

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