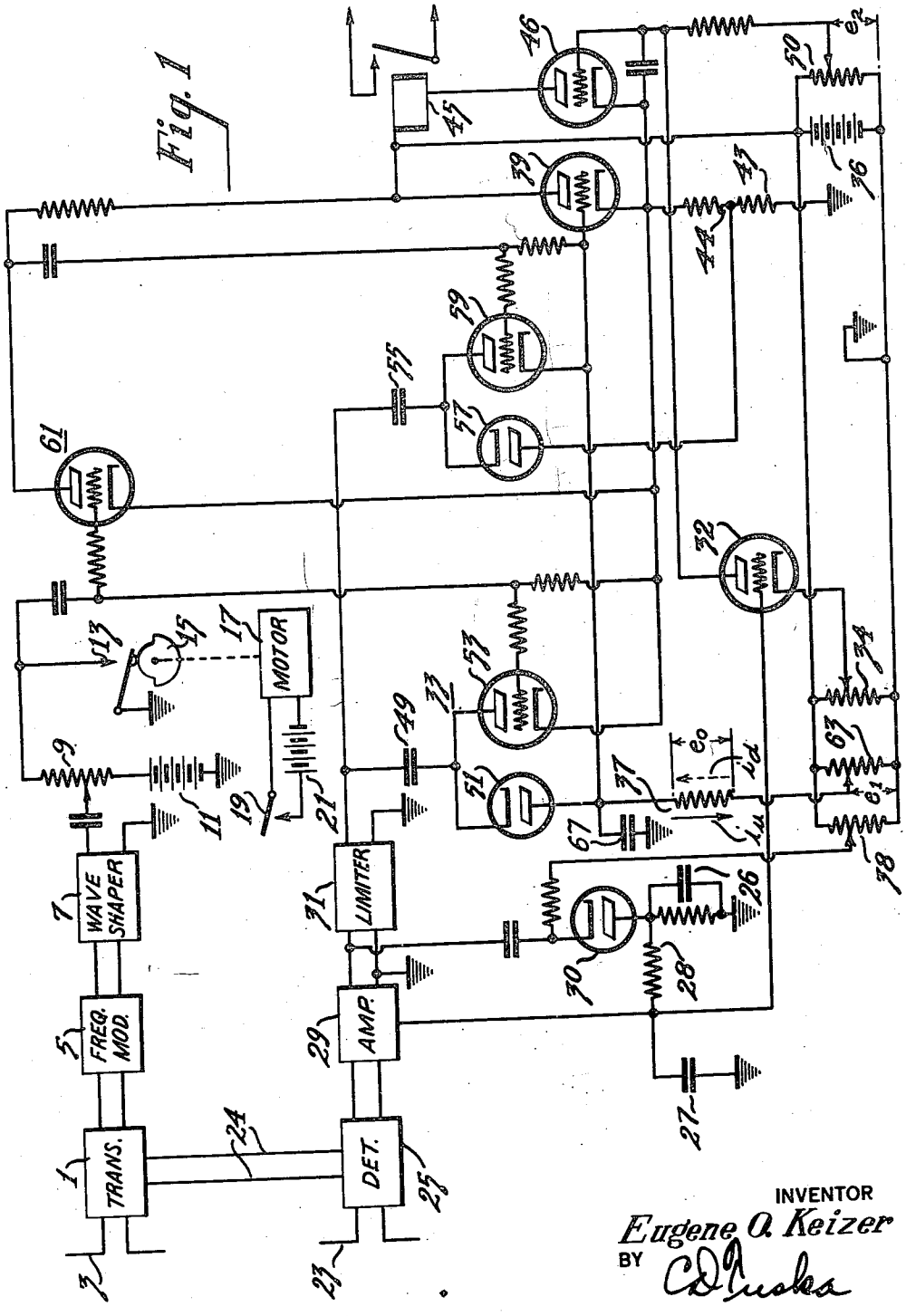
April 27, 1948. E. O. KEIZER 2,440,609

BOMB RELEASE RADIO SYSTEM

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Fig. 1



INVENTOR
Eugene O. Keizer
BY C. D. Nuckolls
ATTORNEY

April 27, 1948. E. O. KEIZER 2,440,609

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Fig. 2

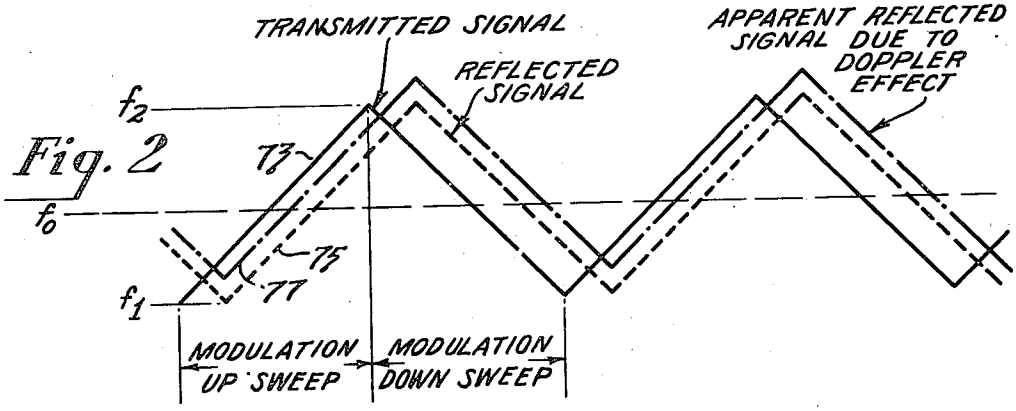


Fig. 3

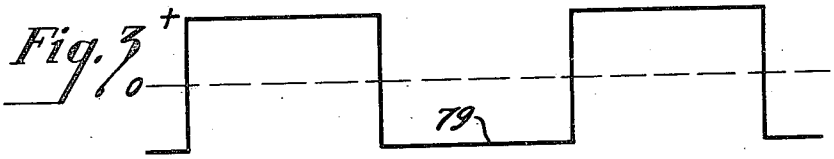


Fig. 4

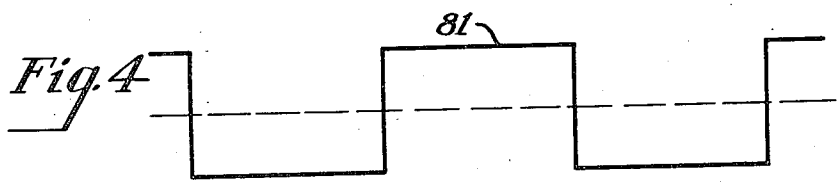
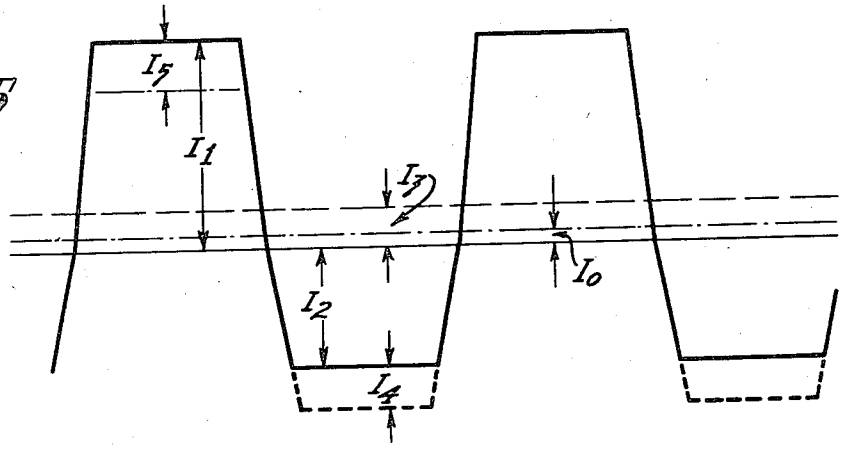


Fig. 5



INVENTOR
Eugene O. Keizer
BY C. D. Puska
ATTORNEY

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UNITED STATES PATENT OFFICE

2,440,609

BOMB RELEASE RADIO SYSTEM

Eugene O. Keizer, Princeton, N. J., assignor to Radio Corporation of America, a corporation of Delaware

Application November 16, 1945, Serial No. 629,171

1 Claim. (Cl. 343—7)

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This invention relates to radio bomb release systems, and more particularly to improvements in systems of the type described in copending application Serial No. 524,794, filed on March 2, 1944, by Royden C. Sanders, Jr., and William R. Mercer and entitled Radio bomb release system, and which has matured into Patent No. 2,412,632 issued December 17, 1946, wherein a frequency modulated signal is radiated from a mobile craft toward a selected target, received after reflection from said target, and the received signal compared with the transmitted signal to actuate a bomb release device upon the occurrence of a predetermined relationship between the target distance and the speed with respect to the target.

Systems of the described type are sometimes subject to disturbances caused by the absence of a desired target or caused by severe fading of the received signals, as a result of multiple path transmission between the target and the bombing craft. Another effect which is almost invariably present in the operation of such systems is that of sea return, or reflection from the surface upon which the target lies. These two effects will, on occasion, conspire to cause premature release during pronounced fading conditions, since the so-called sea return will over-ride the target signal, simulating a signal from a target at minimum range. A similar effect may also be produced by improper adjustment of the radio system.

Copending U. S. patent applications Serial No. 546,269, filed on July 24, 1944, by James H. Ludwig and entitled Radio bomb release system, and Serial No. 623,366, filed on October 19, 1945, by Ben R. Cole and entitled Radio system describe systems for preventing premature releases by simulating, during fading periods, the conditions which would appear if there were a target at maximum range. While these systems operate satisfactorily to prevent premature release, they may cause a late release to occur if the target reflection signal reappears shortly before the proper instant of release, owing to unavoidable delay in the recovery of the computer system.

It is the principal object of the present invention to provide an improved method of and means for preventing false releases. Another object is to provide a system of the described type which will recover rapidly if the target signal returns, thus minimizing the possibility of late releases.

These and other objects will become apparent to those skilled in the art upon consideration of the following description with reference to the accompanying drawings of which

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Figure 1 is a schematic diagram of a bomb release system embodying the invention,

Figure 2 is a graph illustrating variations in frequency of signals transmitted and received in the operation of the system of Figure 1,

Figures 3 and 4 are graphs of square wave switching voltages occurring in the operation of Figure 1, and

Figure 5 is a graph illustrating the switched counter output currents produced in the operation of the system of Figure 1.

Refer to Figure 1. A system of the type described in the above-mentioned Sanders et al. application is illustrated. A radio transmitter 1 is connected to an antenna 3 and to a frequency modulator 5. The modulator 5 may be of the vibratory variable capacitor type such as that described in copending U. S. patent application Serial No. 471,003, filed January 1, 1943, by S. V. Perry and entitled Capacity modulator unit, or any other known device for varying the frequency of the transmitter 1 in response to a modulating voltage. The input circuit of the modulator 5 is connected to a wave shaping circuit 7 which is connected through a voltage divider 9 to a battery 11 and a periodic switch 13. The switch 13 is arranged to be operated by a cam 15 driven by a motor 17. The motor 17 is connected through a switch 19 to a power source such as a battery 21.

A receiving antenna 23, similar in construction to the antenna 3, is connected to a detector 25. The transmitter 1 is also connected to the detector 25 through a line 24. Both antennas 3 and 23 are preferably directive, and are arranged to provide maximum response in the same direction.

The output circuit of the detector 25 is connected to an amplifier 29, which is provided with an A.-V.-C. circuit including a rectifier 30 connected to rectify a portion of the amplifier output, and a filter comprising capacitors 26 and 27 and a resistor 28, through which the rectified voltage is applied to a bias circuit of the amplifier in any known or conventional manner for controlling the amplifier gain. A D.-C. source comprising a battery 36 and a voltage divider 38 is connected to the rectifier 30 and adjusted to bias it so that no rectification will occur with less than a predetermined output from the amplifier 29. The output circuit of the amplifier 29 is connected to an amplitude limiter 31. The output circuit of the limiter 31 is connected to a pair of averaging cycle counter circuits, generally desig-

nated by the reference numerals 33 and 35, respectively.

The counters 33 and 35 are provided with a common load resistor 37, which is connected to the control grid of an amplifier tube 39. The anode of the tube 39 is connected directly to the D.-C. source 36. The cathode circuit of the tube 39 includes a resistor 43 tapped at a point 44. The cathode of the tube 39 is connected to the cathode of a tube 46. The control grid of the tube 46 is connected to a bias source comprising a voltage divider 50, connected across the battery 36. A relay 45 is included in the anode circuit of the tube 46.

The counter 33 includes a capacitor 49 connected to the cathode of a diode 51 and to the anode of the triode 53. The control grid of the triode 53 is coupled to the switch 13. The cathode of the tube 53 is connected to the cathode of the tube 39. The anode of the diode 51 is connected to the load resistor 37. The counter 35 comprises a capactor 55 connected to the cathode of a diode 57 and to the anode of a triode 59. The control grid of the triode 59 is coupled through a phase inverter circuit 61 to the switch 13. The anode of the diode 57 is connected to the cathode circuit of the tube 39 at the point 44. The cathode of the triode 59 is connected to the control grid of the tube 39 and the upper end of the resistor 37. The lower end of the resistor 37 is connected to a voltage divider 63 across the battery 36. The load resistor 37 is bypassed to ground by a capacitor 67.

The operation of the system thus far described is as follows: The motor 17 operates the switch 13 by means of the cam 15 to connect the battery 11 periodically to the voltage divider 9, thus producing a square wave voltage variation of the voltage across the voltage divider 9. The square wave voltage is attenuated to an extent depending upon the position of the adjustable tap of the voltage divider 9, and is applied to the wave shaping circuit 7. The wave shaping circuit 7 includes a low pass filter or other means for integrating the square wave input with respect to time to produce an output of triangular wave shape. The triangular wave output of the wave shaping circuit 7 is applied to the modulator 5, causing corresponding triangular wave variation of the frequency of operation of the transmitter 1. The frequency modulated signal produced by the transmitter 1 is radiated by the antenna 3 to the target, not shown. Part of the energy striking the target is reflected to the receiving antenna 23.

The received reflected signal is combined in the detector 25 with some of the original frequency modulated signal, which is conducted directly from the transmitter 1 to the detector 25 through the line 24. The output of the detector 25 includes a beat signal having a frequency equal to the difference between the instantaneous frequency of the transmitted and received signals. The beat output of the detector 25 is amplified by the amplifier 29 and limited to a constant amplitude by the limiter 31. The output of the limiter 31 is a square wave voltage having a frequency equal to the difference between the frequency of the transmitted and received signals and a constant amplitude, E_s.

Referring to Figure 2, the frequency of the transmitted signal is represented by the solid line 73. This frequency varies throughout the modulation cycle in response to the triangular wave output of the wave shaping circuit 7, between upper and lower limits f_2 and f_1, respectively, about a mean value f_0. The sweep width f_2-f_1 is proportional to the amplitude of the triangular wave input to the modulator 5, and hence is a function of the position of the adjustable contact of the voltage divider 9.

The reflected signal is delayed with respect to the transmitted signal by the time required for the radiation to travel from the transmitting antenna 3 to the target, and back to the receiving antenna 23. This is indicated by the dotted line 75 in Figure 2. The reflected signal varies in frequency over the same range f_2-f_1 as the transmitted signal, but constantly differs in frequency from the transmitted signal by an amount proportional to the distance. This difference in frequency is

$$\frac{Sf_md}{246} \text{ cycles per second}$$

where $S=f_2-f_1$ in megacycles per second. f_m is the modulation frequency in cycles per second, or frequency of operation of the switch 13, and d is the slant distance in feet. If the equipment is moving toward the target, the received signal is increased in frequency, owing to Doppler effect, by an amount

$$\frac{2vf_0}{C}$$

where v is the velocity in feet per second, f_0 is the carrier frequency in cycles per second and C is the velocity of radiation propagation in feet per second. The frequency of the received signal is represented by the dash line 77 in Figure 2. This frequency varies throughout the modulation cycle over a frequency band which is equal in width to that of the transmitted signal. The difference in frequency between the transmitted and the received signal is

$$f_u=\frac{Sf_md}{246}-\frac{2vf_0}{C}$$

cycles per second during increase in frequency of the transmitted signal, and

$$f_d=\frac{Sf_md}{246}+\frac{2vf_0}{C}$$

cycles per second during decrease in frequency of the transmitted signal.

The constant amplitude beat frequency output of the limiter 31 is applied to both of the counters 33 and 35. The connections to the modulator 5 are such that during the modulation downsweep, or decrease in frequency of the transmitted signal, the switch 13 is closed, applying a positive pulse to the control grid of the triode 53 and to the phase inverter 61, as indicated by the graph of Figure 3. The phase inverter 61 provides a negative pulse which is applied to the control grid of the triode 59 of the counter 35, as indicated by the graph of Figure 4. The triode 59 is thereby cut off, and the counter 35 prevented from operating.

During negative half cycles of the limiter output, the capacitor 49 is charged through the diode 51 and the resistor 37. The values of the capacitor 49 and resistor 37 are such that the capacitor 49 becomes substantially fully charged to the limiter output voltage E_s during each cycle of the limiter output. During positive half cycles, the capacitor 49 is discharged through the triode 53 to the potential existing at the cathode of the tube 39, which is substantially equal to that at the anode of the diode 51. Thus during the modulation downsweep, the counter 33

causes an average current i_d to flow upward through the resistor 37 as indicated by the dash arrow. This current is proportional to the product of the charge deposited in the capacitor 49 during each cycle, and the number of cycles per second:

$$i_d=f_rQ=f_rC_2E_s$$

where C_2 is the capacitance of the capacitor 49. Since

$$f_d=\frac{Sf_md}{246}+\frac{2vf_0}{C}$$

$$i_d=\frac{Sf_md}{246}C_2E_s+\frac{2f_0v}{C}C_2E_s$$

During the modulation upsweep, the switch 13 is open, providing a negative pulse at the grid of the triode 53 and the phase inverter 61, and a positive pulse at the grid of the triode 59, as indicated by the portions 79 and 81, respectively, of the graphs of Figures 3 and 4. The counter 33 is now inoperative and the counter 35 operates. The triode 59 is conductive, allowing the capacitor 55 to charge through the resistor 37 during positive half cycles of the output of the limiter 31. During negative half cycles of the limiter output, the capacitor 55 is discharged through the diode 57 to the potential appearing at the tap 44 on the resistor 43, which is slightly less than the potential at the cathode of the tube 39 and hence that of the cathode of the tube 53. Thus during the modulation upsweep, the counter 33 causes a current i_u to flow downward through the resistor 37, as indicated by the solid arrow. This current is proportional to the product of the charge deposited in the capacitor 55 during each cycle, and the number of cycles per second:

$$i_u=f_uQ=f_uC_1E_s$$

where f_u is the beat frequency, Q is the charge per cycle, C_1 is the capacitance of the capacitor 55, and E_s is the amplitude of the output of the limiter 31. Since

$$f_u=\frac{Sf_md}{246}-\frac{2vf_0}{C}$$

$$i_u=\frac{Sf_md}{246}C_1E_s-\frac{2vf_0}{C}C_1E_s$$

The average current through the resistor 37 is

$$i_o=i_u-i_d$$

$$i_o=\frac{Sf_md}{246}E_s(C_1-C_2)-\frac{2f_0v}{C}E_s(C_1-C_2)$$

Refer to Figure 5, wherein I_1 is the average component of current during upsweep due to distance, I_2 is the average component of current during downsweep due to distance, I_3 is the resultant average component of current due to distance, I_4 is the increase in negative average component of current during downsweep due to speed, and I_5 is the decrease in positive average current during upsweep due to speed. The resultant average voltage across the resistor 37 is $e_0=i_oR$, where R is the resistance of the resistor 37.

The tap of the voltage divider 63 is adjusted to apply a positive potential of, for example, approximately 70 volts to the lower end of the resistor 37. The purpose of this arrangement is to provide a suitable operating point for the cathode follower tube 39. Denoting this voltage as e_1, the total voltage at the control grid of the tube 39, referred to ground potential, is e_0+e_1. Inasmuch as the entire load of the tube 39 is in the cathode circuit, the anode current will assume a value such that the drop in said load circuit is very slightly greater than the voltage between the control grid and ground, and as a practical matter, substantially equal to the grid voltage.

This is the case only so long as the tube 46 is non-conductive. The voltage divider 50 is adjusted to apply a positive voltage e_2 to the control grid of the tube 46. Since the cathode is also positive, at a voltage substantially equal to e_0+e_1, the tube 46 will be cut off as long as e_0+e_1 exceeds e_2 by more than a predetermined voltage which depends upon the design of the tube 46 and the anode voltage supplied thereto by the battery 36. The voltage e_2 is adjusted in accordance with the altitude at which a bombing run is to be made, as described in detail in the above-mentioned Sanders et al. application.

Assume that the bombing craft is travelling toward the target at a substantially constant velocity v. Initially, the distance d is relatively great, and hence i_0 is relatively large. The voltage e_0 is therefore of maximum value, and e_0+e_1 greatly exceeds e_2. As the target is approached, e_0 gradually decreases, while e_1 and e_2 remain constant. At a predetermined time T before the bomber is directly over the target, e_0 falls to a value low enough so that the tube 46 will conduct, energizing the relay 45 to actuate the bomb release mechanism. The voltage dividers 9, 50, and 63 are adjusted as described in the above-mentioned Sanders et al. application to make the time T equal to that of that required for a bomb to fall from the altitude h at which the bombing run is to be made.

Under ideal conditions, the above-described operation will cause release to occur at the proper instant to score a hit upon the selected target. Ordinarily the signal reflected by the target is stronger than that reflected by the surface upon which the target is lying, so that the voltage e_0 is a function of substantially only the target distance and the speed of the bomber with respect to that of the target. However, if the target signal fades, surface reflections will be picked up by the apparatus. These reflections may simulate a signal from a target directly under the bomber or that from a target at a distance which is much less than the distance of the actual target. Accordingly, the voltage e_0 will decrease, and may decrease to such an extent that the tube 46 is allowed to conduct, actuating the relay 45 and causing release of a bomb.

This difficulty, although caused by the absence of the target or by fading, is not remedied by the A.-V.-C. device, which merely tends to maintain the general signal level, with no discrimination between target reflection and surface reflection.

In accordance with the instant invention, the tube 32 is provided with its anode connected to the grid of the relay tube 46. The cathode of the tube 32 is connected to the tap of a voltage divider 34 across the source 36, and the control grid is connected to the output circuit of the A.-V.-C. rectifier 30.

Under normal conditions of operation, as described above, relatively strong reflection signals are received from the target, overcoming the threshold bias derived from the voltage divider 38, so that the rectifier 30 operates. This provides a negative voltage to the gain control circuit of the amplifier 29 and also to the control grid of the tube 32. The voltage dividers 34 and 38 are adjusted so that the tube 32 is cut off when the rectifier 30 operates, and therefore

has no effect upon the voltage at the grid of the tube 46. When the received signal falls below a predetermined amplitude, the rectifier 30 ceases to operate and the voltage at the grid of the tube 32 decreases, causing the tube 32 to conduct. The tube 32 then presents a low resistance from anode to cathode, reducing the voltage at the control grid of the tube 46. Thus so long as the received signal is lower than a predetermined amplitude, the tube 46 is prevented from conducting. It should be noted, however, that both the counters 33 and 35 and the cathode follower 39 continue to operate, although the voltage at the cathode of the tube 39 does not correspond to the true relationship between target range and speed.

If the target signal returns before the bomber reaches the release point, the rectifier 30 starts to operate again, cutting off the tube 32 and allowing the grid of the tube 46 to resume its normal potential, causing a normal release to occur. The time required for restoration of normal operating conditions after return of the target signal depends primarily on the constants of the automatic gain control filter elements 26, 27 and 28, and may be made of the order of one twentieth second. The time constant of the counter load circuit, comprising the resistor 37 and capacitor 67, is necessarily much greater; however, the amount by which the voltage in this circuit must change when the target signal reappears is not very great, since the counters 33 and 35 both operate, although inaccurately, during fading. Thus the system recovers rapidly enough to effect correct release even though the target signal reappears just prior to the proper time for release.

Thus the invention has been described as an improved radio bomb release system, including means for preventing false release upon failure of the target reflection signal by means of a single tube connected to respond to the automatic volume control rectifier to disable the relay tube when the received signal falls below a predetermined level.

I claim as my invention:

In a radio bomb release system of the frequency modulation type including a transmitter, a receiver, beat frequency responsive means for producing a voltage of magnitude depending on the relationship between speed and range of a target and relay means normally responsive to the attainment of a predetermined magnitude by said voltage to effect release, apparatus for preventing false operation of said system comprising an automatic gain control circuit for said receiver, normally inoperative means for biasing said relay means to prevent release, and means responsive to the output of said automatic gain control circuit to operate said last-mentioned means and thus bias said relay circuit during signal fading periods.

EUGENE O. KEIZER.

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