Jan. 10, 1967 F. H. PRESTWOOD 3,298,023

SAFETY SYSTEM FOR ARMAMENT TRAINING AND TESTING

Filed July 28, 1965 2 Sheets-Sheet 1

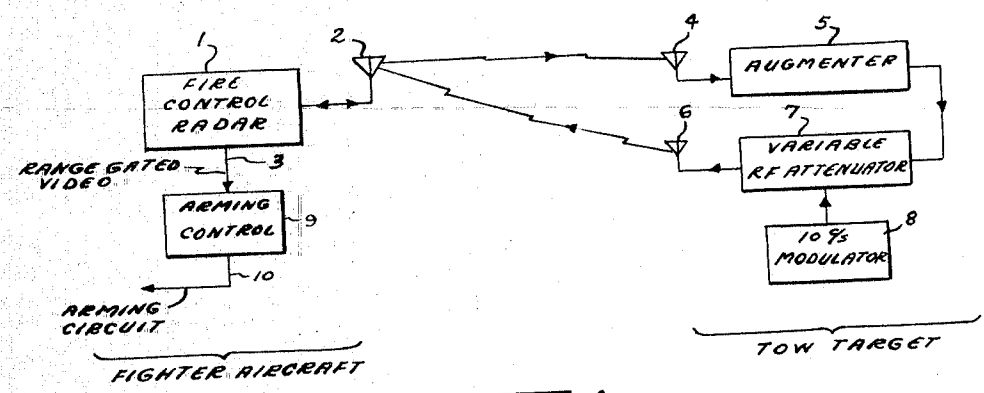


Fig-1

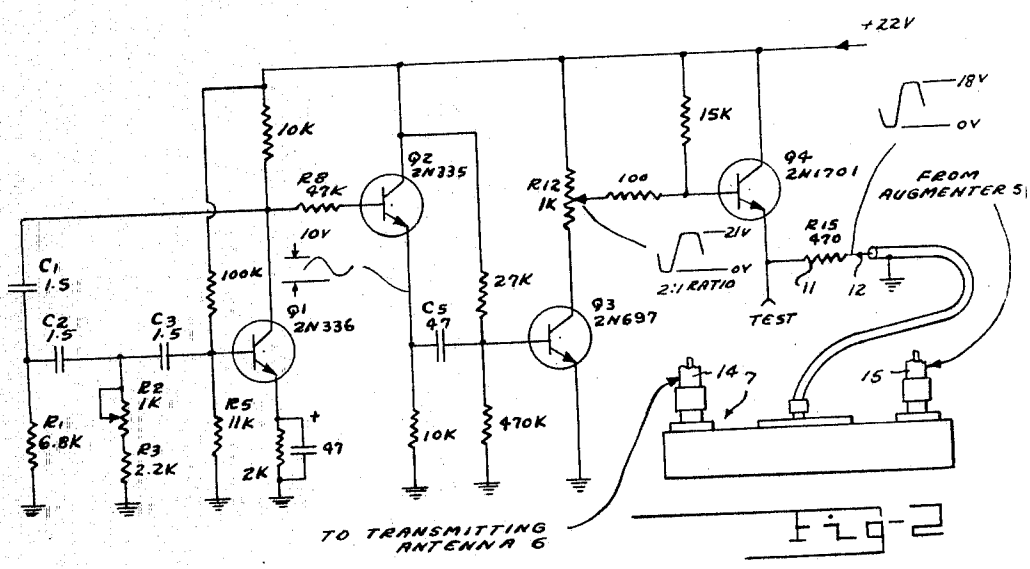


Fig-2

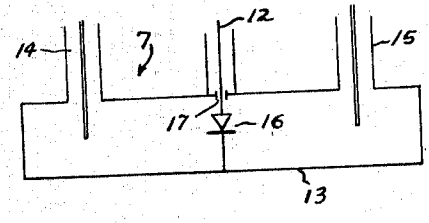


Fig 3

INVENTOR
F. H. PRESTWOOD

BY Harry A. Herbert Jr
ATTORNEY

James S. Shannon
AGENT

Jan. 10, 1967 F. H. PRESTWOOD 3,298,023

SAFETY SYSTEM FOR ARMAMENT TRAINING AND TESTING

Filed July 28, 1965

2 Sheets-Sheet 2

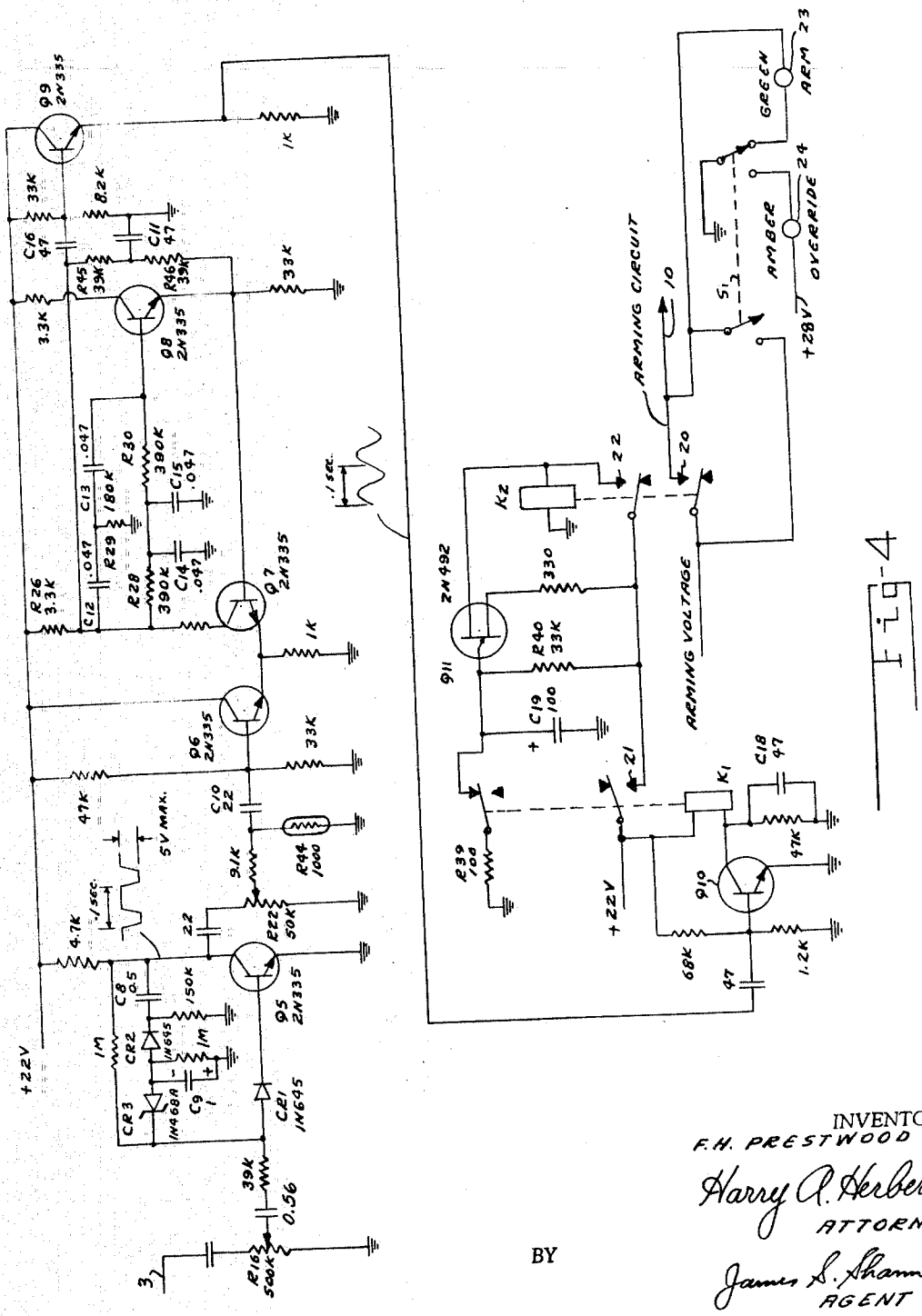


Fig-4

INVENTOR
F.H. PRESTWOOD
Harry A. Herbert Jr
ATTORNEY

BY

James S. Shannon
AGENT

United States Patent Office

3,298,023

Patented Jan. 10, 1967

3,298,023

SAFETY SYSTEM FOR ARMAMENT TRAINING AND TESTING

Franklin H. Prestwood, Valparaiso, Fla., assignor to the United States of America as represented by the Secretary of the Air Force

Filed July 28, 1965, Ser. No. 475,611
4 Claims. (Cl. 343—6.5)

The invention described herein may be manufactured and used by or for the United States Government for governmental purposes without payment to me of any royalty thereon.

Armament training of interceptor pilots and the testing of air-to-air missiles often require the use of radar augmented towed targets. The fire control radar of the interceptor aircraft approaching the towing plane and tow target combination acquires and locks on to a target which may possibly be the towing aircraft. Since it is not always possible for the interceptor pilot to differentiate between the tow target and the towing aircraft, due to closure rate, the angle of attack or the lack of visibility, a hazardous condition may exist. To maintain a high degree of range safety, it is most desirable that a definite, unmistakable indication of interceptor radar acquisition and lock-on of the tow target exists, and that the interceptor missiles are fail-safe disarmed until such indication is obtained and maintained.

It is therefore the primary purpose of this invention to insure that the interceptor radar directs the interceptor fire at the tow target rather than at the towing aircraft or other false target. Further objects of the invention are to provide apparatus for accomplishing the above purpose that is simple and reliable, that can be easily added to existing interceptor radars and augmenters, that is completely automatic, that is usable over a wide frequency band without adjustment and that is fail-safe in operation.

Briefly, these objects are accomplished by providing on the tow target means for amplitude modulating the output of the augmenter at a low frequency, for example 10 c./s., and providing on the interceptor an arming control circuit which receives the interceptor radar video signal and energizes the arming circuit only when the low frequency modulation added at the tow target has been present on the video signal for a prescribed length of time, such as five seconds.

The invention will be described in more detail with reference to the specific embodiment thereof shown in the accompanying drawings in which

FIG. 1 shows a complete system in block form incorporating the invention.

FIG. 2 illustrates schematically the apparatus added at the tow target.

FIG. 3 schematically represents the construction of the variable RF attenuator at the tow target.

FIG. 4 is a schematic diagram of the arming circuit added to the interceptor radar in accordance with the invention.

Referring to FIG. 1, block **1** represents a normal interceptor fire control radar which periodically radiates short duration pulses of high frequency energy from antenna **2** and receives echoes of these pulses through the same antenna. The echoes are detected in the radar receiver to produce video pulses which appear on video output line **3**. At the tow target the radiated pulses are received by antenna **4** and applied to augmenter **5** which is a radio frequency amplifier that, for X-band radar, would normally be of the traveling wave type. Conventionally, the amplified radio frequency pulses at the output of the augmenter would be applied directly to transmitting antenna **6** for reradiation to antenna **2** of

the interceptor radar. However, in accordance with the invention, a variable radio frequency energy attenuator **7** is interposed between the augmenter output and the transmitting antenna. The attenuation of this element is made to vary at a low rate, such as 10 c./s., by modulator **8**, thus placing a 10 c./s. amplitude modulation on the pulses radiated from antenna **6**. At the fighter aircraft, in accordance with the invention, there is provided an arming control circuit **9** which receives the video pulse output of the radar receiver and energizes the arming circuit **10** only when a 10 c./s. modulation has been present on the video pulses for a prescribed interval, as already stated. Further protection against firing upon an undesired target is provided by the range tracking circuits of the radar **1** since, in order for the interceptor's missiles to be armed, the video return having the proper amplitude modulated signature must be in time coincidence with the radar range gate.

The modulator **8** and the manner of coupling its output to the attenuator **7** are shown schematically in FIG. 2. The 10 c./s. modulating frequency is generated by a phase shift oscillator comprising transistor Q_1 and a regenerative feedback circuit comprising elements C_1, R_1, C_2, R_2, R_3, C_3 and R_5. Since the impedance of an RC circuit is capacitive, the voltage across each resistor leads the applied voltage. Each RC section of the feedback circuit contributes approximately 60 degrees of phase advance at the frequency of oscillation, so that the output of Q_1, adds in phase at the input to sustain oscillation. The oscillation frequency may be controlled by R_2.

The nearly sinusoidal output of the oscillator at the collector of Q_1 is applied through R_8 to the base of emitter follower Q_2. The emitter follower provides load isolation of the oscillator for frequency stability. The output of the emitter follower is applied through C_5 to the base of an overdriven amplifier Q_3 which operates between cutoff and saturation to square the sinusoidal input. The squared output appears across R_{12} and the portion of it applied to the base of driver Q_4 may be adjusted by this potentiometer. The parameters of the squaring circuit are such that an unsymmetrical square wave of approximately 2:1 time relation is produced. The emitter current of Q_4 flows through current limiting resistor R_{15} and shielded conductor **12** to a solid state diode in attenuator **7** which acts as the RF attenuating element in a manner to be described later. In the embodiment shown, the voltage on conductor **12**, which is the voltage applied across the diode, varies from 0 v. to +18 v. and causes a forward diode current of 0 to 50 ma.

The internal construction of the variable RF attenuator **7** is shown schematically in FIG. 3. The attenuator comprises a short section of rectangular waveguide **13**, shown in longitudinal section, having couplings at each end to coaxial transmission lines **14** and **15** which serve to insert the attenuator between the output of augmenter **5** and transmitting antenna **6**. The RF energy absorbing element in the attenuator is a PIN diode **16** connected for RF between opposite points inside the rectangular waveguide. As seen in FIG. 3, the cathode of the diode is connected directly to the waveguide wall, whereas an RF coupling to the waveguide for the anode may be established by a small annular capacitor **17** for which lead **12** serves as one element. As explained above, conductor **12** connects the anode of the diode **16** through R_{15} to the emitter of Q_4. Therefore, Q_4 controls the forward biasing voltage across this diode which, as stated above, varies from 0 v. to +18 v. in accordance with the rectangular output of this transistor.

The PIN diode **16** is a silicon device in which an intrinsic (I) layer is situated between P-type and N-type layers. It has the property that, at frequencies about

100 M c./s., the usual rectifying properties disappear and the diode behaves throughout the RF cycle as a linear resistance the value of which depends upon the forward biasing voltage. At zero bias the resistance of the diode is high relative to the characteristic impedance of the rectangular waveguide and the presence of the diode in the waveguide has little effect on the transmission of RF energy through it. However, as the forward bias is increased the resistance of the diode falls, causing an increasing portion of the RF energy to flow through the diode where it is dissipated as heat due to the diode resistance. Thus, as the forward bias increases, the attenuation of attenuator **7** increases until it reaches, in the example given, a maximum value of about 20 db for a forward bias of 18 volts. With this arrangement a rectangular amplitude modulation at 10 c./s. is impressed upon the RF pulses applied to transmitting antenna **6**. Further information on PIN diodes may be found in the literature, for example, an article entitled "The PIN Diode: A Versatile Microwave Component" by Robert E. Heller appearing in the March 8, 1963, issue of Electronics, pages 40–43.

The schematic diagram of the arming circuit **9** is shown in FIG. 4. The video output of the interceptor radar **1**, which consists of a series of video pulses with a 10 c./s. more or less degraded rectangular amplitude modulation envelope resulting from the rectangular modulation of the RF pulses radiated by the tow target, is applied over line **3** to potentiometer R_{16}. The first stage of the arming control circuit is an automatic gain control stage for compensating for the variations in video levels caused by varying ranges and angle of attack as the interceptor approaches the target, and other parameters. The positive-going portions of the video signal are applied through CR_1 to the base of Q_5 for amplification by this transistor, the amplified output at the collector being a 10 c./s. negative-going roughly rectangular wave. This wave charges C_9 through C_8 and CR_2 with the polarity shown. CR_3 is a 5 volt Zener diode. When the sum of the positive input signal at the base of Q_5 and the voltage of C_9 exceeds 5 volts, diode CR_3 breaks down and prevents the base potential of Q_5 from rising appreciably above the value required to produce about 5 volts across C_9. Thus the negative-going output of Q_5 is limited to a maximum swing of approximately 5 volts. The minimum signal level that will cause limiting to occur is adjustable by potentiometer R_{16}.

The limited output of Q_2 is applied cross sensitivity potentiometer R_{22} which adjusts the signal level required to energize the arming circuit. Thermistor R_{44} compensates this sensitivity adjustment for the effects of circuit parameter changes caused by temperature variations.

The negative-going pulses coupled to the base of Q_6 through C_{10} are emitter coupled to Q_7 and result in negative-going pulses at the collector of this transistor. Negative-going 10 c./s. pulses at the collector of Q_7 excite the twin series-T active bandpass filter, composed of C_{12}, C_{13}, R_{29}, R_{28}, R_{30}, C_{14} and C_{15}, causing it to ring at its inherent 10 c./s. frequency. Other frequency components appearing at the filter input are suppressed. A 10 c./s. sine wave is thus developed at the base of emitter follower Q_8 which provides the necessary high impendance load for the filter. Emitter output of Q_8 is coupled to the base of differential amplifier Q_7. The resulting collector current is therefore the differential between the 10 c./s. sine wave and the input pulses. The sinusoidal output developed across R_{26} is coupled through C_{16} to the base of emitter follower Q_9. The network comprised of C_{11}, R_{45} and R_{46} stabilizes the D.C. operating point of Q_7. Emitter follower Q_9 provides isolation between the 10 c./s. filter and the relay driver Q_{10}.

In the quiescent state, Q_{10} is biased near cutoff and C_{18} is charged to approximately 22 volts. Therefore only the positive half cycles of the 10 c./s. sine wave applied to the base of this transistor are effective. Each positive half cycle causes Q_{10} to conduct heavily, energizing K_1 and discharging C_{18}. During the negative half cycles when Q_{10} is cut off, C_{18} charges through K_1 holding the relay in its actuated state until the next positive half cycle occurs. Thus K_1 remains energized as long as a 10 c./s. wave from the filter is present.

The active 10 c./s. filter previously described is inherently a high Q device and has a tendency to ring at its center frequency when power is first applied to the system or when transients are passed through the radar receiver. An arming delay circuit prevents these transients from energizing the arming circuit. This circuit comprises unijunction transistor Q_{11} and associated components. In the quiescent condition (K_1 deenergized), Q_{11} is not conducting and C_{19} is discharged through R_{39}. When K_1 energizes, R_{39} is removed from the circuit, +22 v. potential is allplied to Q_{11} and C_{19} begins to charge through R_{40} toward +22 v. The time constant of R_{40} and C_{19} is approximately 3.6 seconds. After approximately 5 seconds, the voltage across C_{19} is sufficient to place Q_{11} in conduction and energize K_2. Actuation of K_2 energizes the arming circuit **10** through contact **20** and applies a holding voltage through contact **21** of K_1, and contact **22** of K_2 to the K_2 winding so that K_2 does not deenergize when C_{19} is discharged by conduction through Q_{11}. Actuation of K_2 also energizes arming indicator light **23** when the override switch S_1 is in its "out" position as shown. When the 10 c./s. modulation is no longer present, K_1 deenergizes removing power from the delay circuit and the holding voltage from K_2 which releases, thus disarming the missile and extinguishing arming indicator **23**. Also, R_{39} is shunted across C_{19} so that it is completely discharged in preparation for the next arming cycle.

The manual override switch S_1 permits the pilot or maintenance personnel to override the normal safety arming procedure. An amber override indicator **24** illuminates when the override switch is actuated to its arming or "in" position.

I claim:

1. In an armament practice and testing arrangement in which a normally disarmed weapon is directed at a practice target by radar apparatus including a radar receiver having a video output and in which the practice target carries a radar augmenter, safety apparatus for preventing the arming of said weapon when directed by said radar apparatus toward any target other than said practice target, said safety apparatus comprising: means at said practice target for amplitude modulating the output of said augmenter at a predetermined low frequency; and frequency selective means located at said radar apparatus and receiving the video output therefrom for arming said weapon only after the continuous presence for a prescribed minimum time interval of an amplitude modulation of said video output at said low frequency.

2. An armament practice and testing arrangement comprising: radar apparatus for directing a weapon at a practice target, said radar apparatus having a video output and said weapon having a normally deenergized electrical arming circuit; carried by said practice target: a receiving antenna, a transmitting antenna, a radar augmenter and a variable attenuator for radio frequency energy, said augmenter being a radio frequency amplifier having its input coupled to the receiving antenna and its output coupled through said attenuator to the transmitting antenna, and means coupled to said attenuator for cyclically varying its attenuation at a predetermined low frequency; a very narrow band filter centered on said low frequency having its input coupled to the video output of said radar apparatus; a resistor and a capacitor connected in series; a shunting resistor having a resistance value low relative to that of said series connected resistor; means coupled to the output of said filter for connecting said shunting resistor across said capacitor in the

absence of an output signal from said filter and for removing said shunting resistor and applying a direct voltage across said series connected resistor and capacitor in the presence of an output signal from said filter; and means responsive to the voltage across said capacitor and operative when said voltage exceeds a certain value to apply an arming voltage to said arming circuit.

3. Apparatus as claimed in claim 2 in which said variable attenuator comprises a short section of rectangular waveguide having a coupling to the output of said augmenter at one end and a coupling to said transmitting antenna at the other end and a PIN diode connected as an internal radio frequency shunt in said waveguide, and in which said means for cyclically varying the attenuation of said attenuator comprises means for applying an alternating bias voltage of said low frequency between the anode and cathode of said PIN diode.

4. An armament practice and testing arrangement comprising: a radar apparatus for directing a weapon at a practice target, said radar apparatus having a video output and said weapon having a normally deenergized electrical arming circuit; carried by said practice target: a receiving antenna, a transmitting antenna, a radar augmenter and a variable attenuator for radio frequency energy, said augmenter being a radio frequency amplifier having its input coupled to the receiving antenna and its output coupled through said attenuator to the transmitting antenna, and means coupled to said attenuator for cyclically varying its attenuation at a predetermined

low frequency; a vary narrow band filter centered on said low frequency having its input coupled to the video output of said radar apparatus; a resistor and a capacitor connected in series; a unijunction transistor having said capacitor in its emitter circuit; an arming relay having its winding connected in the output of said unijunction transistor, said relay having a first pair of normally open contacts connected between a source of arming voltage and said arming circuit and a second pair of normally open contacts connected in a holding circuit for said relay; a shunting resistor having a resistance value low relative to that of said series connected resistor; and means coupled to the output of said filter for connecting said shunting resistor across said capacitor in the absence of an output signal from said filter and for removing said shunting resistor and applying a direct voltage across said series connected resistor and capacitor and to said unijunction transistor and to said holding circuit in the presence of an output signal from said filter.

References Cited by the Examiner

UNITED STATES PATENTS

2,472,136	6/1949	Whitlock	343—7 X
3,209,349	9/1965	Prestwood	343—7 X

CHESTER L. JUSTUS, *Primary Examiner.*

T. H. TUBBESING, *Assistant Examiner.*