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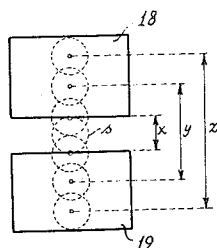
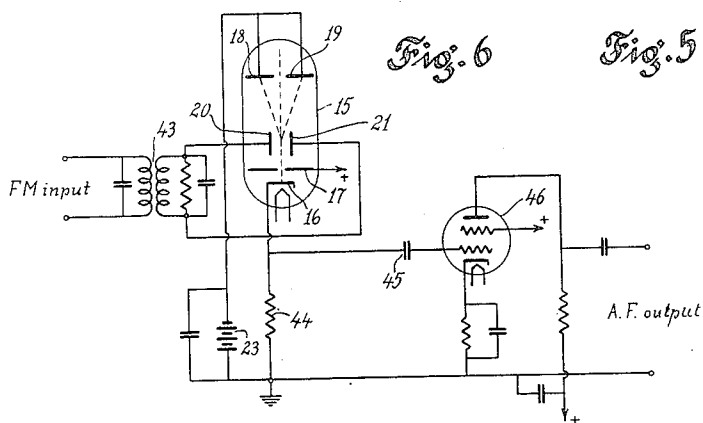
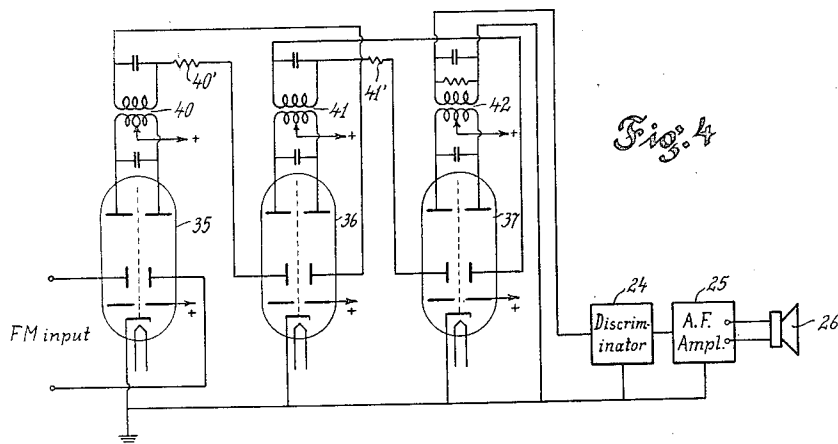
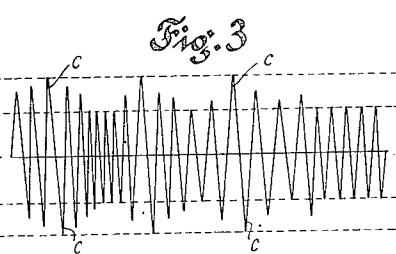
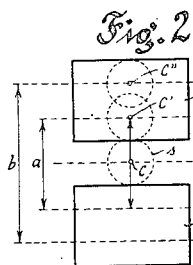
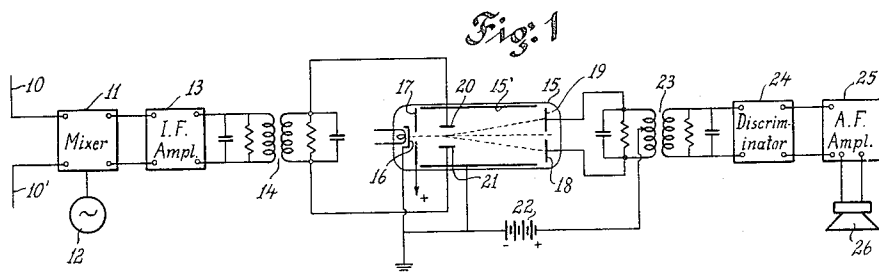
K. RATH

2,262,406

FREQUENCY MODULATION SYSTEM

Filed Nov. 26, 1940

2 Sheets-Sheet 1



INVENTOR

Kul Nam

Nov. 11, 1941.

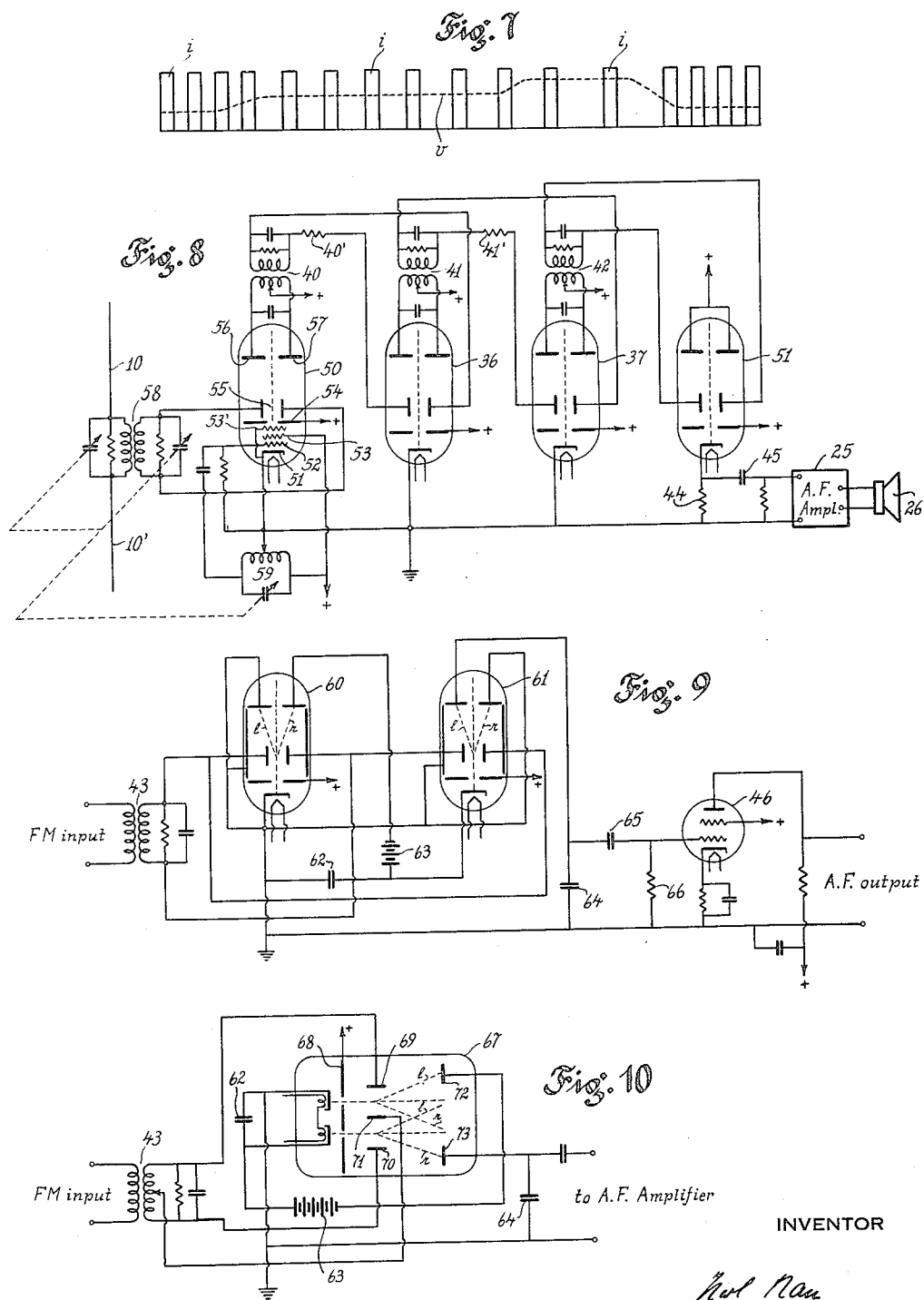
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FREQUENCY MODULATION SYSTEM

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2 Sheets-Sheet 2



UNITED STATES PATENT OFFICE

2,262,406

FREQUENCY MODULATION SYSTEM

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Application November 26, 1940, Serial No. 367,180

10 Claims. (Cl. 250—20)

The present invention relates to frequency modulation systems and methods of operating the same, more particularly to frequency modulation receivers, and has for its general object both to simplify the design and to improve the efficiency of such receivers.

As is well known, one of the main advantages of frequency modulation over amplitude modulation in substantially increasing the signal-to-noise ratio in the receiver is based on the condition that the receiver is responsive to frequency modulated signals only and that amplitude modulation caused by noise or other interference is substantially prevented from affecting the receiver output. In this manner only comparatively weak noise caused by phase or frequency modulation of the carrier vector by a noise vector received from the outside or noise produced in the receiver itself will appear in the output of the receiver, while the comparatively stronger noise or interference due to amplitude modulation of the carrier by the noise vector will be suppressed by the action of the receiver. This frequency modulation noise may be further reduced to an inappreciable level by the use of a wide phase or frequency deviation (± 75 kc. according to present standards) as well as by pre-emphasis and de-emphasis of the higher signal frequencies in the transmitter and the receiver, respectively.

The frequency modulation detectors or discriminators at present known and used are also responsive to a more or lesser degree to amplitude modulation and accordingly one of the essential and fundamental elements of a frequency modulation receiver is the so-called limiter designed to remove amplitude modulation from the received signals caused by noise or other interference prior to the application of the signals to the discriminator or frequency demodulator of the receiver.

The limiters at present in general use are essentially a vacuum tube designed to level the amplitudes of an impressed signal voltage by operation beyond the saturation or plate cut-off point. Such a device, while effective in producing the desired amplitude limiting or clipping action, has a number of disadvantages one of which is the fact that a substantial input voltage is required to operate the tube in the plate cut-off or saturation region. This in turn requires either high radiating power at the transmitting station to ensure sufficient field strength at the receiver resulting in a substantial output voltage of an R. F. or I. F. amplifier preceding the limiter

tube of the receiver. This is not only costly but contrary to the present trend and inherent advantages of frequency modulation broadcasting to prevent mutual interference between stations by the provision of a large number of low power transmitting stations each covering a limited surface area in place of a few high power transmitters designed for greater coverage as in the case of amplitude modulation broadcasting. Moreover, the range of frequency modulation transmitters operating with ultra short waves in the 43 to 50 mc. band assigned to frequency modulation broadcasting is theoretically restricted to the line-of-sight limit which again in turn makes the use of superpower transmitters undesirable.

A major requirement for frequency modulation receivers is therefore to provide sufficient signal amplitude for effectively operating a limiter in the receiver and this requirement with the present limiters necessitates a considerable number of pre-amplifying stages in either the R. F. or I. F. sections of the receiver. Such an increased number of amplifying stages in turn has the effect that the fluctuation or random noise originated by thermal agitation, shot effect etc., in the tubes and circuit elements as well as any received noise or interference is amplified to a considerable magnitude whereby differentiation or separation in the limiter and discriminator becomes more difficult.

Another disadvantage of the limiters at present being used in frequency modulation receivers is the fact that the limiting or amplitude leveling action is an imperfect one due to the curved shape of the saturation characteristic of an electron discharge tube whereby a certain amount of amplitude modulated noise may be passed and demodulated in the discriminator or detector stage.

Accordingly, an object of the present invention is to provide a new type of limiter for frequency modulation receivers capable of effecting a practically perfect levelling of the signal amplitudes to a constant value.

Another object is the provision of a limiter capable of operating with a substantially reduced input signal amplitude compared with limiters in use at present, thereby eliminating the necessity of an excessive number of preceding amplifying stages.

A further object is to reduce the number of parts required in a frequency modulation receiver without sacrificing other desirable design and operating characteristics.

Another object is to provide a combined limiter and frequency discriminator capable of converting weak frequency modulation signals and being substantially non-responsive to amplitude modulation.

Still a further object is the provision of a new type of amplifier-limiter discharge tube for use in frequency modulation receivers whereby a gradually increasing limiting effect may be secured in successive amplifying stages in a most economical and easy manner.

The foregoing and further objects and advantages of the invention will become more apparent from the following detailed description taken with reference to the accompanying drawings forming part of this specification and wherein:

Figure 1 is a circuit diagram partly in block form for a frequency modulation receiver embodying a limiter-amplifier constructed in accordance with the principles of the invention,

Figure 2 is a partial diagram and Figure 3 shows a curve representing a frequency modulated signal explanatory of the function and operation of the invention,

Figure 4 shows a system comprising a plurality of limiter-amplifier tubes according to the invention connected in cascade, whereby a gradually increasing limiting effect is obtained in successive amplifying stages,

Figure 5 is a diagram explanatory of the function of Figure 4,

Figure 6 shows a composite limiter-frequency discriminator stage embodying the principles of the invention,

Figure 7 is an explanatory diagram showing the shape of the output signal pulses obtained in Figure 6,

Figure 8 is a modification of Figure 4 showing a complete frequency modulation receiver embodying a discriminator as shown in Figure 6, and

Figures 9 and 10 are diagrams showing a modified frequency discriminator utilizing limiter-discharge tubes in accordance with the invention.

Like reference characters identify like parts in the different figures of the drawings.

With the aforementioned objects in view, the invention involves in general the adaptation and use of as well as circuit arrangements embodying one or more electron discharge tubes operating on the deflecting principle as amplifiers, limiters and frequency discriminators or detectors in a frequency modulation system, in particular a frequency modulation receiver. Such tubes, in contrast to the known electron discharge tubes, utilize a concentrated electron beam produced from a suitable source or cathode in conjunction with a suitable electron gun or focussing arrangement which electron beam is deflected by the input potential by the aid of a suitable deflecting arrangement to strike a target or output electrode with varying cross-sectional areas thereby effecting a control of the output current collected by the latter. Tubes of this type present various advantages in frequency modulation primarily as limiters as well as amplifiers and frequency detectors as will become evident from the description of the various practical embodiments presented in the following.

Referring more particularly to Figure 1, there is shown an antenna for receiving frequency modulated waves, said antenna having the form of a di-pole or doublet 10-10' connected to the signal input circuit of a first detector or mixer stage 11 wherein the received radio frequency

signals are combined with local signals generated by an oscillator 12 to produce intermediate frequency signals impressed upon the intermediate frequency amplifier 13 for selective and efficient amplification. The amplified intermediate frequency signals are applied to the input of the special limiter constructed and operated in accordance with the invention by way of a resonant transformer or band-pass filter 14 designed in a known manner such as by the provision of damping resistors to pass the wide band frequency modulated ultra-short wave signals (± 75 kc. with respect to the carrier according to present standards).

The limiter stage shown in Figure 1 comprises an electron discharge tube 15 of the so-called deflector type having in the example shown a source of electrons or cathode 16, an electron gun for focussing the electrons into a beam or pencil in the form of an apertured focussing anode 17, a pair of target or output electrodes 18 and 19 arranged at opposite sides of the central axis of the electron beam in its zero or non-deflected position and a deflecting arrangement such as a pair of electrostatic deflecting plates 20 and 21 for sweeping the electron beam from its zero position over the targets 18 and 19. The latter are connected in push-pull to the primary winding of resonant output transformer or band pass filter 23. Item 22 represents a high tension or anode current source having its negative pole connected to the grounded cathode 16 and having its positive pole connected to the center or mid tap point of the primary winding of the transformer 23. Any known type of focussing or electron gun arrangement and deflecting system may be employed for the purpose of the invention. The inner surface of the tube 15 is preferably provided with a grounded metal coating or shield 15' to prevent objectionable wall charges liable to interfere with the proper function of the tube.

The operation of this tube as an amplifier and limiter will be described in connection with Figures 2 and 3. If a frequency modulated voltage supplied by the secondary of the coupling transformer 14 is impressed upon the deflecting plates 20 and 21, the electron beam will oscillate in the rhythm of the instantaneous impressed frequency thus alternately striking the targets 18 and 19. At the instant when the signal voltage passes through zero the electron beam whose cross-section is shown at *s* in Figure 2 will be in the central position *C* between targets 18 and 19. As the signal voltage increases in the positive direction the beam will be deflected towards the target 19 whereby gradually increasing cross-sectional areas of the beam will be impinged upon the target thus causing an output current of corresponding increasing strength to flow from the positive pole of source 22 through the upper half of the primary winding of the transformer 23, the electron beam as return path to the cathode and back to the negative pole of source 22. When the electron beam has reached the position shown at *C'*, the output current through the transformer 23 will have reached its maximum and a further increase of the input voltage and consequent deflection of the electron beam will have no effect on the output current up to a point when the beam reaches the position shown at *C''*, since within the region from *C'* to *C''* the impinged cross-sectional area remains constant. The opposite effect occurs when the beam returns after the signal voltage has reached its maximum and increases in the opposite direction after passing

through zero when the beam will strike the lower target 18 and an output current will flow through the lower half of the primary winding of the transformer 23.

From the foregoing, it is seen that in addition to the amplifying action of the tube, an amplitude limiting effect is obtained within the range between the excursion a of the electron beam from its zero or central position and a maximum excursion b determined by the design and construction of the tube. If the beam is deflected beyond the point C'' , the amplitude of the output signal will decrease again and become zero after the beam has passed the outer edge of the target. Thus by proper design of the diameter of the electron beam and of the spacing between the targets 18 and 19, amplitude changes above a definite limit are effectively removed or levelled as illustrated in Figure 3 showing the signal voltage of a frequency modulated oscillation as a function of time with the sinusoidal wave shape represented by triangles for ease of illustration. In this manner undesired amplitude modulation or amplitude noise peaks as shown at c will be efficiently removed and a pure frequency modulated wave impressed upon the subsequent frequency variation response circuit or discriminator 24 adapted to produce an output current proportionate to the instantaneous frequency changes which may be an audio or other signal current applied to an audio amplifier 25 for further amplification and operation of a translating device, such as a loud speaker 26. If desired, the marginal configuration of the target plates 18 and 19 may be suitably shaped to secure a desired relationship between the output current changes and the impressed input voltage. However, deviations of the output current from the sinusoidal shape of the input voltage will be compensated by the effect of the resonant transformer 23 so that the shape of the electron beam and of the targets is by no means critical.

Referring to Figure 4, there is shown a system comprising a plurality of deflector type amplifying tubes connected in cascade for obtaining a gradually increased limiting action in accordance with the invention. A frequency modulated input voltage which may be derived from an antenna circuit or radio frequency or intermediate frequency transformer is impressed upon the deflector plates of a first tube 35 constructed substantially like tube 15 in Figure 1. The amplified and/or limited output signals produced by this tube are in turn impressed upon the deflector plates of a subsequent stage 36 by way of resonant transformer or band-pass filter 40 and the output signal voltage obtained from tube 36 is applied to the input plates of a third stage 36 by way of resonant transformer 41. The output of tube 37 in the example shown is applied to the discriminator 35 by way of resonant transformer 42. The discriminator feeds an audio frequency amplifier 25 energizing a loud speaker 26 in substantially the same manner to that shown in Figure 1.

The design and adjustment of the tubes 35, 36 and 37 in Figure 4 may be as shown in Figure 5 whereby the excursion of the electron beam of tube 35 in both directions extends within the limits x resulting in a certain initial amplification of weak input signals. The excursion of the beam of tube 36 by the amplified signal voltage supplied by the output of tube 35 extends within the limits y resulting in additional amplification and a certain initial limiting effect within the

region between excursions x and y . The excursion of the electron beam of the last tube 37 caused by the amplified output voltage supplied by tube 36 is shown at z and results in further amplitude limitation as will be understood from the foregoing. The amplified and limited output voltage supplied by tube 37 is detected by the discriminator, amplified at audio frequency and applied to the loud speaker. The input voltages of the separate tubes may be controlled by suitably designing or adjusting the coupling transformers or by the provision of shunt or series impedances such as resistors 40' and 41' shown in Figure 4.

According to a further feature of the invention, a deflector type limiter-amplifier as described may be utilized as a demodulator or frequency discriminator thereby enabling a complete receiver to be constructed with tubes of this type with the exception perhaps of the audio amplifier which latter may be the amplifier of an existing set such as that of an amplitude modulation receiver. The limiter-discriminator circuit shown in Figure 6 substantially comprises a deflector type vacuum tube 15 similar to that shown in Figure 1. Frequency modulated input voltage is impressed upon the deflecting plates by way of resonant input transformer 43. The targets 18 and 19 are tied together and connected to the positive pole of a high tension source such as a battery 23 having its negative terminal connected to ground or any other potential reference point of the system. Item 44 is an output resistance connected in the cathode-to-ground lead of the tube. If the design and adjustment is such that the diameter of the electron beam is small compared with the maximum excursion or size of the targets 18 and 19, short impulses of substantially equal amplitude as shown at i in Figure 7 will be produced each time when the input voltage passes through zero. The spacing between these impulses will vary in accordance with the instantaneous signal frequency i. e. in turn with the momentary amplitude of the audio or other signals being transmitted. The current impulses in the output circuit will cause corresponding impulse voltages produced across the output resistance 44 which will charge a condenser 45 in such a manner that the average voltage supplied by the latter and impressed upon the input grid of an audio frequency amplifier tube 46 will vary according to a curve shown at v in Figure 7, that is in accordance with the variations of an audio or any other modulating signal impressed upon the received signal waves. This device may be compared with a counter in that the average voltage supplied by condenser 45 will be an index of the number of pulses per second, i. e. in turn the instantaneous signal frequency.

Referring to Figure 8, there is shown a complete receiver diagram embodying deflector amplifying tubes performing the functions as frequency changer, amplifier limiter as well as frequency discriminator for the reception of frequency modulated radio signals. The system preceding the discriminator is substantially similar to Figure 4 with the exception that the first tube is replaced by a special deflector type frequency changer or mixer 50 comprising a cathode 51 followed in the order named by a first control grid 52, an anode grid 53 which may consist of a single or a few rods, a further grid 53' tied to the cathode, an electron gun shown in the form of a focussing anode 54, a pair of deflector plates 55 and a pair of output targets or anodes 56 and 57. Control grid 52 and anode grid 53 have associated therewith a self-oscillating system comprising an

oscillating circuit 59 and a suitable power supply to maintain sustained electrical oscillations at a frequency determined by the tuning frequency of the circuit 59. Any one of the known oscillatory circuits of the feedback or other types may be employed for the purposes of the invention. Accordingly therefore, the electron stream emitted by the cathode 51 will cause a concentrated space charge or virtual cathode to be set up in the region between the decelerating grid 53' which is at ground potential and the focussing anode 54. This virtual cathode will act as a source for the electron gun and as a result the electron beam will have an intensity varying in the rhythm of the oscillating frequency, that is the resonant frequency of the circuit 59. By virtue of the additional control of the beam by the deflecting action in accordance with the input signal frequency impressed from the antenna 10—10' upon the deflector plates 55 through input transformer 58, signals of intermediate frequency will be developed in the output transformer 40, or the tube 50 will act as a mixer or first detector in a manner similar to that in known superheterodyne circuits. As is understood, the tuning condensers of the input transformer 58 may be suitably tracked with the tuning adjustment of the oscillating circuit 59 for uni-control of the signal input and local oscillating circuits in a manner customary in superheterodyne receivers.

The function of tubes 36 and 37 is substantially similar to that described in connection with Figure 4, the only exception being that the transformers 41 and 42 are tuned fixedly to the intermediate frequency for which the receiver has been designed. The output of tube 37 is impressed upon the deflecting plates of a discriminator tube 51 of substantially the same type as shown in Figure 6 to produce audio frequency voltage impressed upon the audio frequency amplifier 25 by way of condenser 45.

Referring to Figure 9, there is shown a modified limiter-frequency discriminator embodying deflector tubes in accordance with the invention. According to this exemplification, there are provided a pair of deflector tubes 60 and 61 of substantially similar construction as described. A frequency modulated input voltage is impressed by way of transformer 43 upon the deflecting systems of both tubes, in the example shown in parallel whereby during the opposite half cycles of the signal voltage the electron beams will assume positions as shown at *r* and *l*, respectively. In the example illustrated, the right-hand target or anode of tube 60 is connected to the cathode of tube 61 through a high tension or output current source 63 while the left-hand target of tube 61 is connected to the grounded cathode of tube 60 through a condenser 64. The cathodes of the tubes are further connected through a condenser 62. The remaining unused or idle targets of the tubes are preferably grounded to prevent interference with the proper function of the tubes.

The operation of this system is as follows: In the position of the electron beams shown at *r* the condenser 62 will be connected to the source 63 through the electron beam of tube 60 forming a return path and thus be charged to the voltage of this source. During the other half cycle of the signal input voltage when the electron beams are in a position shown at *l* the source 63 will be disconnected from the condenser 62 and the latter connected across the output condenser 64 through the beam of tube

61. In this manner, condenser 64 will be sequentially charged by short voltage impulses of equal amplitude determined by the limiting or clipping action of the tubes, the sequence or number of impulses per second being proportional to the instantaneous frequency of the input signals impressed upon the tubes 63, i. e. the system will act as an impulse counter in a manner similar to that according to Figure 6. The average charge of and voltage developed by the condenser 64 will therefore vary in accordance with the instantaneous frequency that is in turn with the momentary amplitude of the audio or any other modulating signal to be detected. This voltage is impressed upon the input of the audio amplifier by way of coupling condenser 65 and grid leak resistance 66 for amplification at audio frequency to an amplitude sufficient for operating a loud speaker or other translating device.

Referring to Figure 10, there is shown an arrangement similar to Figure 9 utilizing a composite deflector-discriminator and limiting tube in place of two separate tubes shown in Figure 9. The composite tube 67 according to this modification comprises a pair of cathodes, a common focussing anode 68 provided with two apertures in front of said cathodes in addition to any further concentrating elements known per se which may be desirable for obtaining a pair of sharply focussed electron pencils. There is further provided a composite deflecting system comprising three deflector plates 69, 70 and 71 arranged so that the electron beams will pass between each two of said plates. The central plate is connected to the mid tap or center point of the secondary of the input transformer 43 whose opposite outer ends are connected each to one of the outer deflector plates 69 and 70, respectively. In this manner the electron beams will assume positions as shown at *r* and *l* during opposite half cycles of the impressed signal voltage, thereby alternately striking the targets 72 and 73 and charging and discharging the condenser 62 in a manner substantially similar to that described in connection with Figure 9.

It will be evident from the foregoing that the invention is not limited to the specific circuits and arrangements of parts shown and disclosed herein for illustration but that the underlying thought and inventive principle will be susceptible of numerous modifications and variations coming within the broader scope and spirit of the invention as defined by the appended claims. The specification and drawings are accordingly to be regarded in an illustrative rather than in a limiting sense.

I claim:

1. The combination with a system for translating frequency modulated signals, of at least one electron discharge device interposed in the path of said signals, said discharge device comprising a source of electrons, means for concentrating the electrons supplied by said source into a beam of predetermined cross-section, at least one target arranged for said beam to strike against and a deflecting arrangement for sweeping said beam over said target, an input circuit for impressing a frequency modulated signal voltage upon said deflecting arrangement for deflecting said beam so that varying cross-sectional areas thereof are impinged upon said target, and an output circuit including a source of positive potential connected to said target, the relation of the cross-section and arrangement of

said beam with respect to said target being such that the full area of said beam will be impinged upon said target at a predetermined fraction of the peak amplitude of said signal voltage to substantially limit the amplitudes of the signal current developed in said output circuit to a constant value.

2. The combination with a system for translating frequency modulated signals, of at least one electron discharge device interposed in the path of said signals, said discharge device comprising a source of electrons, means for concentrating the electrons supplied by said source into a beam of predetermined cross-sectional area, a pair of targets disposed at opposite sides of the axis of said beam in the zero position and a deflecting arrangement for sweeping said beam over said targets, an input circuit for impressing a frequency modulated signal voltage upon said deflecting arrangement whereby varying cross-sectional areas of said beam are impinged upon said targets in proportion to and depending upon the polarity of the deflecting voltage, and an output circuit and a source of positive potential connected to said targets in push-pull, the relation of the cross-section and arrangement of said beam with respect to said targets being such that the full area of said beam is impinged upon either of said targets at a predetermined fraction of the peak amplitude of said signal voltage to substantially limit the amplitudes of the signal current developed in said output circuit to a constant value.

3. The combination with a system for translating frequency modulated signals, of at least one electron discharge tube interposed in the path of said signals, said discharge tube comprising a source of electrons, means for concentrating the electrons supplied by said source into a beam of predetermined cross-section, at least one target arranged for said beam to strike against and a deflecting arrangement for sweeping said beam over said target, an input circuit for impressing a frequency modulated signal voltage upon said deflecting arrangement for deflecting said beam so that varying cross-sectional areas thereof are impinged upon said target, and an output circuit and a source of positive potential connected to said target, the relation of the cross-section and arrangement of said beam with respect to said target being such that the full area of said beam is impinged upon said target within the range between predetermined minimum and maximum amplitudes of said signal voltage to substantially limit the amplitudes of the signal current developed in said output circuit to a constant value.

4. The combination with a system for translating frequency modulated signals, of at least one electron discharge device interposed in the path of said signals, said discharge device comprising a source of electrons, means for concentrating the electrons supplied by said source into a beam of predetermined cross-sectional area, a pair of targets disposed at opposite sides of the axis of said beam in the zero position and a deflecting arrangement for sweeping said beam over said targets, an input circuit for impressing a frequency modulated signal voltage upon said deflecting arrangement whereby varying cross-sectional areas of said beam are impinged upon either of said targets in proportion to and depending upon the polarity of the deflecting voltage, and an output circuit and a source of positive potential connected to said targets in push-

pull, the relation of the cross-section and arrangement of said beam with respect to said targets being such that the full area of said beam is impinged upon said targets within a range between predetermined minimum and maximum amplitudes of said signal voltage to substantially limit the amplitudes of the signal current developed in said output circuit to a constant value.

5. The combination with a system for translating frequency modulated signals, of at least one electron discharge device interposed in the path of said signals, said discharge device comprising a cathode, means for concentrating the electrons supplied by said cathode, into a beam of predetermined cross-sectional area, a pair of targets disposed at opposite sides of the axis of said beam in the zero position and a pair of electrostatic deflecting plates for sweeping said beam over said targets, a resonant input circuit for impressing frequency modulated signal voltage upon said deflecting plates whereby varying cross-sectional areas of said beam are impinged upon either of said targets in proportion to and dependent upon the polarity of the deflecting voltage, and a resonant output circuit and a source of positive potential connected to said targets in push-pull, the relation of the cross-section and arrangement of said beam with respect to said targets being such that the full area of said beam is impinged upon said targets within a range between predetermined minimum and maximum amplitudes of the impressed signal voltage to substantially limit the amplitudes of the signal current developed in said output circuit to a constant value.

6. The combination with a system for translating frequency modulated signals, of a plurality of electron discharge tubes in cascade interposed in the path of said signals, each of said tubes comprising a source of electrons, means for concentrating the electrons supplied by said source into a beam of predetermined cross-sectional area, a pair of targets arranged at opposite sides of the axis of said beam in the zero position and a deflecting arrangement for sweeping said beam over said targets, an input circuit for impressing a frequency modulated signal voltage upon the deflecting arrangement of the first of said tubes, means for maintaining said targets at a steady positive potential with respect to the cathodes and intercoupling networks connected to the targets of each tube in push-pull for developing input signal voltage for the deflecting arrangement of the succeeding tube, the relation of the cross-section and arrangement of the electron beams in said tubes with respect to their targets being such that initially varying cross-sectional areas of the beams are impinged upon either of the associate targets in proportion to and depending upon the polarity of the deflecting voltage and that the full area of the beams will strike either target within a range between predetermined minimum and maximum amplitudes of impressed signal voltage to substantially limit the amplitudes of the signal voltage developed by the associate intercoupling networks to a constant value.

7. The combination with a system for translating frequency modulated signals, of a plurality of electron discharge tubes in cascade interposed in the path of said signals, each of said tubes comprising a cathode, means for concentrating the electrons supplied by said cathode into a beam of predetermined cross-sectional area, a pair of targets disposed at opposite sides of the axis of

said beam in the zero position and a pair of electrostatic deflecting plates for sweeping said beam over said targets, a resonant input circuit for impressing a frequency modulated signal voltage upon the deflecting plates of the first tube, means for maintaining said targets at steady positive potential with respect to said cathodes and resonant intercoupling networks connected to the targets of each tube in push-pull to develop input signal voltage for the deflecting plates of the succeeding tube, the relation of the cross-section and arrangement of the electron beams in said tubes with respect to their targets being such that initially varying cross-sectional areas of said beams are impinged upon either of said targets in proportion to and depending upon the polarity of the impressed deflecting voltage and that the full areas of the beams will strike either target within a range between predetermined minimum and maximum amplitudes of impressed signal voltage to substantially limit the amplitudes of the signal voltage developed in the associate intercoupling networks to a constant value.

8. The combination with a system for translating frequency modulated signals, of at least one electron discharge device interposed in the path of said signals, said discharge device comprising a source of electrons, means for concentrating the electrons supplied by said source into a beam of predetermined cross-section, a deflecting arrangement for said beam, a pair of targets arranged to be differentially impinged by fractions of the cross-section of said beam in accordance with a control voltage applied to said deflecting arrangement, an input circuit for impressing a frequency modulated signal voltage upon said deflecting arrangement, and an output circuit including a source of positive potential connected to said targets in push-pull, the relation of the cross-section and arrangement of said beam with respect to said targets being such that the full cross-sectional area of said beam is impinged upon said targets at a predetermined fraction of the peak amplitude of said signal voltage to substantially limit the amplitude of the signal energy developed in said output circuit to a constant value.

9. The combination with a system for translating frequency modulated signals, of a multi-stage cascade system interposed in the path of said signals, each stage comprising an electron discharge tube provided with a source of electrons, means for concentrating the electrons supplied by said source into a beam of predetermined cross-section, a deflecting arrangement for said beam, a pair of targets arranged to be differentially impinged by fractions of the cross-section of said beam in accordance with a control

voltage applied to said deflecting arrangement, an input circuit for impressing a frequency modulated signal voltage upon the deflecting arrangement of the first of said tubes, means for maintaining the targets of the tubes at steady positive potentials with respect to their respective cathodes, and intercoupling networks connected to the targets of each tube in push-pull for developing input signal voltage applied to the deflecting arrangement of the succeeding tube, the relation of the cross-section and arrangement of the electron beams in said tubes with respect to their targets being such that initially varying cross-sectional areas of the beams are impinged upon either of the associate targets substantially in proportion to and depending upon the polarity of the deflecting voltage and that the full area of the beams will strike either target within a range between minimum and maximum amplitudes of impressed deflecting voltage to progressively limit in successive stages the amplitude of the signal energy developed in the associate intercoupling networks to a substantially constant value.

10. The combination with a system for translating frequency modulated signals, of a multi-stage cascade system interposed in the path of said signals, each stage comprising an electron discharge tube provided with a source of electrons, means for concentrating the electrons supplied by said source into a beam of predetermined cross-section, at least one target arranged for said beam to strike against and a deflecting arrangement for sweeping said beam over said target in accordance with variations of a deflecting voltage, an input circuit for impressing a frequency modulated signal voltage upon the deflecting arrangement of the first tube, means for maintaining the targets of the tubes at steady positive potentials with respect to their cathodes, and intercoupling networks connected to the targets of each tube for developing output signal energy applied to the deflecting arrangement of the succeeding tube, the relation of the cross-section and arrangement of the electron beams of the separate stages with respect to their targets being such that initially varying cross-sectional areas of the beams are impinged upon the associated targets substantially in proportion to the impressed deflecting voltage and that the full areas of the beams will be impinged upon the respective targets within a range between minimum and maximum amplitudes of impressed signal voltage to progressively limit in successive stages the amplitude of the signal energy developed in the associate intercoupling networks to a substantially constant value in the final output circuit.

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