

July 7, 1942.

J. N. WHITAKER

2,289,157

FACSIMILE SYSTEM

Filed Dec. 29, 1939

5 Sheets-Sheet 1

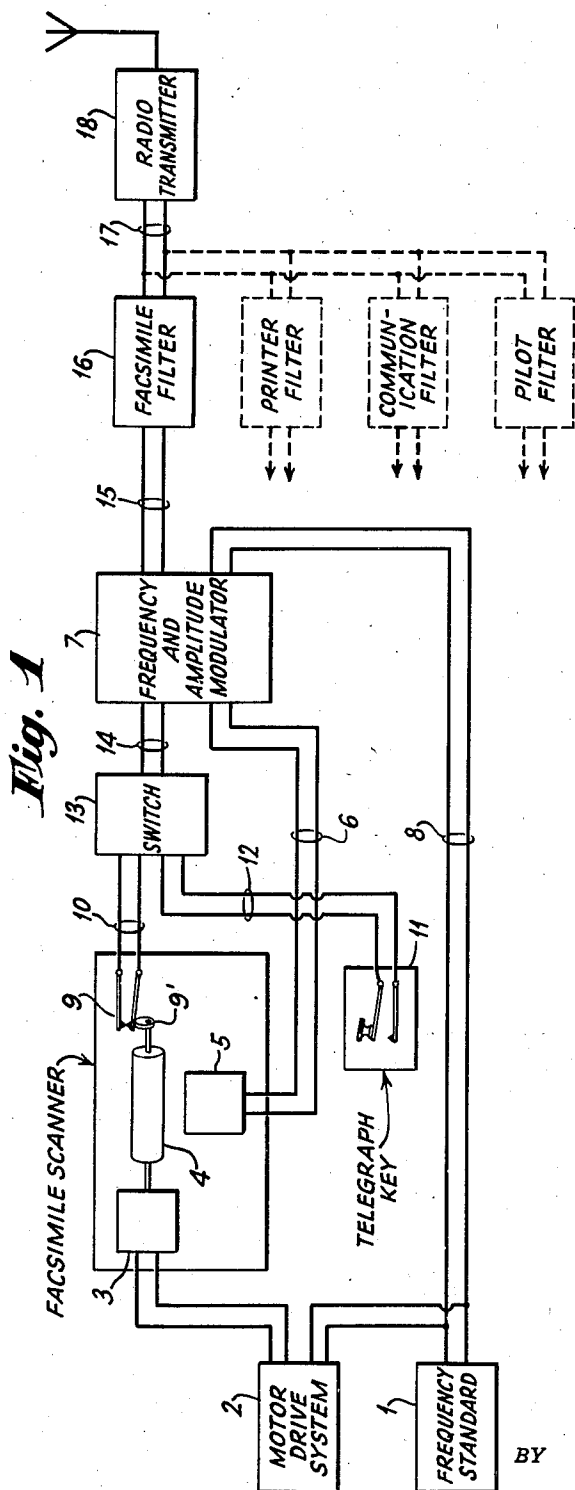


Fig. 2c

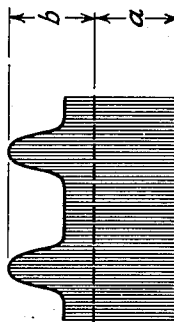


Fig. 2b



Fig. 2a



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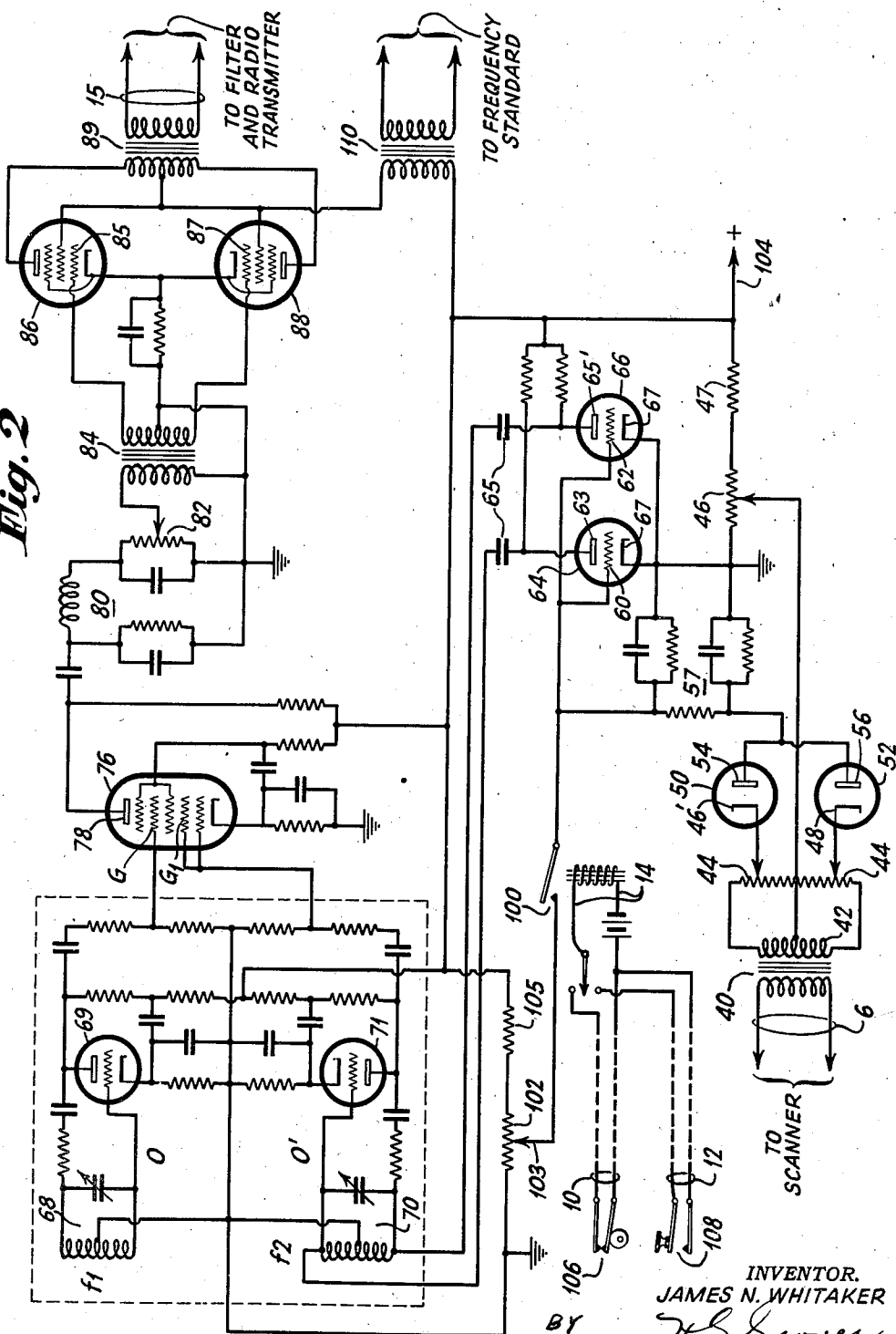
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5 Sheets-Sheet 2

Fig. 2



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FACSIMILE SYSTEM

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5 Sheets-Sheet 3

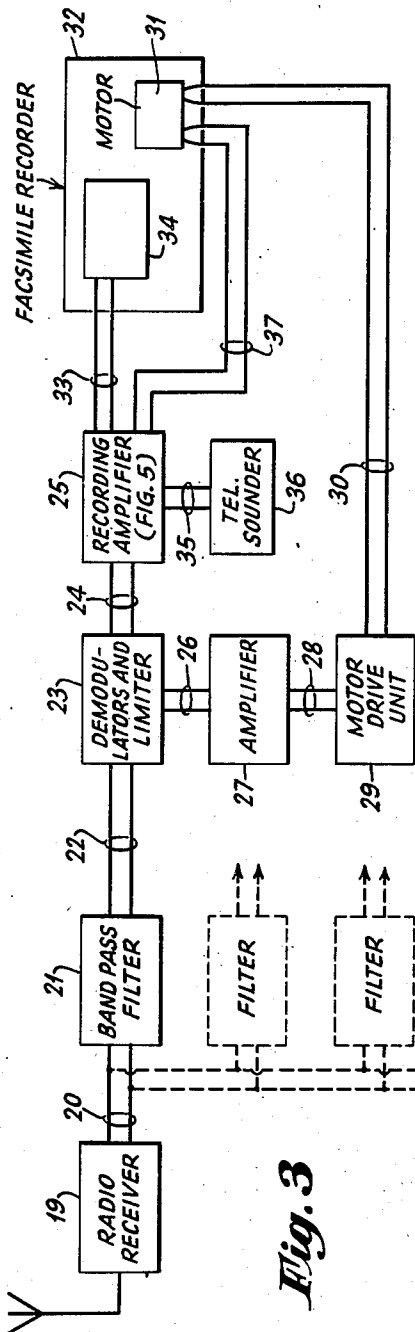


Fig. 3

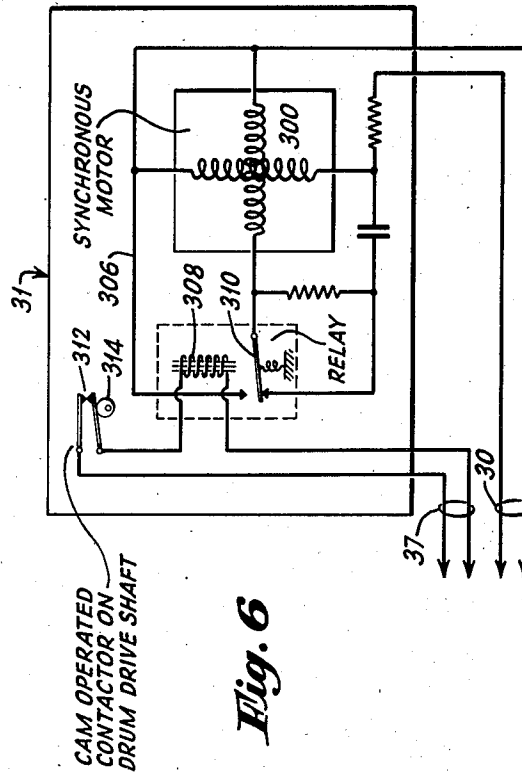


Fig. 6

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FACSIMILE SYSTEM

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5 Sheets-Sheet 5

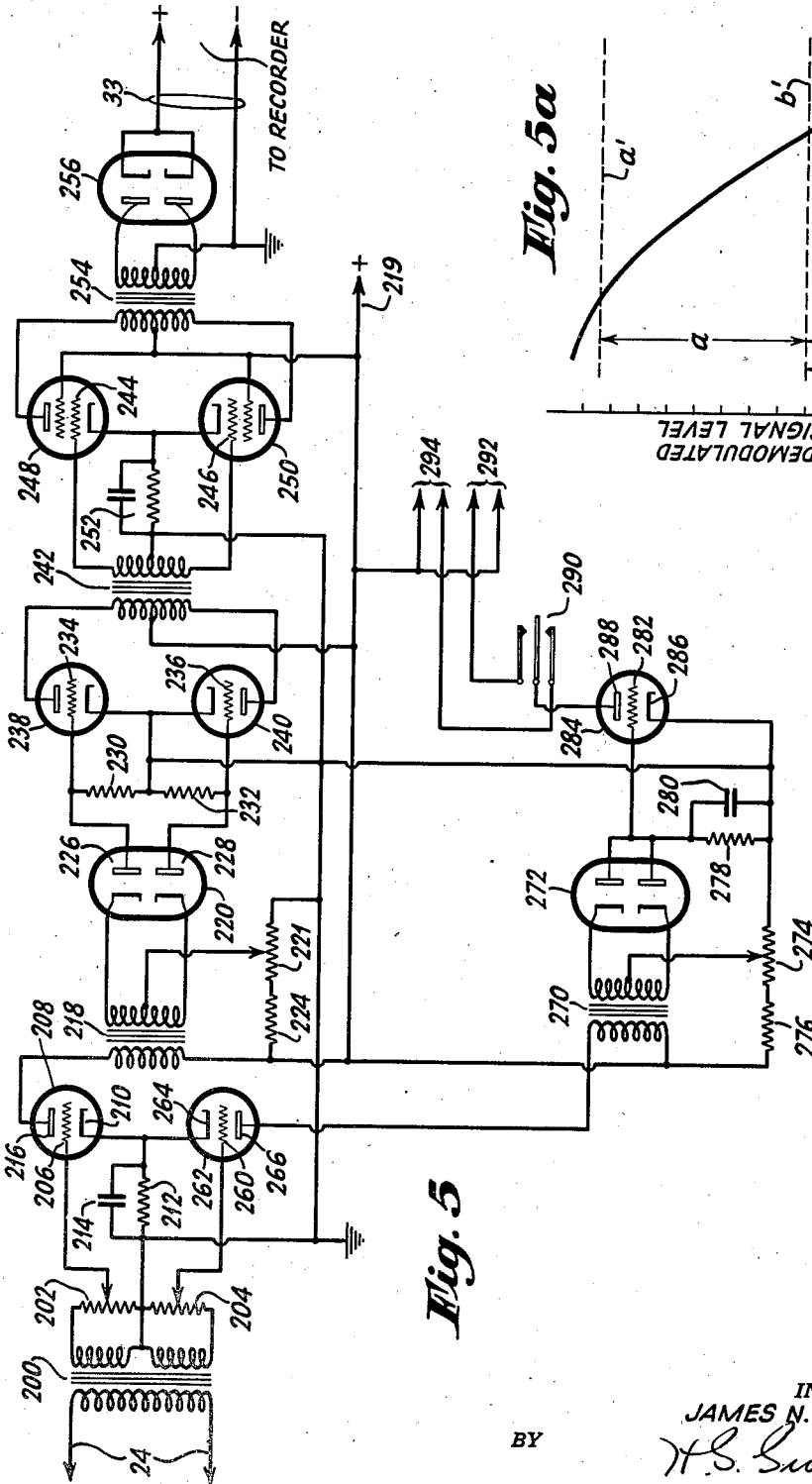


Fig. 5a

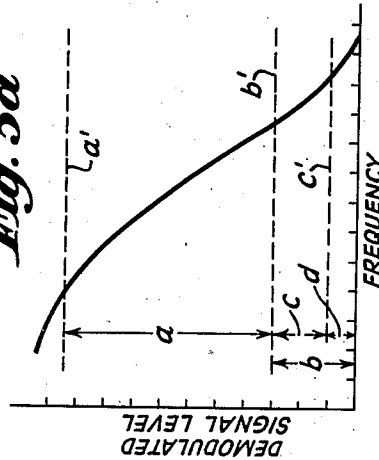


Fig. 5

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FACSIMILE SYSTEM

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Application December 29, 1939, Serial No. 311,495

7 Claims. (Cl. 178—5.6)

This invention relates to the production and transmission of facsimile signals. Transmission of the signals can be accomplished by wire or radio circuits.

In more detail, this application relates to a new and improved means for producing, transmitting, and recording facsimile intelligence on wave energy wherein the wave energy is frequency modulated in accordance with electrical variations produced by scanning a subject. A feature of my invention is means for modulating the frequency of the wave energy by control impulses. This modulation may be used at the receiving end of the system for framing and synchronizing purposes, which may be automatically carried out, and may be considered additional frequency modulation of the carrier. Improved means cooperating with said last means is also included for manually transferring the additional carrier frequency modulation from synchronizing or picture framing purposes to communication of intelligence between operators at the transmitting and receiving terminals. The frequency-modulated wave is subsequently modulated in amplitude in accordance with the synchronizing tone used for controlling the speed of the motor used to drive the facsimile scanning machine.

At the transmitter new and improved means is also provided for adjusting the frequency variations or degree of modulation of the carrier wave to be transmitted with respect to the amplitude variations on the wave derived by scanning the subject and used to frequency modulate the transmitter carrier. A purpose of this means is to provide frequency modulation from a poor facsimile subject which is equal in depth or degree to the modulations which normally would be obtained from scanning a copy or subject having normal contrast.

In a preferred embodiment a sub-carrier of substantially constant amplitude is generated. This sub-carrier frequency is caused to vary in accordance with the facsimile modulations which are supplied through a novel amplifier including wave forming and wave amplitude adjusting means for the purpose described in the preceding paragraph. This frequency modulated sub-carrier is subsequently modulated in amplitude by a synchronizing tone. A means is provided for varying the frequency beyond the normal range of the facsimile modulation by the closure of a relay or by any other appropriate means which, in turn, will be caused to operate by a telegraph key or by a set of cam-operated contacts on the

scanner drum shaft. This latter function provides the desired operator's communication channel and the automatic phasing or framing signals.

The signals thus produced are transmitted as amplitude modulation of a radio-frequency wave over the radio circuit in the usual manner. That is, the waves are frequency modulated in accordance with the currents resulting from scanning and framing or other control potentials and amplitude modulated by a third control potential. At the receiving terminal the radio-frequency wave is detected and the amplitude and frequency modulations of the sub-carrier are separately demodulated. The tone derived from the amplitude modulation is applied as control to a suitable motor drive system for synchronizing purposes. Preferably, I use a small synchronous motor, a winding of which is momentarily short-circuited to relatively displace the phase of the currents, in the windings, when a control impulse occurs at the same time a contact is closed by a cam on the recorder drum drive shaft. The signal derived from the frequency modulation varies through a range corresponding to the modulations due to the scanning current and a second range corresponding to the modulation due to framing control current or signals.

A special discriminating circuit in the recording amplifier having two branches receptive to different amplitude ranges of the signal resulting from conversion of the frequency modulation to amplitude variations separates the normal facsimile signals from the signals desired for use in automatically framing the recording machine and for communication between operators.

At the transmitter and receiver manually operated switches are provided to transfer this last signal to either the communication system or the automatic framing or phasing device need not operate continuously because the recording machine is being synchronized by the same frequency standard as is used for synchronizing the transmitting machine. With this system, it no longer becomes essential to maintain extremely accurate frequency standards at the facsimile terminals. The recording machine will automatically follow any slight variations in the standard frequency source, and the transmitting and recording machines will always remain in perfect synchronization unless the signal is interrupted. If the signal is momentarily interrupted, the operator at the receiver need only throw his control switch to the automatic framing position for a few moments and the recorder will auto-

matically pick up the correct phasing with the transmitting machine.

In the systems known in the art, a sub-carrier tone is amplitude modulated by the facsimile scanning head. The transmitting and recording machines are synchronized by locally generated tones from extremely accurate frequency standards. The receiving operator must manually frame his recorder with the transmitter. A separate communication channel is required for communication between operators.

My system has as objects prevention of spurious amplitude variations of the sub-carrier tone which cause streaking and other irregularities in the recording, and the prevention of crosstalk from other channels from marring the recording. In known systems the frequency standard used at the two terminals may vary slightly, making it necessary to reframe the recorder from time to time. This must be done by the operator, who must also decide when the recorder is in exact frame with the transmitting machine. In my system reframing is accomplished automatically. In known systems a separate communication channel must be available at all times for instructions between operators, whereas in my system the facsimile channel itself is used for this purpose.

Further reference to prior art may be found in J. E. Smith et al. application #270,332, filed April 27, 1939, and in Smith application #271,460, filed May 3, 1939.

The apparatus at the receiving terminal includes means for demodulating the frequency modulations on the wave energy characteristic of the electrical variations caused by scanning the subject, means for separating out and utilizing the frequency modulations on the wave energy due to the framing or synchronizing impulses, means for separating out and putting to use any modulations on the wave energy used for communication between terminals, and means for separating out and utilizing the amplitude modulations superimposed upon the frequency modulated sub-carrier for synchronizing purposes.

The receiver disclosed here and the features thereof which I consider novel are intended primarily for use in connection with a facsimile system wherein the facsimile intelligence is impressed upon the sub-carrier in the form of frequency modulations, and where the tone for synchronizing the facsimile recorder is subsequently applied to the frequency modulated sub-carrier in the form of amplitude modulations. Many features of my system, however, are adapted to wide use in the radio and associated arts as will be pointed out hereinafter.

In a preferred embodiment the frequency modulated wave demodulator consists of an amplitude limiter and demodulating filter or network of the sloping filter type. With this is combined an amplitude demodulator consisting of a full wave rectifier followed by two stages of amplification. A tuned circuit is connected between the grids and ground of each of these amplifiers. These tuned circuits are resonated at the frequency of the amplitude modulations which are, in turn, characteristic of the standard tone frequency used at the receiver for synchronizing.

A feature of my invention is a special type of amplifier which includes a means for discriminating between two different signals, or, more properly, a means for discriminating between different ranges in amplitude of the same signal. This feature of my invention is of wide use in the radio

art in general. In the present case, it is used at the output of the frequency modulated wave demodulator discussed in the two preceding paragraphs. At this point in the circuit the frequency modulations on the wave due to the scanner, the framing or phasing control, or the communication means has been converted to amplitude modulations and detected to derive the said modulations.

A novel feature of this amplifier is means whereby the operator may obtain an adjustment at which the background noise of the system may be eliminated. The amplifier includes circuit means whereby the maximum power output is prevented from exceeding a level at which damage may be caused to the mechanism or circuit apparatus following the amplifier. My new and improved amplifier is arranged in a novel manner such that selected amplitude ranges are separately amplified thereby differentiating between modulation through separate ranges by separate signals. In one branch of the amplifier variations between an upper and lower limit are selected and supplied to a first output. In the present application these variations are characteristic of the modulations on the transmitted energy representative of the electrical variations produced by scanning the subject. In the second branch of this improved amplifier variations falling outside of the limits defined above are selected and utilized by separate utilizing means. In the present application these latter variations are used for automatically framing or phasing the recorder with respect to the transmitting mechanism. Signal modulations for communication between operators at the two terminals may be included in the variations selected by this last branch.

The amplifier includes means for excluding from said first branch variations resulting from signals to be used for other purposes or inadvertent modulations on the transmitted wave. The amplifier of this invention performs this function without impairing the linearity of operation between said specified upper and lower limits.

An object of the entire invention is to provide means whereby the facsimile recording will be substantially free from irregularities caused by normal signal amplitude variations.

Another object of the invention is to assure synchronism between the transmitting and receiving terminal equipment.

A further object is to provide means for automatically framing the recorder with the transmitter scanner.

An additional object is to provide a means of communication between operators.

A primary object of my invention is to provide a system which includes the above features, and yet operates within a normal facsimile channel.

In describing my invention, reference will be made to the attached drawings wherein:

Figure 1 illustrates diagrammatically and by block diagram the elements of the facsimile transmitting terminal arranged in accordance with my invention.

Figure 2 illustrates the circuits and means for generating wave energy and frequency modulating said wave energy in accordance with currents derived by scanning a subject. This means includes means to control the degree of modulation so that the wave modulations represent a good picture of the subject even though a poor picture of the subject is scanned. Means is also disclosed here for additionally frequency modu-

lating said wave energy automatically for picture framing or phasing and manually for communication between terminals, and includes means for subsequently amplitude modulating the wave energy in accordance with the synchronizing tone used for speed control of the motor at the facsimile transmitter.

Figure 3 shows diagrammatically and by block diagram the essential elements of a receiver terminal equipment, arranged in accordance with my invention.

Figure 4 illustrates somewhat completely the essential features of a combined receiver including means for demodulating the frequency modulations on the transmitted wave and additional means for demodulating the amplitude modulations on the said transmitted wave.

Figure 5 illustrates the essential details of an amplifier and wave forming system supplied at its input by wave energy derived from the output of the frequency modulated wave demodulating means of Figure 4. The wave energy supplied by one branch of this amplifier is rectified and used for controlling the recording apparatus, while the output of a second branch of this amplifier is used for picture framing or phasing or for operator's communication.

Figures 2a, 2b, and 2c comprise graphs used to illustrate the manner in which volume expansion is accomplished in the circuits supplying the modulator in Figure 2 to control the degree of modulation and improve the overall operation of the system. By this means, it is possible to obtain a modulation from the scanning of a poor facsimile which will be equivalent to that normally obtained from scanning a normal subject.

Figure 5a is a curve illustrating the manner in which modulation range selection is accomplished in the circuits of Figure 5.

Figure 6 illustrates a motor which may be used for synchronizing and framing purposes.

Referring to the drawings:

Figures 1 and 3 illustrate this invention in block diagram form. Figure 1 illustrates the transmitting terminal and Figure 3 illustrates the receiving terminal. Referring to Figure 1, the operation of the transmitting system is as follows:

Frequency standard 1 controls the frequency of a thyatron inverter or other suitable motor drive source 2 which, in turn, supplies synchronized power to the facsimile scanner drive motor 3. Motor 3 turns scanner drum 4. Variations in the density of the facsimile copy which is secured to drum 4 are converted into variations in electrical energy in scanning head 5. This electrical energy is passed over lines 6 to modulator 7 and performs the function of frequency modulating the output frequency of a source of wave energy (referred to hereinafter as a sub-carrier) in this unit.

Voltages of tone frequency from frequency standard 1 is also applied to modulator 7 over lines 8. This tone is applied to the frequency modulated sub-carrier as amplitude modulation and is used for synchronizing purposes at the receiver. A contactor 9, operated by a cam 9' on the drum shaft, is connected to switch 13 through lines 10 and telegraph key 11 connects to switching means 13 through lines 12. By means of switch 13, the operator may connect either the cam-operated contactor or the telegraph key to the modulator unit over lines 14. The cam-operated contactor is for the purpose of transmitting a signal by frequency modulation for use in automatically framing the recorder

with the transmitting machine. Lines 14 are connected to a relay inside the modulator unit 7 which is arranged to cause the sub-carrier frequency to be shifted beyond the normal facsimile modulation range.

The modulator output is passed on to transmitting filter 16 over lines 15 and from there to the radio transmitter 18 over lines 17 in the usual manner. Other communication circuits may also be connected to the radio transmitter through their respective filters as indicated by the broken lines.

Having thus given a general description of the transmitting system, I will now refer to Figure 3 and proceed with a general description of the receiving system. The radio signal is received and detected by means of the usual radio receiver 19. This receiver may be of a conventional design. The detected signals are applied to the filter group by means of lines 20. Filter 21 separates the frequency and amplitude modulated carrier described above from the rest of the signals on the channel and passes it over lines 22 to a novel demodulator and limiter 23. Demodulator 23 separately demodulates both the frequency and amplitude modulations of the sub-carrier. The signals derived from the frequency demodulation are passed to a novel recording amplifier 25 over lines 24. The signal derived from the amplitude demodulation is passed over lines 26 to amplifier 27 and on through lines 28 to a thyatron or other suitable motor drive unit 29 which maintains the synchronism of the recorder with the scanner. Power from motor drive unit 29 is passed on through lines 30 to drive motor 31 of facsimile recorder 32.

Amplifier 25 includes an amplitude range discriminator arrangement for separating the framing and operator's communication signals from the facsimile signal. The facsimile signal is passed over lines 33 to facsimile recording head 34 of a facsimile recorder 32. By means of a manually operated switch included in amplifier unit 25, the operator may connect the framing or communication signals to lines 37 to control drive motor 31, or to lines 35 to operate telegraph sounder 36.

Reference will now be made to Figure 2 and certain novel features of the transmitting apparatus, described in general with reference to Figure 1, will now be described in detail.

In Figure 2 an amplitude modulated sub-carrier tone from a scanner not shown in this figure is applied through lines 6 (which correspond to lines 6 of Figure 1) to transformer 40. Opposite ends and the center tap of the secondary winding 42 of this transformer are connected to the outer terminals of double potentiometer 44. The mid-point of potentiometer 44 is also connected to the variable contactor of potentiometer 46. The variable contactors of double potentiometer 44 are connected to the cathodes 46' and 48 of rectifier tubes 50 and 52. Anodes 54 and 56 of the rectifier tubes are connected in parallel, and to low pass filter 57. Low pass filter 57 is of the resistance and capacity type, well known to the art, and merits no further description here.

The signal is rectified by rectifier tubes 50 and 52 and the pulsating direct-current resulting therefrom is applied to filter 57 through a portion of resistor 46. The adjustment of double potentiometer 44 and potentiometer 46 constitute the contrast or volume contraction and expansion control previously mentioned, and function as follows.

Potentiometer 46 and resistor 47 are connected between the positive power supply terminal and ground. It follows then that there will be a direct-current potential appearing across these two resistors. The relative potential appearing across each depends upon the relative values of the two resistors. The variable contactor on 46 connects to the center tap of the double potentiometer 44 and through the two variable arms of 44 to cathodes 46' and 48 of rectifiers 50 and 52. From the above description and my reference to Figure 2, it will be understood that a bias is applied to rectifiers 50 and 52, the potential of which will be adjustable by moving the contactor of potentiometer 46.

Refer now to Figures 2a, 2b and 2c. 2a is a representation of a normal facsimile signal after full wave rectification, as might be observed by connecting an oscilloscope between rectifier plates 54 and 56 and ground. 2b represents a facsimile signal derived from a very poor facsimile copy. In order to obtain a signal from the energy represented at 2b which would be equivalent to 2a, the variable arms of double potentiometer 44 are moved outward until the amplitude of the rectified signal reaches the value shown in Figure 2c. The variable arm of potentiometer 46 is next moved toward the positive end of the resistance, thereby increasing the bias on rectifiers 50 and 52 until the portion of the signal *a* in Figure 2c is ineffective. In other words, the rectifier bias potential is adjusted to equal potential *a* derived from the rectified signal. It, therefore, follows that the potentials derived from the rectified signal which are of a value greater than *a* will appear between rectifier plates 54 and 56 and ground; and are represented as *b* in Figure 2c. Thus, we have effectively caused the signal shown in 2b to be equal to signal shown in 2a in contrast by providing a threshold bias to rectifiers 50 and 52.

Having thus described the operation of the contrast control (or volume expander), we will proceed with the succeeding functions.

The rectified signal potentials are filtered by the resistance-capacity filter 57. One side of this filter is connected to ground and the other connects to grids 60 and 62 of modulator tubes 64 and 66. Therefore, it will be understood that the resistance of these tubes will vary in accordance with the rectified signal voltage. Moreover, the anodes of the rectifiers 50 and 52 being connected to that side of the filter connected to the grids of tubes 64 and 66 the potential on these grids becomes more negative as the rectifier output grows and impedance of the tubes 64 and 66 increases as the signal amplitude rises. These variations of impedance may be used to modulate the frequency of a source of wave energy in any manner.

In a preferred embodiment as illustrated in Figure 2, two regenerative oscillators 0 and 0' of any conventional type are used. Oscillators 0 and 0' are independent in operation. Oscillator 0 has an oscillatory circuit 68 connected between the grid and anode of tube 69. Oscillator 0' has an oscillatory circuit 70, also, connected between the grid and anode of tube 71. Each half of the oscillatory circuit 70, however, is shunted by capacitors 65 in series with the impedance of tubes 64 and 66 because the anodes 63 and 65' of these tubes are connected to spaced points on circuit 70 through capacitors 65, while the cathodes 67 of these tubes are tied together and connected through a common

ground to circuit 70. The frequency of the oscillator 0' is changed by the varying resistance of the modulator tubes 64 and 66. The action of the varying resistance of the modulator tubes is to cause condensers 65 to become more or less effective upon the tuning of the tank circuit 70 of the modulated oscillator 0', thereby varying the resonant frequency of said tank circuit, and, therefore, the frequency of the oscillations.

The oscillators 0 and 0' operate at slightly different radio frequencies. The output of oscillator 0 is applied to grid G of tube 76. The output of oscillator 0' is applied to grid G1 of converter tube 76. One of the oscillators, 0', is modulated in frequency as described above. The beat between these two oscillators which is also modulated in frequency is detected in the usual manner in tube 76.

In order to cause the oscillator frequency to be changed to a value beyond the normal operating point, (modulation by a framing or phasing potential or for communication between terminals), it will be necessary to apply a potential to the modulator tube grids 60 and 62 which will be either of a higher value than the maximum signal level at the output of the rectifiers 50 and 52 or which will be of an opposite polarity. The latter is preferable as the rectified signal does not reverse in polarity, although it may rise to an abnormal amplitude at times. Therefore, for the purpose of varying the frequency of the oscillator 0' beyond the normal operating range, a positive bias of a predetermined value is applied to grids 60 and 62 of modulator tubes 64 and 66 through closure of relay contacts 100. This positive bias is obtained from the IR drop across potentiometer 102 and is adjustable by movable tap 103. Potentiometer 102 has one side connected to ground and the other side to the positive terminal 104 of the power supply through fixed resistor 105.

The relay 100 which applies this bias for additional frequency modulation of the oscillator 0' is under the control of a cam and contact arrangement 106 or a manually controllable key 108. The cam 106 may be on the shaft of the scanner drum.

As previously stated, the difference or beat frequency between the oscillators is detected in the conventional manner by tube 76 and its associated components. The output of tube 76 is passed through low pass filter 80 to remove the radio-frequency voltages, leaving only the beat frequency to pass through volume control 82 and transformer 84 to grids 85 and 87 of amplifier tubes 86 and 88.

Amplifier tubes 86 and 88 act to amplify the beat frequency and apply the same to the load circuit through transformer 89. This output then will be an audio-frequency tone of a constant amplitude but modulated in frequency in accordance with a picture signal, or by the operation of the cam in 106 or telegraph key 108, which close relay contactors 100.

In order to transmit a signal for use in synchronizing the equipment at the receiving terminal, I amplitude modulate the frequency modulated sub-carrier wave by a constant standard frequency. This is accomplished by connecting the secondary winding of transformer 110 in series with the plate and screen grid power supply of amplifier tubes 86 and 88. The desired modulating potentials are applied to the primary winding of transformer 110, and amplitude mod-

ulation of the amplifier takes place due to the increase and decrease of the amplifier plate potential and screen potential in accordance with the applied modulating frequency. The output of amplifiers 86 and 88 is applied through transformer 89 and lines 15 (see Fig. 1) to the radio transmitter.

The receiver includes amplifying means 19 and filtering means 21 which may be conventional. The filter 21 supplies modulated wave energy to a demodulation system shown in detail in Figure 4. In this figure the apparatus shown above the dashed line is an amplitude limiter and frequency modulated wave demodulator of the sloping filter type. The modulated wave is supplied by lines 22 to the input transformer 120. Transformer 120 is coupled to a cascaded arrangement of limiting and amplifying stages 122, 123, 124, and 126 which limit the modulated wave and supply it to a sloping filter conversion circuit 139. The details of this system and operation thereof have been set forth in detail in Smith et al. application #270,332, filed April 27, 1939.

The apparatus illustrated below the dashed line comprises the amplitude modulation demodulator, and will now be described.

The signal is passed over lines 140 to the primary winding of transformer 142. The outer terminals of the secondary winding of transformer 142 is connected to the anodes of full wave rectifier 144. The center tap of this winding is connected to ground. The cathodes 146 of rectifier 144 are connected in parallel and to tuned circuit 143 comprising condenser 145 and inductance 147 and to the grid of amplifier 148. The cathode of amplifier 148 is connected to ground through the cathode biasing resistor 150 which is by-passed by condenser 152. The anode of amplifier tube 148 is connected through plate resistor 154 to the positive terminal of the plate supply, and through coupling condenser 156 to the grid of amplifier tube 164 and to tuned circuit 160 comprising inductance 161 and condenser 162. The cathode of amplifier tube 164 is connected to ground through the cathode biasing resistor 166 and by-pass condenser 168. The anode of amplifier 164 is connected to one side of the primary winding of output transformer 170. The other side of this winding connects to the positive terminal of the plate power supply. The secondary winding of transformer 170 is connected to a pair of output terminals which are the leads 26 of Figure 3.

In operation, the incoming signal is rectified by full wave rectifier 144. Tuned circuit 145 and 147 is resonated at the frequency of the amplitude modulations and effectively eliminates the greater part of the rectified carrier frequency. The tone thus derived is amplified by amplifier tube 148 and is passed on to the grid of amplifier tube 164 through coupling condenser 156. Tuned circuit 161, 162 acts to further remove the remaining carrier frequency, leaving substantially nothing but the modulation frequency to be amplified by amplifier 164 and passed on through output transformer 170 to the utilization circuit by way of lines 26—Figure 3 and Figure 4. Lines 26 supply this tone to amplifier 27 connected with motor drive unit 29 by lines 28.

The frequency modulations on the wave, characteristic of the variations derived by scanning the subject and of the framing control and/or the inter-communication control, are amplified, limited and converted by sloping filter 139 to cor-

responding amplitude variations. From the sloping filter output the amplitude variations one range of which is characteristic of the scanned subject and another range of which is characteristic of the additional frequency control are supplied by lines 24 of Figures 3 and 5 to a recording amplifier 25, Figure 3. This recording amplifier is described in detail hereinafter and illustrated in Figure 5.

The modulations from line 24 are supplied to a novel range selecting rectifier and amplifier, as illustrated in Figure 5, to operate as illustrated by the curve shown in Figure 5a. In Figure 5 the demodulated sub-carrier frequency, that is, the amplitude variations characteristic of the frequency modulations is applied over lines 24 to input transformer 200. One half of the secondary of transformer 200 connects to potentiometer 202 and the other half to potentiometer 204. The movable contactor of potentiometer 202 is connected to grid 206 of amplifier tube 208. Cathode 210 of amplifier 208 is connected to biasing resistance 212 across which is connected capacitor 214. Anode 216 of amplifier 208 is connected to one side of the primary winding of transformer 218. The other side of this primary winding is connected to the positive plate supply terminal 219. The two outer terminals of the secondary of transformer 218 are connected to the cathodes of rectifier 220, and the center tap is connected to the variable contactor of potentiometer 221. One side of potentiometer 221 connects to ground and the other connects to the positive side of the power supply through fixed resistor 224.

The purpose of this arrangement is to provide a particular controllable bias to rectifier 220. This bias fixes the lower limit of the effective portion of the facsimile signal, which at this point in the system has been converted from frequency modulation to amplitude variations. Anodes 226 and 228 of rectifier 220 are connected to resistors 230 and 232 and grids 234 and 236 of amplifiers 238 and 240. The anodes of amplifiers 238 and 240 are connected to the outer terminals of the primary winding of transformer 242, and the center tap of this transformer is connected to the positive terminal of the plate supply. Amplifiers 238 and 240 operate in the conventional manner except that only the negative half of each cycle of the applied signal tone is effective. This arrangement is provided for two reasons. First, the signal may be limited by applying a bias to the rectifier without seriously discriminating against the overall linearity of the amplifier, and, secondly, if the signal rises to an abnormal amplitude, the grids of amplifier tubes 238 and 240 become negative to a point of plate current cut-off or greater, and, therefore, the maximum output of the amplifier is limited.

The outer terminals of the secondary of transformer 242 are connected to grids 244 and 246 of power amplifier tubes 248 and 250. The center tap of this winding is connected to ground. Bias for the power amplifier is obtained by means of the conventional cathode resistor combination 252. The anodes of the power amplifiers are connected to the outside terminals of the primary winding of transformer 254. The center tap of transformer 254 is connected to the positive plate supply terminal 219. Amplifiers 248 and 250 act as linear amplifiers in the conventional manner.

The secondary winding of transformer 254 has its outer terminals connected to the plates of rectifier 256. The center tap of this winding is connected to one output terminal of the am-

plifier, and the paralleled cathodes of rectifier 256 is connected to another output terminal. These are the lines 33 of Figure 3.

In operation, the level of the facsimile signal is appropriately adjusted by means of the contactor on input potentiometer 202. The signal is amplified by amplifier tube 208 and rectified by rectifier 220. The threshold bias of rectifier 220 is adjusted so that the undesired lower portion of the signal is eliminated and the remaining signal is passed on to the grids of intermediate amplifier tubes 238 and 240 in the form of alternate half cycles. The alternate half cycles combine in transformer 242 to produce an alternating wave due to the push-pull action, as in the said application #270,332 and will provide a wave approaching a sine wave (depending upon the rectifier bias and signal amplitude) which is further amplified by power amplifier 248 and 256. This amplified signal is then rectified by full wave rectifier 256 and applied to the recorder in the form of a pulsating direct current. It may be found desirable in some applications to place a smoothing condenser across this amplifier output, that is, across lines 33.

Referring again to Figure 5, it will be noted that the secondary winding of input transformer 200 is divided into two sections. One section is connected across potentiometer 202 and the other across potentiometer 204. The portion of the input signal appearing across this second half of the secondary of transformer 200 is applied to the grid 260 of amplifier 262 by means of a connection to the movable contactor on potentiometer 204. Cathode 264 of amplifier 262 is connected to the cathode of amplifier 208 and to bias resistor and condenser 212 and 214. As will be seen from the drawings, this biasing arrangement is common to both amplifier 208 and 262. In practice, these two amplifiers are the two triode sections of a twin triode tube. Plate 266 of amplifier 262 is connected to one side of the primary winding of transformer 270. The other side of this winding is connected to the positive side of the plate power supply 219. The two outer terminals of the secondary of transformer 270 are connected to the cathodes of rectifier 272 and the center tap is connected to the movable arm of the rectifier biasing potentiometer 274.

One side of potentiometer 274 is connected to ground and the other side is connected to the positive side of the plate power supply through fixed resistor 276. The anodes of rectifier 272 are connected in parallel and to ground through resistor 278, across which is placed smoothing condenser 280. The plates of rectifier 272 also are connected to grid 282 of keyer tube 284. Cathode 286 of the keyer tube 284 is connected to ground. Anode 288 of keyer tube 284 is connected to the center member of transfer switch 290. The two outer members of switch 290 are connected to output connections 292 and 294. The leads at 292 and 294 supply the framing impulses to the motor through, say lines 37, of Figure 3 and the communication signals to the operator, say through lines 35, of Figure 3.

In operation, the signal is amplified by amplifier tube 262 and rectified by tube 272. When the amplitude of the signal is sufficient to overcome the rectifier threshold bias, an IR drop will appear across resistor 278. The polarity of the potential developed across resistor 278 will be positive toward the grounded end and negative toward the upper end. As the potential

appearing across resistor 278 rises, the plate current drawn by keyer tube 284 is reduced until complete cut-off is reached and any additional increase in signal level will have no further effect on this portion of the circuit.

The operation of the complete system of Figure 5 may be better understood by reference to Figure 5a. In this illustration the output of a typical filter type of frequency demodulator (such as shown at 139 in Figure 4) is shown, with the output amplitude plotted against frequency. For purposes of illustrating one mode of operation, dashed lines are drawn across portions of this figure to indicate the various threshold settings. *a'* indicates the maximum usable level of the facsimile signal. It is at this point that the rectified signal causes the grids of amplifiers 238 and 240 (Figure 5) to reach cutoff. *b'* represents the normal minimum of the facsimile signal, and the proper threshold bias to be applied to rectifier 220 (Figure 5). Therefore, the usable facsimile signal will fall between the limits indicated as *a* in Figure 5a. Any signal appearing either above or below these limits will not be amplified and passed on to the facsimile recording mechanism.

In practice, the operator may adjust the input amplitude and the rectifier bias in such a manner as to effectively increase the contrast of the signal to compensate for a low level of modulation.

In the embodiment used to describe my invention the portion of the signal which is to be utilized for automatic framing or for operator's communication purposes is indicated as *b* in Figure 5a and represents all the signal remaining between *b'* and zero.

It is, however, understood that I do not limit my invention to use of variations of amplitude which lie below *b'* only for framing or communication purposes. My invention involves use of variations falling above *a'* for this purpose also. The position of the variations due to scanning relative to those due to framing are interchangeable, and can be controlled in various manners. For example, in the arrangement shown in Figure 2, the additional modulation by framing or communication signal control increases the frequency of the beat frequency by increasing the oscillation frequency of *O'*. Under these circumstances, it is assumed *O'* is operating at a higher frequency than *O*. By reversing the positions of these oscillators in the frequency spectrum and modulating *O'* as it is now modulated, the additional modulation of the frequency of the beat frequency by the framing or communication impulses would be in a downward direction, that is, would decrease the beat frequency. Under these latter circumstances, the amplitude variations resulting from conversion and detection of the frequency modulation appear as illustrated in Figure 5a. Extremely low signal amplitudes are usually accompanied by circuit noise. For this reason, the threshold of the rectifier 272 of Figure 5 in the framing or communication channel is adjusted to exclude all of that portion of the signal which appears below *c'* and which is indicated as *d* in Figure 5a. The operator, therefore, adjusts the input potentiometer 204 of Figure 5 and the rectifier threshold bias 274 of Figure 5 until the keyer tube 284 of Figure 5 ceases to draw current when the signal level reaches amplitude *b* of Figure 5a and until the rectifier 272 of Figure 5 ceases to pass current when the signal is reduced to level *d* of Figure 5a.

Thus, the operating conditions are realized where only the signal indicated as *a* (Figure 5a) operates the facsimile recorder and the portion of the signal indicated as *c* operates the framing device or operator's communication system. The extremely low level of the signal indicated as *d* is eliminated.

When the framing or communication variations are above the range in which the variations resulting from scanning occur, the latter range is moved down proportionally but is still above that range wherein circuit noises appear.

The operator may apply the communication signal or framing signal to either the telegraph sounder through 294 Figure 5 and lines 35 Figure 3 or to the automatic framing device through lines 292 Figure 5 and lines 37 Figure 3 by proper manipulation of switch 290 of Figure 5.

I may use any known type of motor or equivalent means controlled by the output taken from lines 292 or lines 294. For example, the motor in unit 31 of Figure 3 may be as illustrated in Figure 6. Here a synchronous motor 300 has a winding which is short-circuited or partly short-circuited by a circuit 306 which is completed through armature 310 when a framing impulse is supplied from output 292 or 294 of Figure 5 over leads 37 (Figures 3 and 5) to the relay 308 at the same time contacts 312 are closed by any means such as, for example, a cam 314 on the recorder drum shaft. The synchronous motor is also connected by leads 30 (Figure 3) to the motor drive unit 29 and is synchronized with equivalent means at the transmitter scanner by the standard tone frequency used to amplitude modulate the transmitted wave (Figure 2) and separated out at the receiver (Figure 4).

What is claimed is:

1. In a facsimile system in combination, a source of wave energy to be modulated, a source of modulated wave energy derived by scanning a subject, means for modulating said first wave energy in accordance with the modulation of said second wave energy, and means for expanding the amplitude of the modulated wave energy to produce a normal modulation of said first wave energy when the modulations on said modulated wave energy are sub-normal, said means comprising a rectifier with adjustable minimum threshold and adjustable signal amplitude input excited by said modulated wave energy and coupled to said means.

2. In a facsimile system a means for controlling the effectiveness of the amplitude modulation derived from scanning a picture on the frequency of a wave generator comprising a wave generator having frequency determining circuits including a reactance, a pair of rectifier tubes each having a cathode and anode, means for impressing modulated wave energy derived by scanning a picture in push-pull relation on said cathodes, wave energy amplitude adjusting means in said last named means, means tying the anodes of said rectifier tubes together, means for biasing the anodes of said rectifier tubes relative to the cathodes of said rectifier tubes by a potential such that the unmodulated portions of the input wave will be ineffective and the modulated portions will have an amplitude sufficient for modulation purposes, a pair of amplifier tubes having input and output electrodes, means connecting the plate-cathode impedance of said amplifier tubes in shunt to said reactance, and a filter circuit which passes the modulations only of said input wave coupling the anodes of said

rectifier tubes to the input electrodes of said amplifier tubes.

3. In a facsimile system in combination, a first source of oscillation, a second source of oscillations comprising an oscillatory circuit including reactance, means for beating the oscillations generated by said first and second oscillators to derive a beat note for signalling purposes, a pair of electron discharge devices having input and output electrodes, means coupling the output electrodes of said discharge devices in shunt to the reactance of said oscillatory circuit of said second oscillator, a source of modulating energy, a pair of rectifiers having input electrodes coupled to said source of modulating energy said rectifiers having output electrodes, a filter coupling the output electrodes of said rectifiers to the input electrodes of said pair of amplifier tubes, and means for expanding the amplitude of said modulating potentials to produce a normal modulation of said oscillation generated by said second oscillator irrespective of noise background on said modulating energy comprising means for adjusting the minimum threshold value of said rectifiers, and means for adjusting the amplitude of the modulation energy supplied to the rectifier inputs.

4. In apparatus for reducing the idle current or electrical disturbances on wave energy derived by scanning a subject to increase the effectiveness of said current, a rectifier device having input and output electrodes, means for impressing said wave energy on said input electrodes, means for biasing said rectifier in a direction to increase its threshold of conductance to a value such that said disturbances are substantially eliminated in its output, and means for increasing the amplitude of said wave energy impressed on said input electrodes to a value such that the rectifiers output is normal in the presence of said electrical disturbances.

5. In apparatus to be used with wave energy modulated by signal currents from a first source and additionally modulated by signal currents from a second source, a pair of rectifiers having input and output electrodes, means for impressing said wave energy in phase opposition on said inputs electrodes whereby said rectifiers alternately pass current on corresponding portions of each cycle, means for biasing said rectifiers by a potential such that said rectifiers pass current only for wave amplitudes corresponding to said first modulations on said wave energy, a separate rectifier means having an input on which said wave energy is impressed, and means for biasing said separate rectifying means by a potential such that it passes current for excitation amplitudes corresponding to said additional modulations on said wave energy.

6. In apparatus responsive to a particular range of modulation on wave energy modulated through a plurality of ranges by different signals, and discriminating against modulations falling outside said particular range, a pair of electron discharge tube rectifiers each having a cathode and an anode electrode, means for impressing said wave energy in phase opposition on said cathodes, a resistance connected between each of said anodes and said cathodes the potential drops in said resistances producing at each of said anodes a negative potential, means for biasing said cathodes relative to said anodes by potentials such that said rectifiers alternately pass current pulses during that portion of corresponding cycles of said wave energy which falls

within said particular range, said rectifier being non-conductive for wave amplitudes less than said particular range and a pair of amplifier tubes having control grids coupled to the anodes of said rectifiers to be excited by said negative potentials to values such that they are cut off for wave amplitudes which exceed said range.

7. In signaling systems, an input resistance adapted to contain a potential wave with modu-

lated and unmodulated portions, a source of electromotive force, a rectifier having its cathode and anode connected adjustably across said resistance through said electromotive force counter to the potential thereof, and means for varying said electromotive force to oppose increase of the unmodulated portion when the connection to said resistance is varied.

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