Dec. 9, 1952 G. J. C. ANDRESEN 2,621,290

LIMITER SYSTEM

Filed March 29, 1947 3 Sheets-Sheet 1

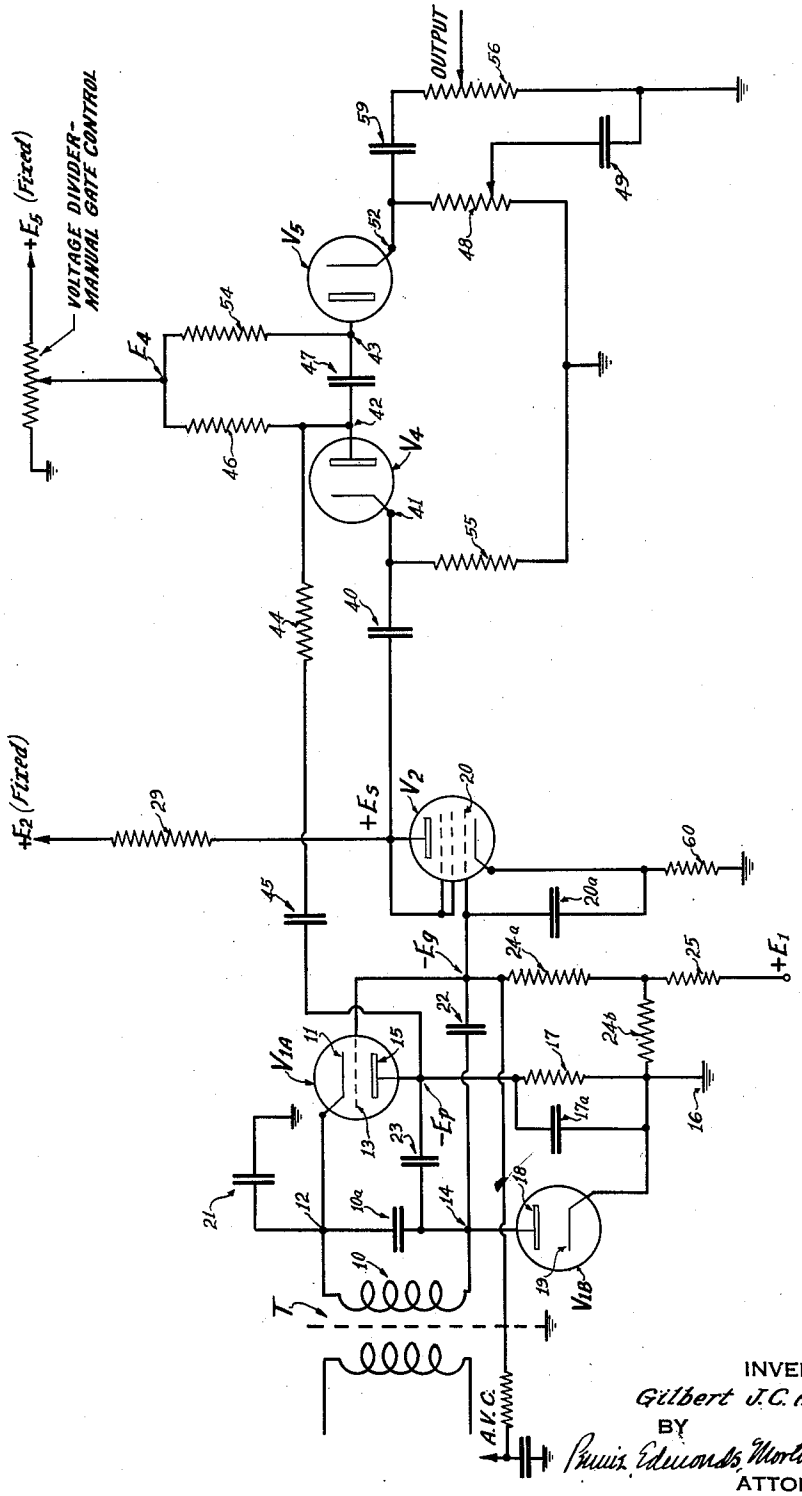


Fig-1

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LIMITER SYSTEM

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Fig. 3

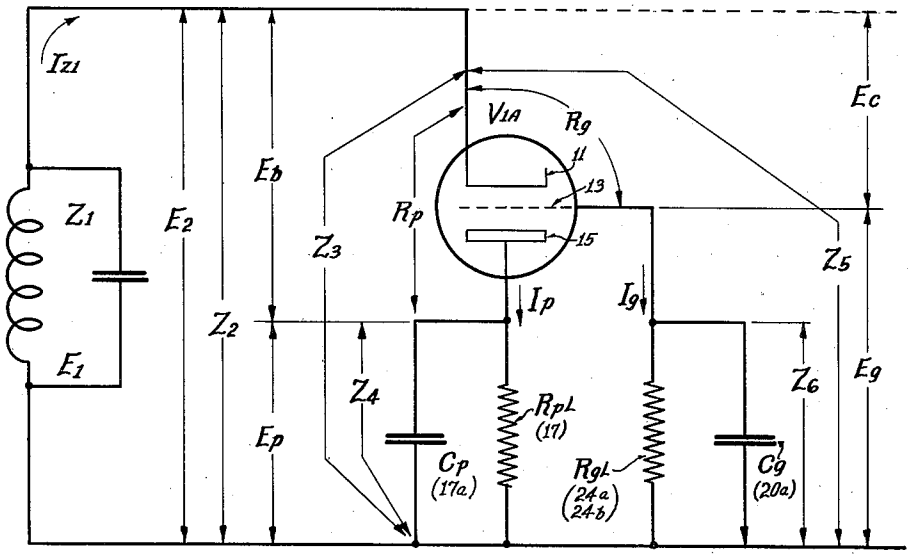
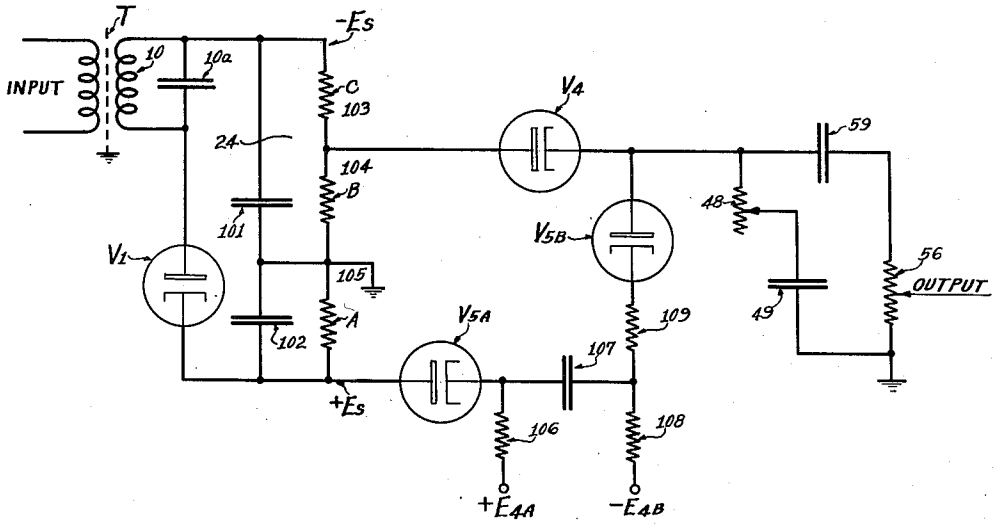


Fig. 2



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LIMITER SYSTEM

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Fig. 4

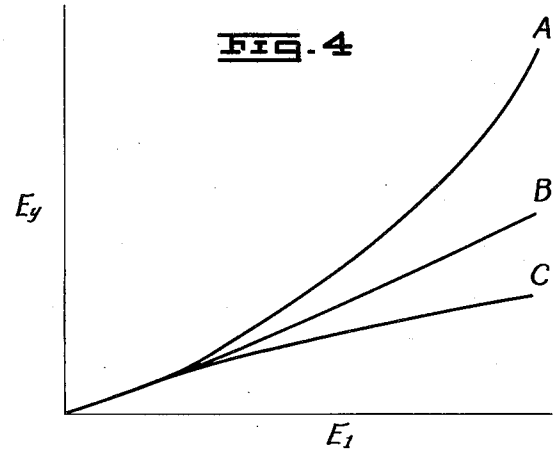


Fig. 5 A

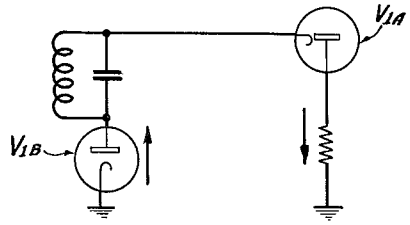


Fig. 5 B

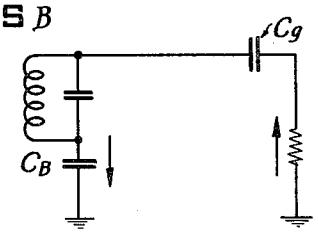


Fig. 5 C

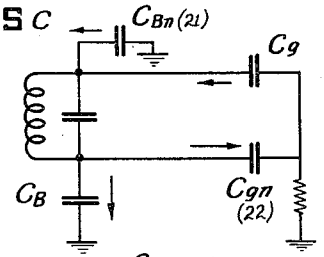


Fig. 5 D

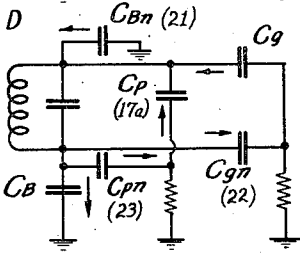
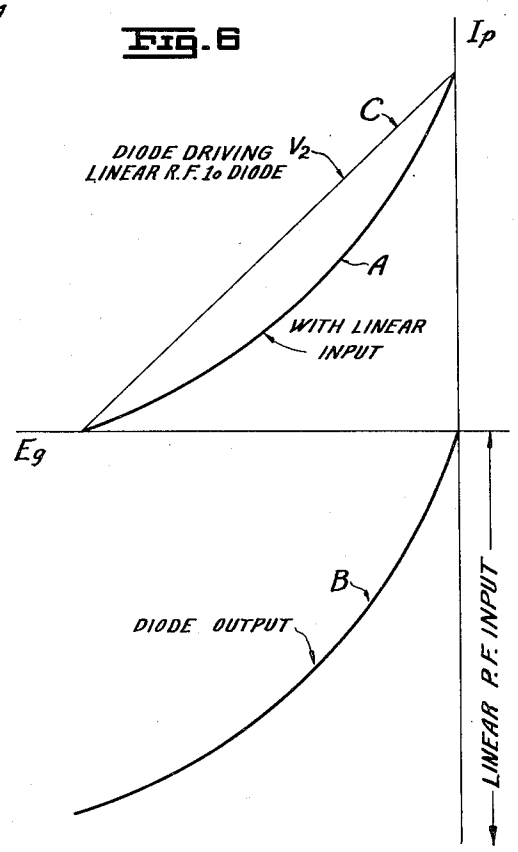


Fig. 6



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UNITED STATES PATENT OFFICE

2,621,290

LIMITER SYSTEM

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Application March 29, 1947, Serial No. 738,165

17 Claims. (Cl. 250—20)

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This invention relates to a limiter system for effectively reducing static and noise and the like interference, in the reception of radio signals and is a continuation in part of my copending application, Ser. No. 606,415, filed July 21, 1945, which matured into U. S. Patent No. 2,418,389 on April 1, 1947.

The principal object of the invention is to provide a limiter with which discrimination may be attained, within reasonable limits, between signal and noise in periods of strong static, particularly during the reception of relatively weak signals.

The invention is particularly adapted for use in the reception of voice modulated carrier signals to improve the clarity of speech which otherwise would be distorted, or partially or wholly masked, by the interference.

In accordance with the invention, an improved system is provided comprising in combination several component electron tube circuits and arrangements, some of which are broadly old in the art, others specifically new.

A feature of the invention is the provision of both direct and inverse coupling for signal and static from the signal detector to the audio system of a receiver in such manner that the static peaks are not only limited but are also inverted.

A preferred embodiment of the invention includes a pair of electron tube rectifiers which are adapted to supply half-wave rectification components of radio-frequency carrier and modulation to an electron tube reversing repeater for producing an opposite-polarity replica of said components, two coupling circuits (direct and inverse) for coupling the opposite polarity rectification components, a limiter tube in each of said coupling circuits, means for establishing gate voltages determining the cutoff levels of the limiter tubes and means for coupling the final output to the audio system of a radio receiver.

A complete understanding of the improved system and the mode of operation of the several component electron tubes and circuits of the invention will be had by reference to the following description and to the drawings to be considered in conjunction therewith.

In the drawings:

Fig. 1 is a circuit diagram illustrating the several component electron tubes and the circuit arrangements of a preferred embodiment of the improved system;

Fig. 2 shows a modification of the system of Fig. 1;

Fig. 3 shows a simplified analysis of the signal rectifier of Fig. 1;

Fig. 4 shows certain characteristic curves relating to signal rectifier.

Figs. 5A–D show schematically certain current paths in the rectifier which are of particular interest in connection with the neutralization; and

Fig. 6 shows certain characteristic curves relating to the reversing amplifier and the signal rectifier.

Referring now to Fig. 1, the invention is illus-

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trated by an embodiment in a radio receiver, of which there are shown in detail only those parts needed to describe the invention. These parts include the detector and the circuits for coupling the detector to the audio-frequency system. The receiver proper may take any desired form and preferably include some provision for automatic volume control. For coupling from the intermediate-frequency amplifier to the detector, the transformer T is provided, equipped with shielded primary and secondary to avoid undesired coupling. Although any convenient signal rectifier may be used, the rectifier shown has special advantages among which is the ability to vary the output characteristics curve as will be later discussed. The rectifier V_{1A}, a triode, is connected as a diode to the signal input circuit comprising the transformer secondary **10** and the tuning capacitor **10***a*, with its cathode **11** connected to the point **12**, and its grid **13**, which serves as one diode anode, coupled to the point **14** through resistance **24***a*, **24***b* and electron tube rectifier V_{1B}. This rectifier V_{1B} is a coupling valve and is used to facilitate neutralization in conjunction with neutralizating capacitors **21**, **22**, and **23** as will be explained more in detail later. The plate **15** of tube V_{1A}, which serves as another diode anode, is connected to point **14** through resistance **17** and rectifier tube V_{1B}. Capacitances **17***a* and **20***a* are connected in parallel respectively to resistors **17** and **24***a*, **24***b*, both of which are connected to ground **16**.

The tube V_{1A} supplies half-waves of radio-frequency carrier and modulation of the signal as a negative potential $-E_g$, to the control element **20** of electron tube V_2, a radio-frequency limiter and amplifier which serves also as a reversing repeater.

Directing attention specifically to the tube V_{1A} of Fig. 1, the cathode-to-plate and cathode-to-grid load resistors **17** and **24***a* thereof provide leakage paths of high resistance for the signal and static voltages which are rectified in this tube. The rectified half-waves appear across these resistors and are preserved in some degree by making the shunt capacitance **17***a* and **20***a* rather small, perhaps only the inherent capacitance of the circuit elements.

The instantaneous relationship of the various voltages and currents are affected by the anode and grid resistance-capacitance (RC) time constants which, if greater than one-half the carrier period, accumulate substantial negative bias potentials on the diode anodes of tube V_{1A}, of magnitude proportional to the amplitude of the voltage from the input circuit.

To obtain the fastest response in the rectification of the carrier-frequency voltage from the input circuit, the RC time constant of the load of each diode is made less than the time interval or pulse width of the shortest pulse of noise, as determined by the preceding selective circuits in the receiver. The stray capacitance of the wiring connections and the tubes and additional

capacitance, if present, will not seriously affect the performance, provided the time constant does not exceed the minimum pulse width.

The preferred RC time constant for one-half cycle would be $RC=\frac{1}{2}f$, in which f is the frequency of the voltage applied to the rectifiers.

Referring again to Fig. 1, and in particular to the rectifier load **24***a*, there is sometimes developed at the point $-E_g$ an undesired amount of negative potential caused by electron flow. To counteract that undesired condition, a divided load resistor **24***a*, **24***b* is provided and a small opposing current is supplied in resistor **24***a* through the resistor **25** from the power supply voltage source $+E_1$.

If it is desired to provide the usual grid bias on the tube V_2, a cathode resistor **60** may be employed as shown in Fig. 1. If a resistor **60** of proper value is used, resistors **24***b* and **25** may not be required. The negative feedback action of the voltage drop across resistor **60** serves to reduce distortion and to permit a higher input voltage to be applied to the control element **20** before overloading occurs.

As pointed out above, the negative half-waves of radio-frequency voltage of the rectifier output are supplied to the control electrode **20** of the electron tube V_2. Thereupon the output current of this tube will decrease in proportion to the voltage from the rectifier.

It is not necessary to control tube V_2 with the resultant sum of the half waves. It may be preferable to actuate the control electrode **20** thereof by the voltage of each increment. In that case, the internal resistance of V_2 should be restored quickly to its no-signal value between the half-wave conducting phases of the rectifier to assure the fast operation which is required to follow static pulses.

The repeater or amplifier tube V_2 is provided with the usual plate coupling resistor **29** between the plate and a source of fixed positive voltage $+E_2$. This voltage is assigned the least value which permits this repeater to function over a wide range of signal strengths; its small voltage prevents the static pulse amplitude from exceeding a limited amplitude preferably not much greater than the peak amplitude of the signal.

As explained hereinbefore, in the absence of signals the preferred voltage on the control electrode **20** is zero. During the negative half-cycle of the signal, the control-electrode voltage is negative and of a value directly proportional to the amplitude of the radio-frequency voltage applied to the rectifiers. During the positive half-cycle of the signal the control-electrode voltage should be zero or preferably as near thereto as it is possible to attain. Thus the rectified voltage output $+E_5$ from the repeater tube V_2 is limited by the voltage E_2.

The output of the half-cycle radio-frequency voltage $+E_5$ includes the rectified modulation of the carrier, and when the half-wave increments thereof are impressed upon an audio system the original modulations are reproduced.

The repeater tube V_2 is preferably of the variable-mu type and is, therefore, adapted to operate with a high voltage input. However, a conventional triode tube, screen-grid tube, pentode or beam tube can be used. The pentode or beam tube, for example, would provide satisfactory limiter or cut-off characteristics if the input and element voltages are held within limited values.

The positive voltage E_4, which is a manually adjustable fraction of the fixed positive voltage of the source $+E_5$, is the gate voltage which determines the cutoff levels in the series-limiter rectifier tubes V_4 and V_5. For any desired value of signal intensity, the voltage E_4 is adjusted so that the limiter V_4 cuts off at the level of greatest outward modulation, preferably the level corresponding to unity modulation so as to preserve the desired modulation and cut off only the excessive peaks of noise. With the same adjustment, the other limiter V_4 cuts off at the level of greatest inward modulation. While not ordinarily required, of course a separate adjustment corresponding to E_4 could be provided for the second limiter V_5 to meet special requirements.

With proper adjustment of E_4 the limiter V_4 stays closed for the normal range of modulation, but opens up on peaks of greater amplitude such as strong pulses of static.

The various elements having been explained in the foregoing, the limiter system proper and its mode of operation will now be discussed.

While the clipping of static pulses is known to be a great aid in reception, this invention gains a major advantage by a further action, namely, inversion of the strong pulses which otherwise would cause the loudest residual clicks. The inversion requires two coupling paths for rectified modulation from the detector to the limiter. The first is a direct coupling path, which predominates in the amplitude range of normal modulation but which is cut off at greater amplitudes. The second is an inverse coupling path which predominates at greater amplitudes and causes inversion of the peaks of strong pulses.

In Fig. 1, the so-called direct path is through the repeater V_2 and biased limiter tube V_4. It conveys the desired modulation in what may be called the positive sense and but for the limiter V_4 would conduct the static peaks. The inverse path which also conveys the desired modulation and static peaks but at a lesser amplitude, is through the capacitor **45** and resistor **44**, and around the limiter V_4 so this path is not subject to its clipping action.

Now considering the performance toward a signal accompanied by strong pulses of static, the pulse peaks coupled to point **42** for example, by resistor **44** and capacitor **45** from $-E_p$ predominate at instants when the tube V_4 is cut off. The static pulse voltage is weakly coupled to point **42** so that the anode voltage of V_4 becomes less positive, cutting off further passage of the static pulse through V_4. The value of resistor **44** should be such that strong static will not modulate the voltage at point **42** beyond the zero axis value of the signal while unmodulated. The capacitor **45** should be of sufficient value to prevent any substantial phase shift in the passage of the pulse current from $-E_p$ to point **42**.

As insurance that the inverted pulse peak will not recede past the zero axis of the modulation, there is added a second electron tube limiter V_5 coupled by capacitor **47** to V_4 and having a separate gate voltage. The limiter V_5 is adapted to operate and limit on the inverted peak of a strong static pulse.

The output of V_5 has a time constant determined by resistor **48** and capacitor **49**, of the same order of magnitude as the period of the highest modulation frequency to be reproduced. The advantages gained by the use of limiter V_5 as just described, are that the coupling of the inverse peak of the static pulse can be increased to obtain a more precise limiting thereof.

The inverse peak of a strong static pulse at point 42 is coupled to point 43 making tube V_5 non-conductive beyond a certain point, for the reason that the time constant of 48, 49, effective at point 52 will not permit the voltage on the cathode of V_5 to follow the sudden inverse peak at point 43. Before equilibrium can be established between point 52 and point 43, tube V_4 has cut off in the manner explained hereinbefore. This mode of operation effects a very sharp cut-off of the static pulse because the inverse coupling may be increased to permit the effective use of rapid charging of the small interelectrode capacitance, wiring connection capacitance, etc., of the limiter tubes V_4 and V_5.

During the static pulse interval the limiter between points 43 and 52 prevents the inverted peaks from passing the zero axis value of the signal modulation. This is a desirable mode of operation because the inverted peak amplitude is within the range of normal modulation.

When the static pulse voltage has decreased from its peak to a value where point 41 becomes negative with respect to point 42, the limiter V_4 becomes conductive and V_5 is already conductive so the normal response to modulation is resumed.

In the absence of a static pulse the limiters V_4 and V_5 remain conductive to signal amplitudes of the full range determined by the gate voltage E_4.

The operation of the limiter as a whole will be summarized briefly with reference to the essential functions of some parts of the circuit as described above. The principal parts are the signal detector including tubes V_{1A} and V_{1B}, the reversing amplifier including tube V_2, the inverse coupling path including resistor 44, the limiter including tubes V_4 and V_5, and the adjustable gate-voltage E_4.

The signal detector utilizes the rectifier tube V_{1A} to deliver rectified signal voltages of negative polarity from electrodes 13 and 15, both acting as anodes. The other rectifier tube V_{1B} is needed only to preserve the potential at point 14 during the non-conductive phase of V_{1A} and thus permit neutralizing capacitors 22 and 23 to be effective.

The reversing amplifier utilizes the tube V_2 to reverse and amplify the rectified signal received from electrode 13 of the detector. The amplified signal is coupled from the anode of tube V_2 through the capacitor 40 to the limiter. In the usual manner, the signal is reversed in this amplifier, so the amplified signal coupled through the capacitor 40 may be regarded as positive, meaning that outward modulation of the signal causes a change of voltage in the positive direction. Since this amplifier provides the principal coupling from the detector to the limiters, it is termed the direct coupling circuit in contradistinction to the inverse coupling circuit now to be identified.

The inverse coupling circuit utilizes resistor 44 to couple to the limiter the rectified signal received from electrode 15 of the detector. This signal is negative in polarity, and is therefore inverse relative to the positive signal output from the amplifier. The purpose of this coupling will be further summarized below.

The limiter includes two rectifier tubes connected in series opposition for limiting the signal in both directions corresponding to outward and inward modulation. The first tube V_4 is poled to cut off beyond a certain level of outward modulation. The second tube V_5 is poled oppositely to cut off beyond a certain level of inward modulation.

When a peak of the signal envelope, for example a static pulse, has a peak voltage exceeding the cutoff level for outward modulation, as defined above, it is applied with positive polarity to point 41 and the cathode of limiter tube V_4, and causes this tube to become non-conductive. Therefore the peak of this pulse is not coupled in this tube through the limiter. However, the inverse coupling path through resistor 44 is still operative on the peak of such a pulse and couples the peak with reverse polarity to the point 42 in the limiter, detouring around the tube V_4 which is cut off. Therefore the peak of the pulse appears inverted in the output of the limiter so the peak is actually at a level lower than the above identified cutoff level for outward modulation. This is one of the principal advantages of the present invention, because thereby the effective peak amplitude of a strong pulse is actually reduced to a level less than the level at which the highest signal peaks of modulation are permitted to pass without distortion.

It is desirable that the inverse static pulse should not indent the signal too far. The second limiter tube V_5 achieves this purpose by limiting any excessive peak values of inverse pulses. Furthermore, by relating the time constant of resistor 48 and capacitor 49, in the limiter output circuit, to the highest modulation frequency, the limiting level for pulses of short duration of either signal or static can be reduced without detriment to the desired modulation components of lower frequencies and maximum amplitude. The clipping of short pulses of modulation at a level lower than low-frequency components of modulation is permissible because the desired modulation seldom includes short pulses of strong modulation.

The manually adjustable direct voltage E_4 is the gate voltage which is applied to the limiter tubes V_4 and V_5 to determine their clipping or limiting levels, as described above.

In the foregoing description, it is presumed that a strong pulse of static superimposed on a modulated carrier has all the appearances of a pulse of modulation, that is, an excessive peak in the modulation envelope. A static pulse is distinguished only if its peak amplitude exceeds the modulation peaks of the signal. In that case, the present invention minimizes its disturbing effect by reducing its peak value as it remains in the output of the limiter.

Illustrative circuit constant values and types of electron tubes for the successful reception of voice modulated signals through both atmospheric static and locally produced noises are set forth below.

V_{1A}	Single section of RCA 6SL7.
V_{1B}	Diode rectifier—may be contained in the V_2 envelope such as an RCA 6SF7.
V_2	RCA 6SK7 or 6SF7.
V_4, V_5	RCA 6H6.
17	36 K ohms.
24a, b	Section a—100 K ohms. Section b—500 to 1000 ohms.
29	100 K ohms.
25	250 K ohms.
46, 54	500 K ohms.
55, 48, 56	1 megohm.
44	.5 to 5 megohms.
21 (C_{Bp}), 23 (C_{pa}), 22 (C_{gp})	Neutralizing capacitors, 3–10 $\mu\mu f$.
17a (C_p), C_g	Load capacitances usually inherent strays—approximately 10 $\mu\mu f$.
49	.001 μf.
45	.001 to .01 μf.
47	.01 μf.
40, 59	.05 μf.
60	0–5,000 ohms.

Fig. 2 shows a modification of the arrangement of Fig. 1, in which a simplified detector circuit is employed to deliver both polarities of rectified signal, and in which the dual function of the limiter tube V_5 is performed separately by two tubes with some advantage in performance. Corresponding elements are designated as in Fig. 1.

The signal detector or rectifier function is performed by the diode tube V_1. Its load comprises the three resistors, **103**, **104**, **105**, bypassed for radio frequencies by the condensers **101** and **102**. Rectified voltages of both polarities are developed respectively at $-E_s$ across resistors **103** and **104**, and at $+E_s$ across resistor **105**.

The direct coupling of the signal from the detector to the output is from the tap between resistors **103** and **104**, through the series limiter tube V_4, the coupling condenser **59** and the output voltage divider **56**. The cutoff or clipping level in this path is determined by the current from the source of direct voltage $-E_{4B}$ through resistors **108** and **109** and the diode V_{5B}. By selection of the value of this voltage, this cutoff level is set at or near the level of outward peaks of maximum modulation.

The inverse coupling path is from the signal voltage $+E_s$ through the limiter diode V_{5A}, the coupling condenser **107**, the resistor **109**, the diode V_{5B}, the coupling condenser **59** and the output voltage divider **56**. A novel feature of this arrangement is the connection of a source of voltage $+E_{4A}$ through resistor **106** so chosen that the diode V_{5A} permits coupling through the inverse path only during pulses of strong static which exceed the signal modulation, but not during normal modulation. It is therefore not necessary to restrict the amount of coupling in the inverse path so severely and the inversion of pulse peaks can be accomplished more abruptly by more inverse coupling.

Fig. 3 is a simplified diagram, omitting neutralization, of the special form of rectifier shown in Fig. 1. This rectifier consists of two diodes both simultaneously rectifying the same half waves. By choice of suitable circuit constants for each rectifier, this double diode rectifier may be made to give a practically linear rectifying characteristic or a characteristic which varies from linearity in either direction as illustrated in Fig. 4. In addition to the electrical symbols, the parts shown in Fig. 3 bear reference characters corresponding to the reference characters used on the same elements in Fig. 1. If the plate **15** and leakage path **17**, **17***a* are removed, the remaining elements **11**, **13**, with leakage path **24***a*, **24***b*, **20***a*, function as a conventional rectifier. The cathode-grid resistance R_g is not substantially affected by the plate current if the input voltage E_2 is held at the same relative potential when the plate load is removed. However, the value E_2 will be lowered as the impedance Z_3 begins to draw additional current from the source impedance Z_1, and the increased current will result in a voltage loss.

The total rectifier impedance Z_2 is the parallel resultant of the output impedance Z_5 of the diode rectifier **11**, **13** and the variable shunt impedance Z_3 of the diode rectifier **11**, **15**. The arrangement thus operates in effect as a variable impedance rectifier, the Z_3 impedance characteristic of which may be predetermined by proper selection of the plate characteristic R_p, and the load impedance Z_4. The input voltage characteristic may be given a downward slope to compensate for the characteristic of output voltage E_g. If a downward slope of E_g is desired it may be attained by decreasing R_p or Z_4, or both.

The resistance load R_{pL} (**17**) and capacitance C_p (**17***a*) develop the negative potential $-E_p$ providing a delay bias for the conductive phase of the anode. The cathode-to-grid current is independent of the anode current if the input voltage E_2 is constant. Since the grid voltage $-E_g$ affects the anode current, no plate or anode current will flow until the negative difference between $-E_g$ and the cathode input voltage E_2 is less than the grid bias required for plate current cut-off at the instantaneous plate voltage (E_2-E_p).

The following equations expressed in terms of the symbols appearing on Fig. 3 will permit ready analysis to be made of the various voltages and currents of the rectifier:

Voltage to rectifier at no load $=E_1$

Voltage to rectifier under load, $E_2=E_1-(I_g+I_p)Z_1$

Voltage across grid load (Z_6), $E_g=I_gZ_6$

Voltage across anode load (Z_4), $E_p=I_pZ_4$

Cathode-to-grid voltage, $E_c=E_2-E_g$

Cathode-to-anode voltage, $E_b=E_2-E_p$

Grid current when (E_2-E_g) is positive, $I_g=K(E_2-E_g)^{3/2}$

When

(E_2-E_g) is negative, $I_g=$ zero (0)

Anode current when (E_2-E_g) is negative, $I_p=K\left(E_2-E_g+\frac{E_2-E_p}{G_mR_p}\right)^{3/2}$

When

$\left(E_2-E_g+\frac{E_2-E_p}{G_mR_p}\right)$ is negative, $I_p=$ zero (0)

When

(E_2-E_g) is positive, $I_z=K\left(E_2E_g+\frac{E_2-E_p}{G_mR_p}\right)^{3/2}-K(E_2-E_g)^{3/2}$

When

(E_2-E_g) is negative or positive, $I_{g1}=K\left(E_2-E_g-\frac{E_2+E_p}{G_mR_p}\right)^{3/2}$

When

$\left(E_2-E_g+\frac{E_2-E_p}{G_mR_p}\right)$ is negative, $I_{g1}=$ zero (0)

When the voltage to rectifier under load, E_2, is low, corrections should be made for contact potentials and electron velocities at the grid and anode, **13**.

Fig. 4 illustrates the relation between rectifier input voltage E_1 and the output voltage E_g. Curve A is that of a non-compensated rectifier showing the output distorted by reason of increased efficiency at the higher input voltages. Curve B is that which may be attained in the improved system with the downward slope of E_2 effected by proper choice and proportioning of internal and external impedances. It may be made linear and distortion-free by careful choice of these impedances. Curve C is an output curve having a logarithmic characteristic and the downward slope thereof is useful when strong signal voltages are present. The distortion in this case is not greater than that had with a conventional rectifier, and is to be preferred to that caused by an overloaded amplifier with a

conventional rectifier, since the signal-to-noise ratio is much less on weak signals.

Ordinarily the output current of the tube V_2 connected as a triode, and having a negative potential impressed upon its control electrode **20**, would have a characteristic curve like A of Fig. 4. The rectified output voltage of the rectifier is plotted along the abscissas to represent the negative voltage $-E_g$ applied to the control electrode **20** of tube V_2. The output current I_p of tube V_2 is plotted along the ordinates. If the rectifier characteristic is adjusted to be substantially as in curve B of Fig. 4, the resultant negative voltage impressed upon control element **20** of tube V_2 will produce an output current characteristic substantially as in C, a substantially linear relation with respect to the radio-frequency input voltage $-E_g$. In other words, the curvature of rectification in tube V_{1A} will compensate for the curvature of amplification in tube V_2 to effect a linear response to modulation of the input signal.

Referring again to Fig. 1, and in particular to the tube V_{1A} thereof, it is to be understood that the stray capacitance of wiring and the internal capacitance of the tube provide a radio-frequency coupling path across the rectifier, which is the principal path effective during the nonconductive phase.

The diode rectifier tube V_{1B} is connected in series with the ground return of the signal input circuit **10** and is poled the same as the diode formed by tube V_{1A} to conduct current on the same phase as said diodes. Thus, during the non-conductive phase, both the tubes V_{1A} and V_{1B} and their wiring connections still provide capacitive coupling to the output circuits of the diode rectifiers, namely, resistors **17** and **24***a* and the subsequent circuits coupled thereto.

The small capacitors **21**, **22**, **23**, are provided to neutralize or balance out this capacitive coupling to the output circuit. During the non-conductive phase, the capacitor **21** and the capacitance of tube V_{1B} are connected in series across the input circuit, and their junction is connected to ground. This forms a bridge circuit such that alternating voltages of opposite polarity appear at points **12** and **14** on opposite sides of the input circuit **10**. By virtue of this bridge circuit, capacitor **22** neutralizes the cathode-to-grid capacitance of tube V_{1A}, and **23** the cathode-to-plate capacitance of tube V_{1A}.

Figs. 5A–D are simplified diagrams of those parts of Fig. 1 that are involved in the neutralization, and are shown to facilitate the explanation of this function. Fig. 5A shows schematically the current path, and by arrows the direction of electron flow, during the conductive phase of the rectifier, referring to either of the diodes in tube V_{1A}. Figs. 5B–D show the capacitive current paths effective during the non-conductive phase of the rectifier and make clear the means of effecting complete or approximate balance of the capacitive coupling as above described.

In Fig. 5B the flow of capacitive current during the non-conductive phase is shown, the cathode-grid diode of tube V_{1A} and the tube V_{1B} acting as capacitive coupling means C_g and C_B, respectively. The arrows in this and subsequent figures show the direction of capacitive currents in various parts of the circuit at the same instant, chosen arbitrarily for the purpose of explanation. Fig. 5C illustrates the balancing of capacitance C_g by capacitor **22** (C_{gn}), C_g denoting the cathode-grid capacitance in tube V_{1A} and wiring. Fig. 5D shows in addition the balancing of capacitance C_p by capacitor **23** (C_{pn}), C_p denoting the cathode-plate capacitance in tube V_{1A} and wiring. The balancing of the capacitive coupling paths results in the required approximate neutralization of the tendency for radio-frequency current to be coupled to the diode loads during the non-conductive phase.

The voltage E_4 and "gate" voltages referred to in the specification are further defined as a conductance determining voltage causing the rectifier limiters to conduct modulation for amplitude levels determined by the conductance voltage.

The control grid **13** of the tube V_1 is utilized in this invention as an anode of one rectifier and is more specifically defined as a secondary anode.

The improved system and its components comprising the preferred embodiment of the invention may be modified without departing from the gist and scope of the invention as those skilled in the art will recognize. Therefore, only such limitations as may be imposed by the pertinent prior art should be considered in relation to the appended claims.

I claim:

1. A signal coupling and amplitude limiting system comprising rectifier means having load impedance means connected in series therewith across which alternating modulations of signal voltage appear, a second rectifier having anode and cathode electrodes, means coupling said modulations to said second rectifier and comprising a connection from a point on said load impedance means to one of said electrodes, the second of said electrodes being connected to an output circuit, and second means for coupling said modulations to said second rectifier and comprising second connections from said load impedance means to the said second electrode through a phase inverter means.

2. A signal coupling and amplitude limiting system comprising rectifier means having load impedance means connected in series therewith across which alternating modulation of signal voltage appear, a second rectifier having anode and cathode electrodes, means coupling said modulations to said second rectifier and comprising a connection from a point on said load impedance means to one of said electrodes, the second of said electrodes being connected to an output circuit, and second means for coupling said modulations to said output circuit and comprising second connections from said load impedance means to the said output circuit through a phase inverter means.

3. A signal coupling and amplitude limiting system, in accordance with claim 2 in which a conductance determining voltage means is provided and is connected to the said second rectifier to cause the said second rectifier to conduct the said modulations for amplitudes determined by the conductance determining voltage of said conductance determining voltage means.

4. A signal coupling and amplitude limiting system in accordance with claim 2 in which a further rectifier having anode and cathode electrodes in series electrical connection with one of the said means for coupling the said modulations to the said output circuit is provided, a conductance determining voltage means is provided and is connected to the said further rectifier causing the said further rectifier to conduct the said modulations for outward modulation amplitudes above an amplitude level determined by

the conductance determining voltage of the said conductance determining voltage means.

5. A signal coupling and amplitude limiting system in accordance with claim 2 in which the said phase inverter means is a reversing repeater means.

6. A signal coupling and amplitude limiting system in accordance with claim 2 in which a portion of the said load impedance means is also the said phase inverter means.

7. A signal coupling and amplitude limiting system in accordance with claim 2 in which an input circuit is provided and is connected to the said rectifier means, said rectifier means being a variable impedance rectifier comprising a triode with cathode and secondary anode forming a first rectifying diode and cathode and anode forming a second rectifying diode, an impedance connected in series with said first rectifying diode across the input circuit, and an impedance connected in series with said second rectifying diode across the input circuit, whereby said diodes with their series impedances operate simultaneously in parallel to rectify the voltages impressed thereon and the rectifier output characteristic may be made linear by altering said impedances.

8. A signal coupling and amplitude limiting system in accordance with claim 7 in which the parallel rectifying diodes with their series impedances are connected across the said input circuit through a rectifier and in which the undesirable capacity of the first diode is neutralized by a capacity connected from the secondary anode to the input circuit and the undesirable capacity of the second diode is neutralized by a capacity connected from the plate to the input circuit.

9. A signal coupling and amplitude limiting system in accordance with claim 8 in which one element of the rectifier coupling the two rectifying diodes to the input circuit is connected to ground and the other element thereof is connected to one end of the input circuit and in which the inherent capacity of said rectifier is neutralized by a capacity connected from the other end of the input circuit to ground.

10. A signal coupling and amplitude limiting system, in accordance with claim 2 in which a third rectifier having anode and cathode electrodes is provided and the said third rectifier electrodes are in series electrical connection with the said second means for coupling the said modulations to the said output circuit, a conductance determining voltage means is provided and is connected to the said third rectifier causing the said third rectifier to conduct the said modulations for amplitude limits determined by the conductance voltage of the said conductance determing voltage means.

11. A signal coupling and amplitude limiting system in accordance with claim 10 in which the said phase inverter means is a reversing repeater.

12. A signal coupling and amplitude limiting system in accordance with claim 10 in which a portion of the said load impedance is also the phase inverter means.

13. A signal coupling and amplitude limiting system in accordance with claim 10 in which a second conductance determining voltage means is provided and is connected to said second rectifier, and the said limits of the said modulation amplitude conductance in the said second rectifier and in the said third rectifier for the outward modulation amplitude cut off at amplitude levels is determined respectively by the said conductance determining voltages of said second conductance determining voltage means and said first-named conductance determining voltage means.

14. A signal coupling and amplitude limiting system in accordance with claim 13 in which a fourth rectifier having anode and cathode electrodes in series electrical connection with one of the said means coupling the said load impedance means and the said output circuit is provided, a third conductance determining voltage means is provided and is connected to the said fourth rectifier causing the said fourth rectifier to conduct the said modulations for outward modulation amplitudes above an amplitude level determined by the conductance determining voltage of said third conductance determining voltage means.

15. A signal coupling and amplitude limiting system in accordance with claim 13 in which a fourth rectifier having anode and cathode electrodes in series electrical connection with the said second means for coupling the said modulations to the said output circuit is provided, a third conductance determining voltage means is provided and is connected to the said fourth rectifier causing the said fourth rectifier to conduct the said modulations for outward modulation amplitudes above an amplitude level determined by the said conductance determining voltage of said third conductance determining voltage means.

16. A signal coupling and amplitude limiting system in accordance with claim 10 in which the said third rectifier is also in series electrical connection with the said second rectifier.

17. A signal coupling and amplitude limiting system in accordance with claim 16 in which the said second rectifier and the said third rectifier are in series electrical connection coupling to the said output circuit, one of the said second and third rectifiers limiting the conductance of outward modulation, and the other of said second and third rectifiers limiting the conductance of inward modulation for the said modulations coupled in the said series electrical connection.

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REFERENCES CITED

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

UNITED STATES PATENTS

Number	Name	Date
1,678,653	Schroter	July 31, 1928
1,908,381	Travis	May 9, 1933
1,933,773	Terman	Nov. 7, 1933
1,971,646	Farnham	Aug. 28, 1934
2,052,613	Farnham	Sept. 1, 1936
2,271,915	Belleville	Feb. 3, 1942
2,293,835	Landon	Aug. 25, 1942
2,324,275	Becker	July 13, 1943
2,338,418	Dallos	Jan. 4, 1944
2,418,389	Andresen	Apr. 1, 1947
2,422,976	Nicholson	June 24, 1947
2,423,263	Sprague	July 1, 1947
2,423,671	Wolff	July 8, 1947
2,453,958	Andresen	Nov. 16, 1948