July 13, 1937. B. S. McCUTCHEN 2,087,063

DEMODULATOR

Filed March 16, 1936 2 Sheets-Sheet 1

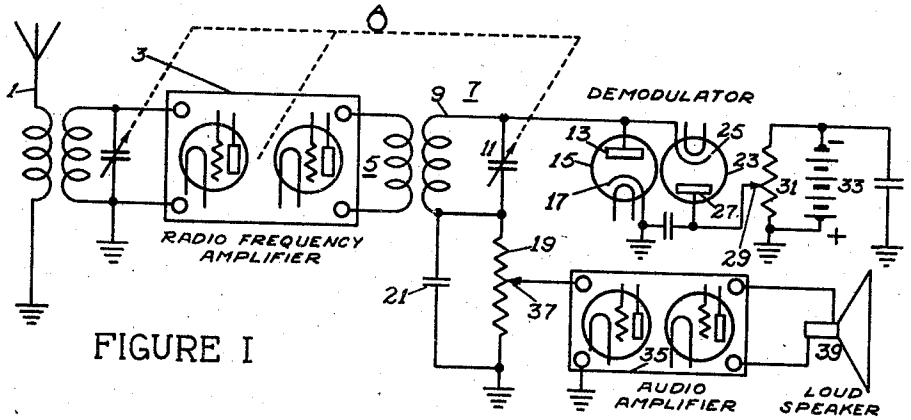
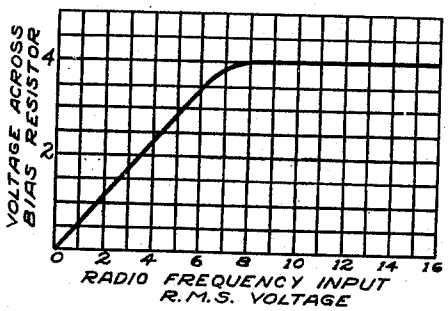


FIGURE I

FIGURE II A.



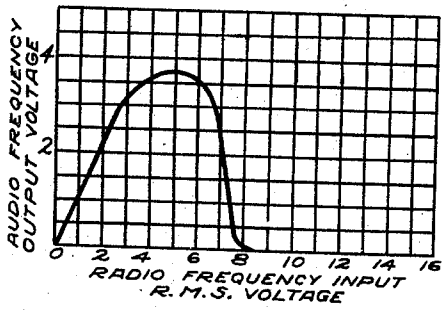


FIGURE II B.

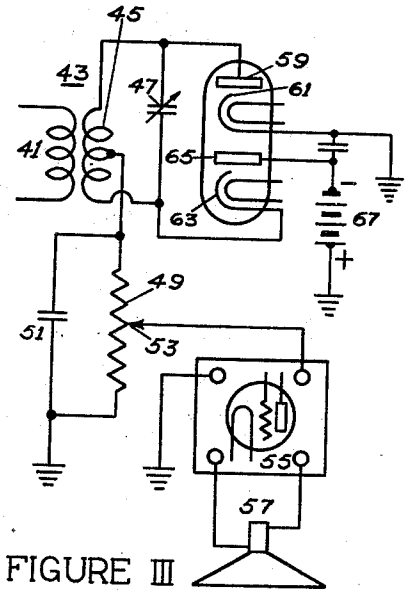


FIGURE III

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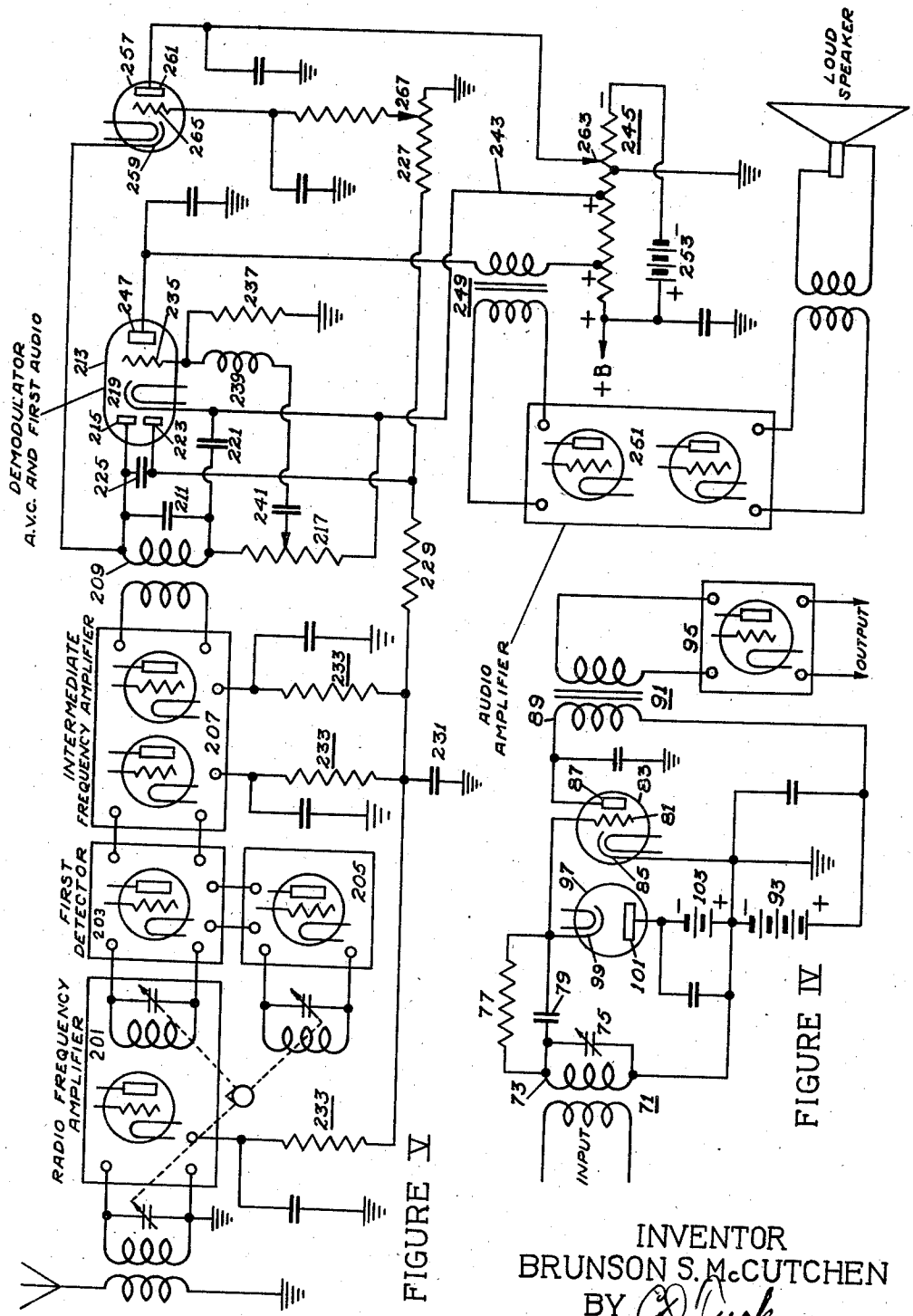


FIGURE V

FIGURE IV

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2,087,063

DEMODULATOR

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Application March 16, 1936, Serial No. 69,071

12 Claims. (Cl. 250—27)

My invention relates to demodulators for radio frequency currents. More specifically my invention relates to demodulators for radio frequency currents in which the demodulation is substantially linear for carrier input currents below a predetermined value and in which no demodulation occurs when the input carrier currents exceed the predetermined value.

I am aware of numerous demodulator circuits employing thermionic tubes, crystal rectifiers, and the like and especially those in which balancing, or limiting effects have been proposed. In general these devices have either distorted the desired signals, or failed to hold the output currents within the required limits.

One of the objects of my invention is in means for demodulating carrier currents without distortion, and to prevent demodulation for currents which exceed a predetermined threshold value. Another object is to provide means in a demodulator which may be adjusted to establish a threshold value above which substantially no demodulation will result. Another object is to devise a radio frequency demodulator which will detect modulated carrier currents but which will not detect impulses in excess of predetermined values. An additional object is to automatically regulate the threshold value in proportion to the applied carrier currents. A still further object is to provide a distortionless demodulator for desired signals and a balanced, or anti-demodulator, for impulses in excess of said desired signals.

Further objects of my invention and the theory and application of the circuits may be best understood by reference to the accompanying specifications, and drawings in which,

Figure I is a circuit diagram of the demodulator of my invention applied to a tuned radio frequency receiving set,

Figures IIA and IIB are graphs which illustrate the operation of my invention,

Figure III is a circuit diagram representing a modification of the demodulator of Figure I,

Figure IV is a representation of a further modification of my invention, and

Figure V is a circuit diagram of the demodulator applied to a superheterodyne receiver and illustrating one means for automatically establishing the threshold value.

In Figure I, a suitable antenna system 1 is coupled to a tunable radio frequency amplifier 3. The output circuit 5 of amplifier 3 is coupled to a tunable circuit 7 which is composed of an inductor 9 and a variable capacitor 11. The upper terminal of the tunable circuit 7 is connected to the anode 13 of a diode rectifier 15. The cathode 17 of this rectifier is grounded. The lower terminal of the tuned circuit 7 is connected to ground through a resistor 19, which is shunted by a capacitor 21. I prefer to make the resistance of this resistor about one megohm, although I do not limit my invention to any particular value.

A second rectifier 23 is connected as follows: the cathode 25 is connected to the anode 13 of rectifier 15; the anode 27 is connected to the slider 29 of potentiometer 31. A battery 33 is connected across the potentiometer 31. The positive terminal of the battery is grounded as shown. An audio-frequency amplifier 35 is connected as follows: the input is connected between the slider 37 on resistor 19 and ground, and the output is connected to the loudspeaker 39 or other signal indicator.

Although I do not intend to limit my invention to any particular theory of operation, I believe the following description will be helpful in understanding the operation of the circuits and the demodulator: Modulated radio frequency currents induced in the antenna 1 are amplified by the radio frequency amplifier 3. The amplified currents create voltages across the tuned circuit 7. These alternating currents make the anode 13 alternately positive and negative with respect to the cathode 17. When the applied voltage is below a predetermined value, a positive charge on the anode 13 causes electrons to flow from the cathode 17 to the anode 13. Due to the well known unilateral conductivity of a diode rectifier, no electrons flow from the cathode 17 to the anode 13, when that electrode is negatively charged with respect to its cathode.

While no electrons will flow from the cathode 17 to the anode 13 when the latter is negative, the polarity is apparently correct for electrons to flow from the cathode 25 to the anode 27, because the anode 27 is then positive with respect to its cathode 25. However, no electrons can flow in the diode 23 under the assumed condition, because the negative bias applied to the anode 27 from the battery 33 is made to exceed the positive potential applied to the anode 27 by the incoming currents below the predetermined value. Thus under the assumed conditions electrons only flow from the cathode 17 to the anode 13 when the latter is positive as explained. These electrons which do flow can only escape to ground through the load resistor 19. The radio frequency currents are by-passed to ground through

the capacitor 21. The currents through the load resistor establish biasing voltages which correspond to the audio modulation of the incoming modulated radio frequency carrier. These audio voltages are applied in two ways: one as bias voltages to the diodes 15, 23, (the grounded terminal of the resistor 19 being of a positive polarity); the other as audio signalling voltages impressed on the amplifier 35 through ground and slider 37.

The foregoing theory is in accord with the conventional explanation of the diode detectors with resistive load circuits, and explains the operation of my device when normal desired modulated carriers are applied to the receiving system. When excessive impulses are applied, such as may be caused by static, the operation of the demodulator of my invention may be best explained as follows: The excessive impulses establish voltages across the load resistor 19 which momentarily bias the anode 13 of diode 15 and the cathode 25 of diode 23 negatively with respect to the cathode 17 and anode 27. The incoming carrier voltage is superimposed on this momentary bias. When the momentary bias attains a voltage which is somewhat less than half the steady bias of the battery 33 as applied to the anode 27, a condition is reached in which some of the electrons passing to the anode 13 during positive cycles will pass during the negative cycles from the cathode 25 to the anode 27 and hence to ground through the potentiometer 31. This direct path to ground prevents the building up of high voltages across the load resistor 19. When very strong impulses are received, the balancing action is complete, and the only current flowing in the load resistor will be pure direct current which produces no audio frequency output. Under such conditions no demodulation takes place, and no audio frequency is supplied to the amplifier 35 to be reproduced in the loud speaker 39.

In Figure IIA a graph is shown which is based on measurements of applied radio frequency input R. M. S. voltage plotted against voltage across the bias resistor. The values are not absolute but relative for purposes of illustration. For increasing input voltages, the voltage across the bias or load resistor at first increases, gradually turns to a steady value, and continues without indicating any change in voltage across the load resistor for greatly increased input voltages.

The foregoing is in accord with the explanation of the currents flowing in the bias or load resistor. Now examine the graph of Figure IIB. As was the case in Figure IIA, the present curves are based on measured values. The demodulator of my invention was applied to a commercial radio receiver. The input voltages to the receiver were observed versus the output voltages measured across the loudspeaker voice coil. The values are shown as arbitrary units for purposes of illustration. The voltage output is substantially directly proportional to the applied radio frequency input voltage from 0 to approximately 2. Just beyond the point 2 the curve begins to bend, then becomes flat, and beginning at about 6 starts to fall abruptly to a zero value of output voltage in accordance with the explanation previously offered.

Viewing the two graphs together, it will be understood that the audio output shown on the curve of Figure IIB becomes zero and stays at this value when the steady bias state has been reached as shown in Figure IIA from point 8 to 16. The zero output signal condition is recognized as a balanced condition rather than a limiter action. The balance condition offers an anti-demodulator, or silencer device for excessive static or noise impulses exceeding the predetermined level.

In the matter of a proper steady bias for diode 23, it should be apparent that an optimum bias condition exists for every value of input carrier. If the bias is too low, strong desired signals will produce distortion, or the desired signals may be eliminated because they are not demodulated. If the bias is too high, excessive impulses will not be balanced out and will cause crashes in the loud speaker. It is highly desirable to automatically establish the optimum bias as will be described. Manual control may be used for establishing the steady bias, or having established the bias, the signal amplitude may be adjusted to the bias.

A modification of the demodulator of Figure I has been shown in Figure III. The theory of operation of the circuit of Figure III does not materially differ from the preceding description. In this circuit, the primary 41 of a tunable radio frequency transformer 43, is coupled to the secondary inductor 45, which is shunted by a capacitor 47. The mid-point of the secondary inductor 45 is connected to a resistor 49 which is grounded. The resistor is shunted by a capacitor 51. A slider 53 connects the resistor to the input of an audio amplifier 55 whose output circuit includes the loudspeaker 57.

The demodulator is connected as follows: The normal detector is a diode whose anode 59 joins the upper terminal of the tuned circuit 45, 47 and whose cathode 61 is connected to ground. The cathode 63 of a second diode is joined to the lower terminal of 45, 47, and the anode 65 is connected to the negative terminal of a biasing battery 67. The positive terminal is grounded. The first diode rectifier is effectively connected across the upper half of the tuned circuit, while the second diode is connected across the lower half of the tuned circuit. The load resistor 49 is serially connected with respect to the biasing battery 67. The first diode normally acts as the demodulator. The second diode has an operating threshold which is determined by the effect previously described. The diode rectifiers in this and the preceding figures may be enclosed within a single envelope, or separate envelopes. In general a load resistor of about one megohm is preferred to lower values.

A modification of my invention is illustrated in Figure IV. In place of a diode rectifier a grid detection triode is used. The input circuit is represented by a tunable radio frequency transformer 71. The secondary of this transformer is comprised of an inductor 73 and variable capacitor 75. The upper terminal of the tuned circuit 73, 75 is serially connected through the grid leak resistor 77, grid capacitor 79, to the grid electrode 81 of the thermionic triode 83. The cathode 85 is connected to ground. The anode 87 is connected through the primary 89 of the audio frequency transformer 91 to the positive terminal of the B battery 93. The negative terminal is grounded. The output of the transformer 91 is connected to an audio frequency amplifier 95 whose output may be connected to any suitable indicator.

The means which prevents demodulation of signals exceeding the threshold value includes the diode rectifier 97. The cathode 99 of this

diode rectifier is joined to the junction of the grid leak resistor 79 and grid electrode 81. The anode 101 of the rectifier 97 is biased negatively by the battery 103. The operation of this circuit is essentially the same as Fig. I. In the present arrangement the demodulation of normal signal representing carriers is effected by the rectification in the grid-cathode circuit of the triode. The operating threshold of the second diode 97 is determined by the voltage of the fixed bias minus the rectified voltage across the grid leak resistor 77. The fixed bias voltage may be obtained by a potentiometer or the like, and in this as may be the case in the other circuits, the several voltages may be obtained from rectified, and filtered alternating current.

In the foregoing arrangements of demodulator circuits a manual adjustment is made to determine the operating threshold, or value of applied voltages for which no demodulation takes place. I shall now describe Figure V, which illustrates a circuit with automatic volume control (hereinafter called AVC). Incoming carrier currents are amplified by the radio frequency amplifier 201. The amplified output currents are detected in the first detector 203, and mixed with currents from the local oscillator 205. The combination of these currents produces an intermediate frequency current which may be amplified by one or more stages 207 of intermediate frequency amplification.

The output circuit of the intermediate frequency amplifier 207 is coupled to a resonant circuit comprising an inductor 209 and a capacitor 211. The duo-diode section of thermionic tube 213 is connected across the resonant circuit as follows: The anode 215 is connected to the upper terminal of the resonant circuit. The lower terminal of this circuit is connected through the load resistor 217 to the cathode 219. A capacitor 221 is shunted across the resistor 217. The remaining anode 223 of the duo-diode is coupled to the first anode 215 through a capacitor 225. The anode 223 is also connected to ground through the resistor 227. The voltage for the AVC is developed across this last mentioned resistor. Variations in the AVC voltage are filtered by a network comprising resistor 229 and capacitor 231. The AVC voltage may be applied through additional filters 233 to the radio frequency amplifier 201, and intermediate frequency amplifier 207.

The audio frequency amplifiers are connected as follows: The grid electrode 235 is grounded through a resistor 237 and is connected through a radio frequency choke 239 and capacitor 241 to the slider on load resistor 217. The cathode 219 is biased positively with respect to the grid 235 by lead 243 which is connected to a point of positive potential on the potentiometer 245. The anode electrode 247 of the tube 213 is connected through the primary of an audio frequency transformer 249. The secondary of this transformer is connected to the input of a second audio amplifier 251 whose output circuit includes signal responsive means. The B power source may be a battery 253 or any conventional power source. The several cathodes may be energized by alternating or direct current. The cathode heater circuits have been omitted in this and the several modifications for the sake of simplicity.

The circuit of Figure V thus far described is a conventional superheterodyne with diode detection, and AVC. The detector is converted to the demodulator of my invention by including the triode 257. This tube 257 is connected as follows: The cathode 259 is connected to the anode 215 of tube 213. The anode 261 of tube 257 is connected to the slider 263 on the potentiometer 245. The voltage between the slider 263 and lead 243 biases the anode negatively and partially determines the operating threshold as previously described in connection with the other demodulator circuits. It should be understood that the cathode 259 and anode 261 form the rectifier which cooperates with the normal detector to prevent demodulation for voltages exceeding the threshold value. Instead of manually adjusting the threshold voltage, the grid electrode 265 is connected to a slider 267 on the resistor 227 across which the AVC voltage is developed. The grid 265 is thus automatically biased by the AVC voltage, and thereby automatically establishes the threshold voltage at which demodulation is prevented. The bias voltage applied to the grid is negative and is equivalent to applying a much larger voltage to the anode. In this connection an accurate, sensitive automatic threshold control is obtained. Of course, the preliminary adjustment is made manually.

A demodulator and a method of demodulation have been described in which a normal demodulation of modulated radio frequency carriers may be obtained while impulses exceeding a predetermined threshold value are not demodulated. This system is very effective to prevent loud static crashes or the like in the loud speaker of a radio receiver. In the preferred embodiment of my invention the relation between incoming carrier currents and the threshold value is maintained by automatic bias means. My invention is not limited to the precise circuits shown, as these circuits are examples and illustrations rather than limits. Numerous modifications will occur to those skilled in the art; for example, the demodulator applied to the superheterodyne may be applied to a tuned radio frequency receiver, and vice versa. Likewise the triode grid detector may be used with any type of receiver, and other types of thermionic tubes or rectifiers may be used. The bias voltages may be applied to bias the cathode positively, with respect to anode which is then grounded, instead of biasing the anode negatively with respect to the grounded cathode as shown.

I claim:

1. The method of demodulating normal modulated carrier currents and preventing demodulation of excessive impulses by means of a normal signal rectifier, an opposing rectifier for excessive impulses normally biased to prevent its operation, and a common load circuit for said rectifiers, which comprises rectifying normal modulated carrier currents, rectifying said excessive impulses in said opposing rectifier by automatically reducing the bias of said opposing rectifier, applying rectified currents from both rectifiers across said common load circuit whereby no substantial demodulation occurs for said excessive impulses.

2. The method of demodulating modulated carrier currents and preventing demodulation of excessive impulses by means of a normal signal rectifier, an opposing rectifier for excessive impulses normally biased to prevent its operation, and a common output circuit for said rectifiers which comprises rectifying normal modulated carrier currents and excessive impulses in said normal signal rectifier, rectifying said excessive

impulses in said opposing rectifier by automatically reducing the bias of said opposing rectifier, applying rectified currents from both rectifiers to said common output circuit whereby no substantial demodulation occurs for said excessive impulses.

3. The method of demodulating normal carrier currents and preventing the demodulation of impulses exceeding a predetermined limit which comprises rectifying normal carrier currents, rectifying both phases of excessive impulses applying the rectified phases of such excessive impulses through a common load circuit so that such phases oppose each other, and preventing the rectification of both phases of normal carrier currents.

4. The method of demodulating normal carrier currents and preventing the demodulation of impulses exceeding a predetermined threshold which comprises rectifying normal carrier currents, rectifying both phases of excessive impulses, preventing the rectification of both phases of normal carrier currents, and automatically establishing the said threshold in accordance with incoming carrier currents.

5. The method of demodulating carrier currents and preventing the demodulation of excessive impulses in accordance with claim 2 plus the additional step of automatically adjusting the bias of said opposing rectifier in accordance with incoming carrier currents.

6. A demodulator comprising an input circuit, a normal signal rectifier connected thereto, a second circuit connected with such rectifier adapted to be traversed by the rectified current from such rectifier, a second rectifier connected with said circuits and so disposed as to feed voltage of reversed phase to said second circuit as compared with the voltage from said first rectifier biasing means tending to render said second rectifier inoperative under normal conditions, and means for causing potential to build up in said second circuit tending to counteract said biasing means.

7. A demodulator comprising an input circuit, a normal signal rectifier connected thereto, a load circuit connected with such rectifier, a second rectifier connected with said circuits and so disposed as to feed to said load circuit voltage of reversed phase as compared with the voltage from said first rectifier, biasing means for limiting the operation of said second rectifier to voltages of predetermined values and means for causing a voltage automatically to build up in said load circuit tending to counteract the said biasing means.

8. A demodulator comprising an input circuit, a normal signal rectifier connected thereto, a second circuit connected with such rectifier comprising a resistance shunted by a capacity, a second rectifier connected to receive currents from said input circuit and adapted to transmit rectified currents to said second circuit, biasing means for limiting the operation of said second rectifier to voltages of predetermined values, and means for automatically building up voltage in said second circuit tending to counteract said bias.

9. A device for demodulating carrier currents and preventing demodulation of excessive impulses comprising an input circuit, two diode rectifiers connected across said input circuit in mutually reversed relation, a load circuit comprising a resistance and capacity, means for connecting said diodes to said load circuit to deliver voltages to said load circuit in opposed phase relation and biasing means for establishing a threshold for one of said rectifiers.

10. A device as specified in claim 9, in which the resistance and capacity comprised in the load circuit are of such values as to produce a time factor in such load circuit of sufficient magnitude so that voltages produced by successive opposite phases will oppose each other.

11. A device for demodulating carrier currents and preventing demodulation of excessive impulses, comprising a normal signal rectifier for rectifying normal carrier currents and excessive impulses, an opposing rectifier for rectifying excessive impulses normally biased to prevent its operation, means for automatically reducing the bias of said opposing rectifier so that such opposing rectifier will serve to rectify excessive impulses without rectifying normal carrier currents, a common load circuit for said rectifiers, and means adapted to apply rectified currents from each of said rectifiers to said common load circuit whereby no substantial demodulation occurs for excessive impulses.

12. A device for demodulating normal carrier currents and preventing the demodulation of impulses exceeding a predetermined threshold, which comprises means for rectifying one phase of normal carrier currents and of excessive impulses, a second rectifying means for rectifying the opposite phase of excessive impulses, means to establish a threshold to prevent the rectification of the opposite phase of normal carrier currents by said second rectifying means, means whereby such threshold is modified in accordance with incoming carrier currents, and a common load circuit for both of said rectifying means.

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