Oct. 22, 1946. E. R. SHENK ET AL 2,409,989

SIGNALING SYSTEM

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Fig. 1a.

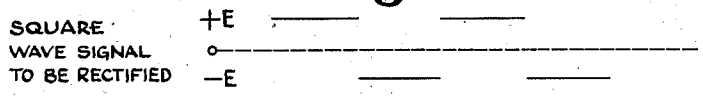

Fig. 1b.

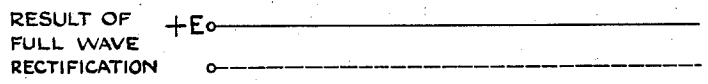

Fig. 2a.

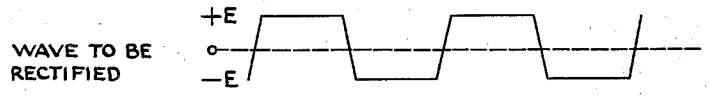

Fig. 2b.

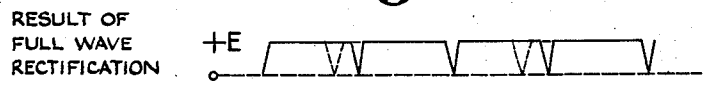

Fig. 3.

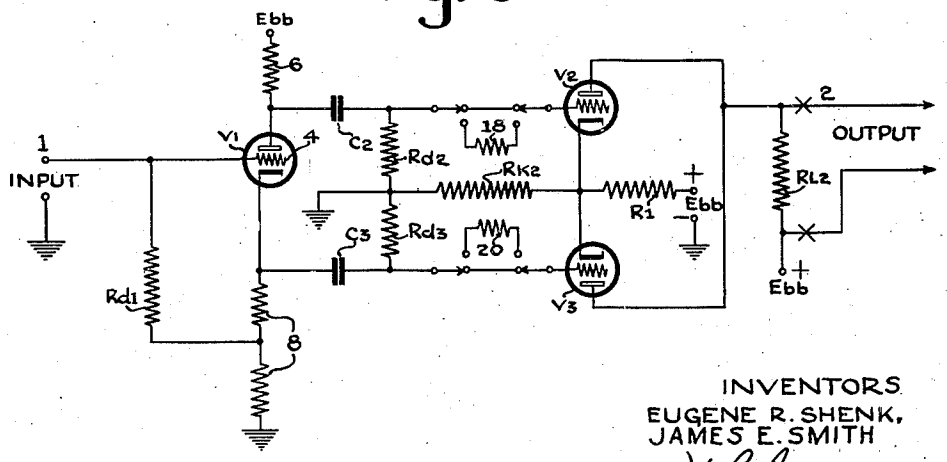

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Fig. 4a.

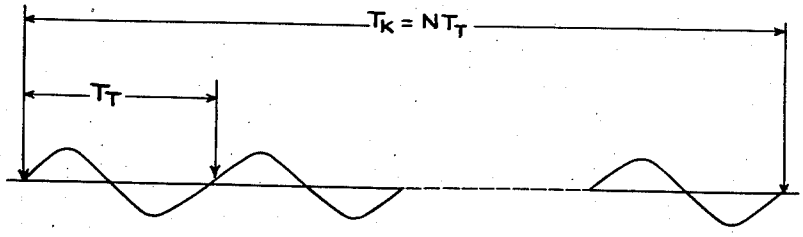

Fig. 4b.

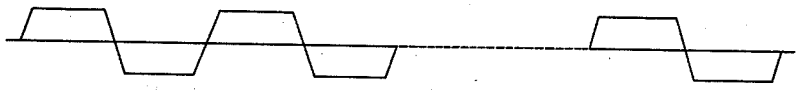

Fig. 4c.

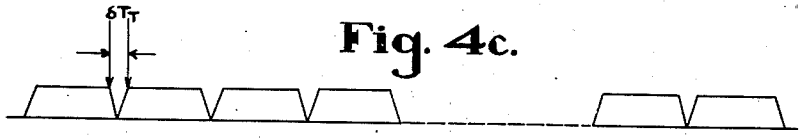

Fig. 5.

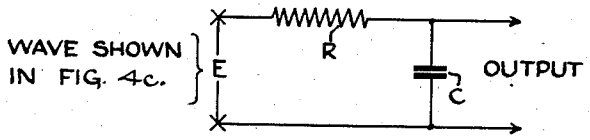

Fig. 7.

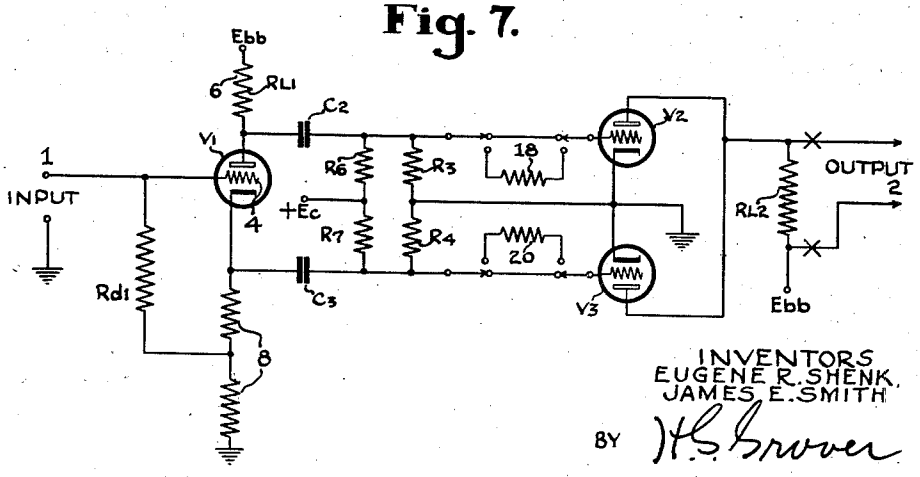

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Fig. 6.

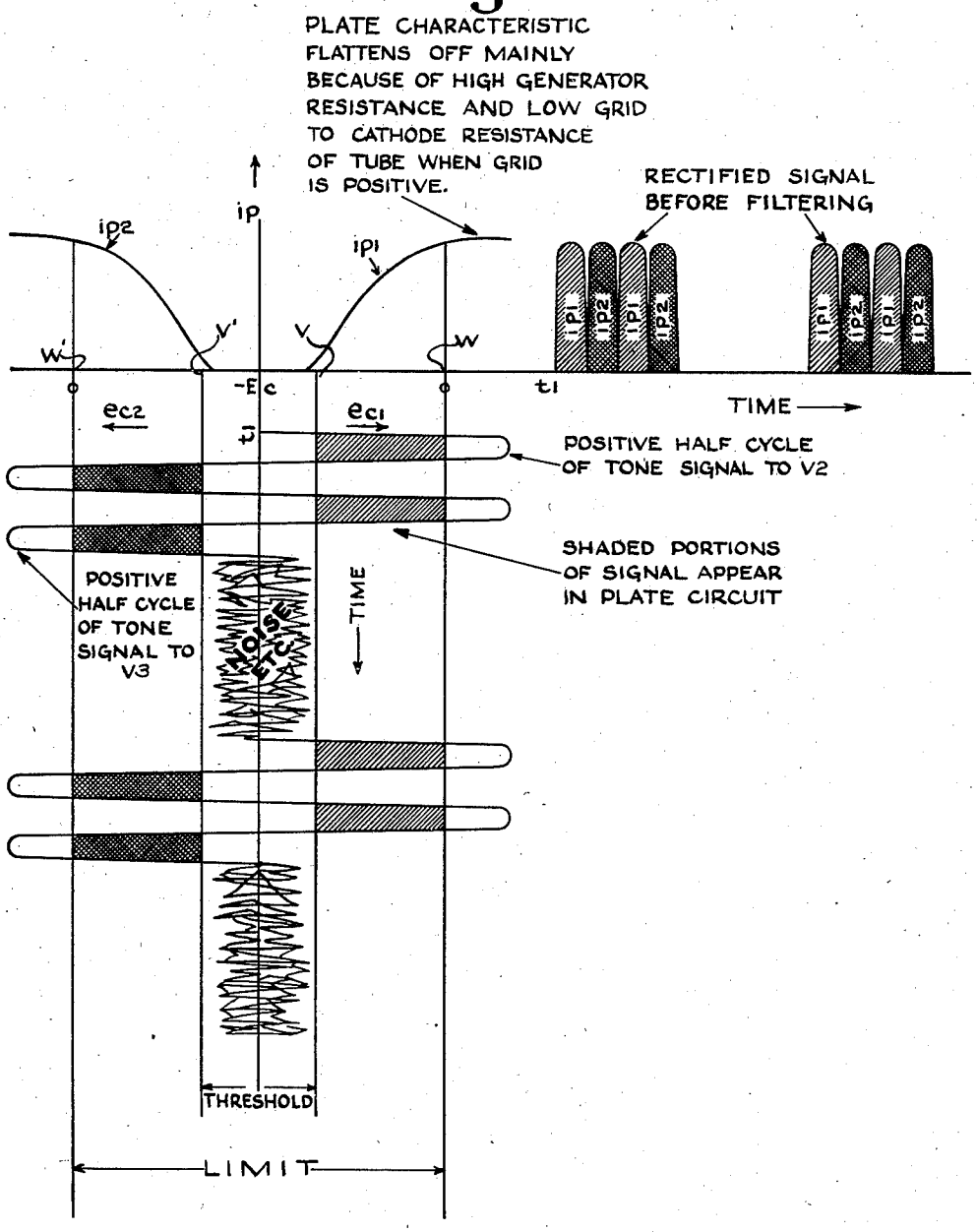

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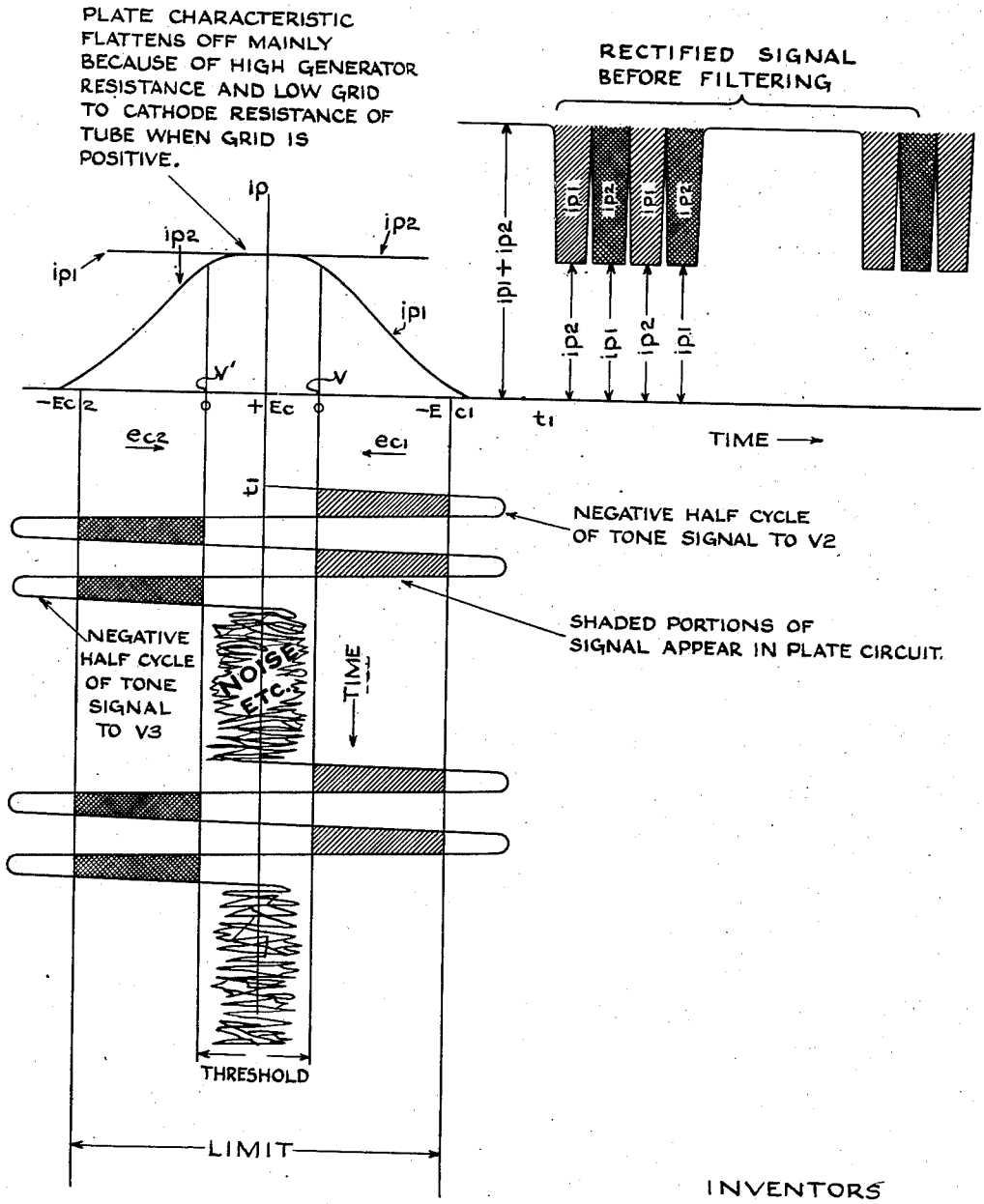
Fig. 8.



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Patented Oct. 22, 1946

2,409,989

UNITED STATES PATENT OFFICE

2,409,989

SIGNALING SYSTEM

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Application July 15, 1944, Serial No. 545,060

8 Claims. (Cl. 178—88)

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This application relates to a new and improved method and means for converting interrupted tone currents into uni-directional currents.

For purposes of description we have shown our improved method and means as being used in the reception of telegraphy in the form of keyed tone currents. It will be understood, however, that our invention is of wide use in the radio art, and is not limited in use except by the terms of the claims appended hereto.

A general object of our invention is to improve reception of keyed tone currents.

Radio printer and telegraph systems transmit intelligence in the form of a succession of so-called marking and spacing intervals. The marking intervals are characterized by the presence of current of tone frequency (usually audio interrupted or otherwise modulated in accordance with signals). The spacing intervals are identified either by the absence of tone or by the presence of a tone differing in frequency from the marking tone. These tone signals must be rectified before they are applied to the receiving printer; or in the case of time division multiplex signals, before they are applied to the signal regenerator. Heretofore, common practice has been to use a rectifier and filter based upon the same principles used in power supply systems for converting from A. C. to D. C. In general, a filter system of this type is satisfactory when the tone signals are considerably higher in frequency than the keying rate. However, when the ratio of tone to keying rate is low—of the order of 2 to 4—the filter required to attenuate the ripple frequencies to a satisfactory degree without unduly increasing the buildup and decay times of the rectified signal becomes quite elaborate.

A broad object of our invention is to improve reception of keyed tone currents.

A more specific object of the present invention is to reduce the need of filtering of the rectified signal before recording, to thereby reduce the need of elaborate filters and provide a system wherein a simple inexpensive filter is satisfactory.

A particular object of our invention is to provide a tone signal rectifier which, ideally, does not require the use of any filter and, in the practical case, requires only a very simple filter, e. g., a single shunt capacitor. This rectifier is especially useful where the ratio of tone frequency to keying rate is low.

An additional object of our invention is reduction of effect of noise in the recording signal by improving the signal to noise ratio. The noise referred to here includes noise received with the signal as well as noise generated in the receiver.

Another object of the present invention is to provide an efficient, simple, and inexpensive keyed tone amplifier, wave former, rectifier and filter to

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produce, for recording if desired, uni-directional currents substantially free of ripple or other forms of distortion.

In keyed tone and similar rectifying and recording systems there is present in all cases a filtering problem, since it is desirable to have at the recorder a uni-directional current substantially free, or as free as possible, from ripples and harmonics derived from the keyed tone.

In recording systems known heretofore, the keyed currents of sine wave form are amplified and rectified and then filtered before recording. In accordance with our improved method and means we propose to first square off the tone current signal and then rectify the same. This limiting process preceding rectification greatly decreases the amplitude of the ripple components, thereby in itself considerably simplifying the filter problem. This squaring off of the tone signal is accomplished in a single limiting and rectifying stage.

In systems known heretofore, noise and disturbances brought in with the received signal and those generated in the system are supplied to a large extent to the rectifier and appear in the rectifier output thereby in effect reducing the signal to noise ratio and adding to the filtering problem discussed above.

In our present invention, the limiting and rectifying stage described above is also arranged to subject the squared off keyed tone currents to a thresholding action to remove all noise components represented by currents or energy, the absolute amplitudes or intensities of which fall within selected adjustable limits.

Thus in effect we make use of only that part of the received tone currents which falls within upper and lower limits wherein there is the least noise and disturbance.

The features which we claim as novel reside in the method and means for amplifying the currents, the method and means for limiting the peak swings of the currents, the method and means for limiting or thresholding the current to do away with the effects of noise brought in with the signal or generated in the circuits, and in the method and means for rectifying the signals after forming the same as described hereinbefore.

In describing our invention in greater detail, reference will be made to the attached drawings wherein

Fig. 1*a* represents an idealized form of square wave signal to be rectified. This square wave form signal may consist of tone current, a number of cycles of which make up a signal element such as, for example, a baud. As used in this description the word "baud" is the shortest marking or spacing element of time in the telegraph signal.

Fig. 1*b* represents current derived by full wave rectification of a signal of idealized wave form, as illustrated in Fig. 1*a*.

Fig. 2*a* represents keyed currents after limiting but before rectification. Fig. 2*b* illustrates the output of a full wave rectifier excited by keyed currents of the form shown in Fig. 2*a*.

Fig. 3 illustrates by circuit diagram the essential features of a wave limiting rectifying and filtering system arranged in accordance with our invention.

Fig. 4*a* illustrates a signal element consisting of several alternations of tone current of sine wave form.

Fig. 4*b* illustrates the sine wave current of Fig. 4*a* after limiting in accordance with our invention.

Fig. 4*c* represents the limited current after rectification. These Figures 4*a*, 4*b* and 4*c* are used in describing the operation of our invention.

Fig. 5 illustrates a simple filter circuit used across the output of the rectifier of Fig. 3, or at the input of the recorder not shown.

Fig. 6 illustrates graphically the operation of the arrangement illustrated in Fig. 3.

Fig. 7 illustrates a modified embodiment of our improved circuit. The arrangement of Fig. 7 is used when it is desired for some reason to reverse the keying action, i. e., to have marking in the presence of spacing current, and spacing in the presence of marking current.

Fig. 8 shows graphically the operation of the arrangement of Fig. 7.

Basically the method of our invention is to first amplify and limit the sine wave tone current representing the signal in order to obtain a rectangular wave. If this rectangular wave was characterized by leading and trailing edges having infinite slopes as illustrated in Fig. 1*a*, then the result of full-wave rectification would be a pure direct current voltage or current as illustrated in Fig. 1*b*. If the rectangular wave to be rectified has finite buildup and drop off times—as it always must in practice due to finite band width—then the wave to be rectified will appear as in Fig. 2*a*, and the rectified wave will appear as in Fig. 2*b*. The sloping edges of the wave of Fig. 2*a* result from high frequency response limitations in the limiter and rectifier circuits. If care is exercised in designing the limiter circuit, these slopes can be made very great, even at high tone frequencies. As the slope of the sides of the wave of Fig. 2*a* is increased, the holes in the rectified wave of Fig. 2*b* become progressively smaller. As these holes decrease, the ratio of direct current to alternating current in the wave increases and the filter problem becomes simpler.

In Fig. 3 we have illustrated a system wherein the objects and purposes of our invention are attained. In this circuit keyed currents of say tone frequency and of sine wave form are impressed on the terminals at 1, to be supplied to the grid 4 of an amplifier and phase reverser tube V1. The tube V1 has a load resistance 6 connecting its anode to a high potential source, and a potentiometer resistance arrangement 8 connecting its cathode to ground. A point on the resistance 8 is connected by resistance R*d*1 to the grid of V1. The arrangement is such that voltages characteristic of the sine wave form but of opposed polarity are developed across resistances 6 and 8, so that they may be supplied as input to a pushpull stage comprising tubes V2 and V3. Such voltages are obtained by properly

dimensioning the resistances 6 and 8 and R*d*1 to derive for the grid 4 of V1 the proper negative bias due to potential drop in the upper portion of 8. The tube V1 then may be considered a somewhat conventional phase inverter tube supplying the signals in push-pull relation to the control grids of tubes V2 and V3. These potentials are supplied by way of coupling condensers C2 and C3 of appropriate size to couple into the grid circuits currents of the tone frequency supplied at the input 1.

The grids of V2 and V3 are connected to the cathodes by resistors R*d*2 and R*d*3 respectively, and cathode biasing resistance RK2. The resistance RK2 with resistance R1 provides a bleeder circuit between the positive end of a direct current power source represented by E*bb* and ground. This bleeder circuit raises the cathodes of tubes V2 and V3 positive with respect to ground direct current potential, so that the grids, operating at ground or slightly negative potential by virtue of the drop in resistances R*d*2 and R*d*3, are negative the desired amount with respect to the cathodes. The anodes of the tubes V2 and V3 are tied together and connected through a load resistance RL2 to the common direct current source.

In this embodiment the bias on the grids of tubes V2 and V3 is made such that in the absence of signal no plate current flows through the tubes V2 or V3, because the cathodes of these tubes are sufficiently positive, as a result of the bleeder current flowing in resistances R1 and RK2, to bias the grids beyond cutoff.

In operation the currents of tone frequency and sine wave form supplied at point 1 are usually of good strength. Then these waves of sine wave form are amplified in tube V1 and applied in opposed polarity to the grids of tubes V2 and V3.

The tubes V2 and V3 differentially excited conduct on alternate portions of the signal cycle. The tube which is excited by the positive tone cycles becomes conductive and draws current. This tube soon draws maximum plate current and the plate current does not increase with further increases in excitation voltage. In the meantime the other tube also negatively biased to cutoff is excited by the negative part of the tone cycles and remains cutoff. On reversal of the applied cycles operation of the tubes, as described above, is reversed. The wave of Fig. 2*a* is subject to rectification in the tubes V2 and V3, and the wave of Fig. 2*b* is obtained at the point 2.

It should be noted that the positive and negative portions of the wave input to tube V1 do not have to be equal, i. e., the tone cycles need not be of 50–50 weight. The reason for this is that since the current is applied in pushpull relation to tubes V2 and V3, the conducting times of these tubes are complementary, i. e., together they conduct for substantially one cycle, but one thereof may conduct for less than a half cycle, the other thereof conducting for more than a half cycle. This is illustrated by dotted lines in Fig. 2*b*.

Where a weak signal is received some limiting action may be carried out before the signal is impressed on the input of tube V1. In this case the wave impressed on tube V1 might be somewhat as indicated in Fig. 2*a*. Then rectification takes place, as described above, in tubes V2 and V3. However, in the usual case, a signal of sufficient strength is applied at V1 in order to accomplish the limiting action in the rectifiers V2 and V3. This limiting action is derived as described above, and as described hereinafter.

In the tubes V2 and V3 then, the keyed tone of sine wave form is limited as well as rectified. These tubes also perform a thresholding action as will be described hereinafter.

The tubes V2 and V3 are individually self-degenerative by virtue of the action of the resistor RK2 and of the fact that they conduct alternately, not simultaneously, i. e., when current flows in tube V2 the drop of potential across RK2 is applied to the grids of both tubes. Conversely, when current flows in tube V3, the drop of potential across RK2 is applied to both grids. Because of this degeneration a larger signal input to tubes V2 and V3 is required to get a given amount of direct current output voltage across RL2. If this degeneration is undesired, the bias voltage for tubes V2 and V3 may be obtained by means of a negative direct current voltage in the grid return circuits, rather than the positive voltage in the cathode circuit provided by RK2.

The method and means for deriving substantially only direct current output from keyed impulses each comprising several cycles of tone wave to thereby reduce the need of filters, has been described briefly above. The same will now be described in greater detail.

Suppose a keyed tone of sine wave form and of a period T_T, as illustrated in Fig. 4*a*, is to be rectified. The shortest marking or spacing interval (in time) (baud) is T_K, and T_K is N times T_T, i. e., N times the tone period where N may be any number. In Fig. 4*b* is shown the same tone after it has been amplified and limited in our system (or if necessary preceding our system). The signal after full-wave rectification appears as in line 4*c*. The fundamental ripple frequency is $2/T_T$. If a simple series condenser-resistor filter CR is to be used to separate the ripple frequency from the keying rate—i. e., current of wave form as illustrated in Fig. 4*c*, applied to the circuit of Fig. 5—then two limitations must be placed on the value of the product CR.

a. CR must be considerably less than T_K. This is necessary in order that the leading and trailing edges of the rectified signal retain the considerable slope obtained by limiting the tone.

b. CR must be considerably greater than δT_T. This results from the requirement that the condenser voltage shall not follow the alternating current component of the individual bauds.

Limitations *a* and *b* can be combined in the simple mathematical notation

$$T_K >> CR >> \delta T_T \qquad (1)$$

from (1) it follows that

$$T_K = NT_T >> \delta T_T$$

$$N >> \delta \qquad (2)$$

Therefore, if (2) is satisfied, limitations *a* and *b* can be met simultaneously. For a given baud length (keying speed) T_T increases as N decreases. Also, with a given limiter circuit, δ will decrease as T_T increases. δT_T is a function of the frequency band width of the limiter circuit. Hence, for a given limiter, δT_T is practically independent of T_T. Consequently, as N becomes smaller, δ also tends toward smaller values, so that the problem of filtering low tone frequencies is not greatly different from that of filtering higher tone frequencies, and herein lies a great advantage of the present invention. When the filter CR is used and the output is taken from across C as shown in Fig. 5, it is connected across RL2. To do this the output leads, Fig. 3, are

broken at the crossed points and the filter of Fig. 5 inserted. The resistance seen by looking back into the circuit across RL2 must be considered a part of R. The above analysis is approximate mainly due to the fact that this generator resistance is not constant but in the circuit of Fig. 3 tends to be greater during δT_T intervals. In practice, this is advantageous because it has the effect of emphasizing relation (1) above.

If a sufficiently high signal level is available, tubes V2 and V3 are made to threshold, limit and rectify the signal. This operation is shown in Fig. 6. The limiting action takes place as described above and hereinafter. The thresholding action is obtained by providing a more negative grid bias, $-Ec$, than that required for plate current cutoff. For example, the values of RK2 and R1 are so chosen as to make the voltage across RK2 sufficiently greater than cutoff, so that that tube (say V2) which is excited by the positive half cycle of the differentially applied voltage does not draw plate current until the applied grid voltage reaches a value V. As the excitation grows the plate current grows until the maximum tube current is obtained. The current then flattens off say at the point W of the grid excitation. This point may be approximately at zero bias on the grid of the tube then excited by the positive cycle. The plate current *ip1* through the tube before filtering is shown at the right of the diagram. During this time the negative portion of the tone cycle is applied to the grid of tube V3 which is already cutoff and no action takes place in this tube.

When the tube V3 is excited by the positive portion of the tone cycle tube V3 cutoff bias $-Ec$ is overcome and this tube draws plate current until maximum current is reached in this tube, as described above. This tube's rectified output is represented at the right of Fig. 6 by the block of current *ip2*.

The limiting action will automatically result if the peak value of the input signal is considerably greater than the magnitude of the grid bias, as is apparent from the above description. Under these operating conditions, the grids might be driven considerably positive with respect to their cathodes. In order to minimize the resulting rectifier action in the grid circuit, and to improve the limiting on positive peaks, it is desirable to insert resistances 18 and 20 in the grid circuits of V2 and V3 by the switching means shown in Fig. 3. Due to the fact that insertion of these resistances decreases the high frequency response of the grid circuits and therefore tends to increase δ (Fig. 4), (mainly because the grid to cathode capacity of each tube sees a higher resistance generator), the resistance values used should be no larger than necessary.

It will be noted that noise components etc., within the adjustable limits V to V' have no effect on the rectified output. The range V' to V is adjusted by adjusting the bias $-Ec$ applied to the grids of the tubes V2 and V3. The more negative the grid bias is made, the greater the portion of the signal that is thresholded out of the output circuit.

The invention might take the alternative form shown in Fig. 7. Such an arrangement is useful where for some reason it is desired to invert the signal, i. e., produce current for recording in the absence of "marking." In this circuit tubes V2 and V3 are supplied through resistances R6 and R7 with a positive grid bias $+Ec$. Consequently, both tubes normally pass current in the absence

of tone input and cause a voltage drop in RL2. When signal is applied to the input of the circuit at 1, the tubes V2 and V3 alternately become nonconducting so that during "signal on" periods the current through RL2 is supplied by one tube instead of two tubes and then is about half as strong as the current in RL2 during "signal off" periods. The operation of this circuit is clearly illustrated by Fig. 8. In this case thresholding is obtained by means of the positive grid supply voltage Ec. At points V and V' the two tubes each draw maximum current. This point in the operation may coincide with zero grid bias. When one tube say V2 receives the negative part of the tone cycle the grid bias is reduced and the current *ip1* falls as shown. The other tube V3 then is excited by the positive part of the tone cycle but is already operating at maximum plate current and its output does not change. When the negative parts of the tone current is applied to tube V3 the operation in the tubes is as described above. The rectified outputs of the two tubes is shown at the right of the plate current curves. The amount of thresholding is adjusted by changing the bias Ec within limits.

As in Fig. 3, resistances 18 and 20 may be included to limit grid current and minimize rectification in the grid circuits on the positive portion of the tone cycle.

The criterion for selecting a suitable filter for this circuit is similar to that previously outlined for Fig. 3.

It is clearly apparent that the principles of the invention can be extended to multiple phase rectifiers by feeding the common load resistor, RL2, from additional tubes (similar to V2 and V3) whose input signals are shifted the appropriate number of degrees with respect to the signals supplied V2 and V3. For example, the invention may be applied to three-phase systems or four-phase systems substantially as it is applied to the two-phase or pushpull system.

We claim:

1. In a signaling system in combination, a source of keyed currents, a multiphase rectifier system, a phase splitting device coupling said source to said multiphase rectifier system for applying the keyed currents thereto, a load impedance coupled to the output of said rectifier system means for biasing said rectifier system so that the same responds only to multiphase currents which exceed a selected minimum intensity and are less than a selected maximum intensity, series capacity and resistance connected in shunt to said load impedance and an output circuit connected across said capacity.

2. In a signaling system in combination, a multiphase rectifier system, a source of keyed currents of sine wave form, a phase splitting device coupling said source to the rectifier system, the current phases at the phase splitter output corresponding to the number of phases in the rectifier system, a load impedance coupled to said rectifier system, and means for biasing the rectifier system so that the rectifiers for the different phases respond in sequence to currents of an intensity above a selected minimum and below a selected maximum.

3. In a signaling system in combination, a full-wave rectifier, a source of keyed currents of sine wave form, a phase inverter coupling said source to the input of said full-wave rectifier, a load impedence coupled to the output of said full-wave rectifier, and means for biasing said rectifiers so

that they are alternatively operative for intermediate portions of the half cycles of said keyed currents.

4. In a signaling system in combination, two tube rectifiers each having input and output electrodes, a source of keyed currents of sine wave form, a phase inverter coupling said source to the input electrodes of said tubes to apply said currents in pushpull relation to said rectifiers, a load impedance coupling the output electrodes of said tubes in parallel, and a circuit for biasing said tubes so that they are alternatively operative for intermediate portions of half cycles of said keyed currents.

5. A system as recited in claim 3, wherein series capacity and resistance is connected in shunt to said load impedance and the output currents to be utilized are obtained across the capacity.

6. In the apparatus for signaling with keyed currents, a phase reverser having input electrodes excited by said keyed currents and having output electrodes from which correspondingly keyed currents of opposed polarity may be derived, a full-wave rectifier comprising a pair of electron discharge systems having input electrodes including control grids differentially excited by said correspondingly keyed currents from the output of said first tube and having output electrodes coupled in parallel by a load impedance, and means for biasing the control grids of said rectifiers by potentials such that the same become operative to produce changes in the load current only in the presence of currents of a desired polarity which exceed a selected value, said bias and load impedance being such that the rectifiers draw maximum current before the peaks of said input currents are reached.

7. In the apparatus for signaling with keyed currents, a phase reverser having input electrodes excited by said keyed currents and having output electrodes from which correspondingly keyed currents of opposed polarity may be derived, a full-wave rectifier comprising a pair of electron discharge systems having input electrodes including control grids differentially excited by said correspondingly keyed currents from the output of said first tube and having output electrodes coupled in parallel by a load impedance, and means for biasing the control grids of said rectifiers by negative potentials such that the same become operative only in the presence of currents of positive polarity which exceed a selected positive value, said bias and load impedance being also such that the rectifiers draw maximum current before the peaks of currents are reached.

8. In the apparatus for signaling with keyed currents, a phase reverser having input electrodes excited by said keyed currents and having output electrodes from which correspondingly keyed currents of opposed polarity may be derived, a full-wave rectifier comprising a pair of electron discharge systems having input electrodes including control grids differentially excited by said correspondingly keyed currents from the output of said first tube and having output electrodes coupled in parallel by a load impedance, and means for biasing the control grids of said rectifiers by positive potentials such that maximum current flows in said load resistance in the absence of signals, which current is reduced in the presence of currents of negative polarity which exceed a selected value.

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