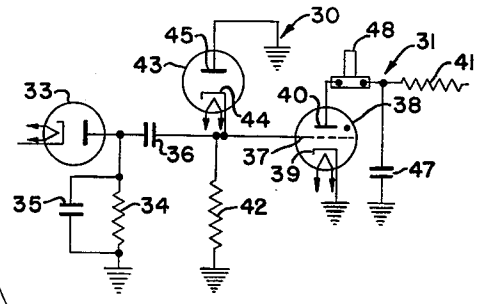
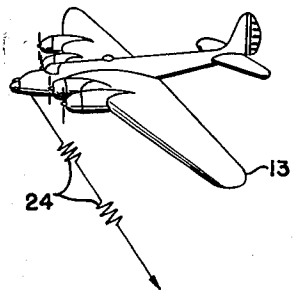
Dec. 3, 1963 E. P. TROUNSON ETAL 3,113,305

SEMI-ACTIVE PROXIMITY FUZE

Filed May 4, 1951 2 Sheets-Sheet 1

FIG.3.





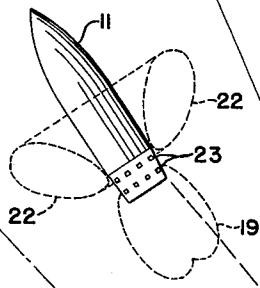
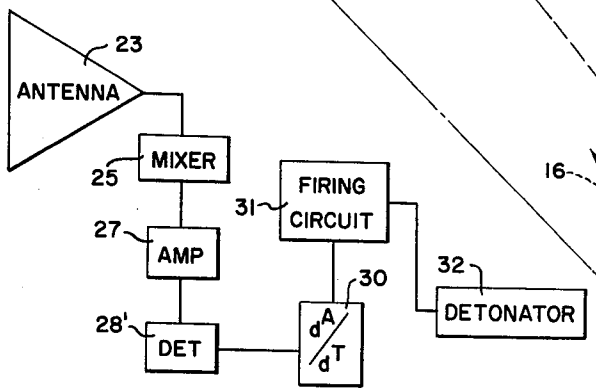


FIG.1.

FIG.5.



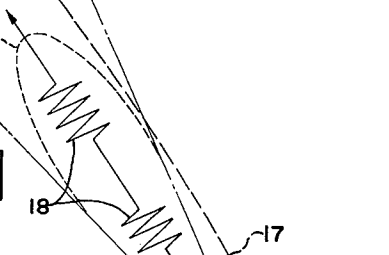
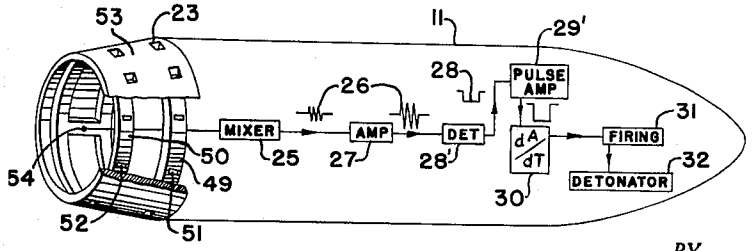
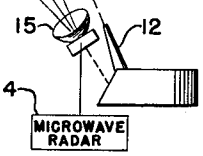


FIG.2.





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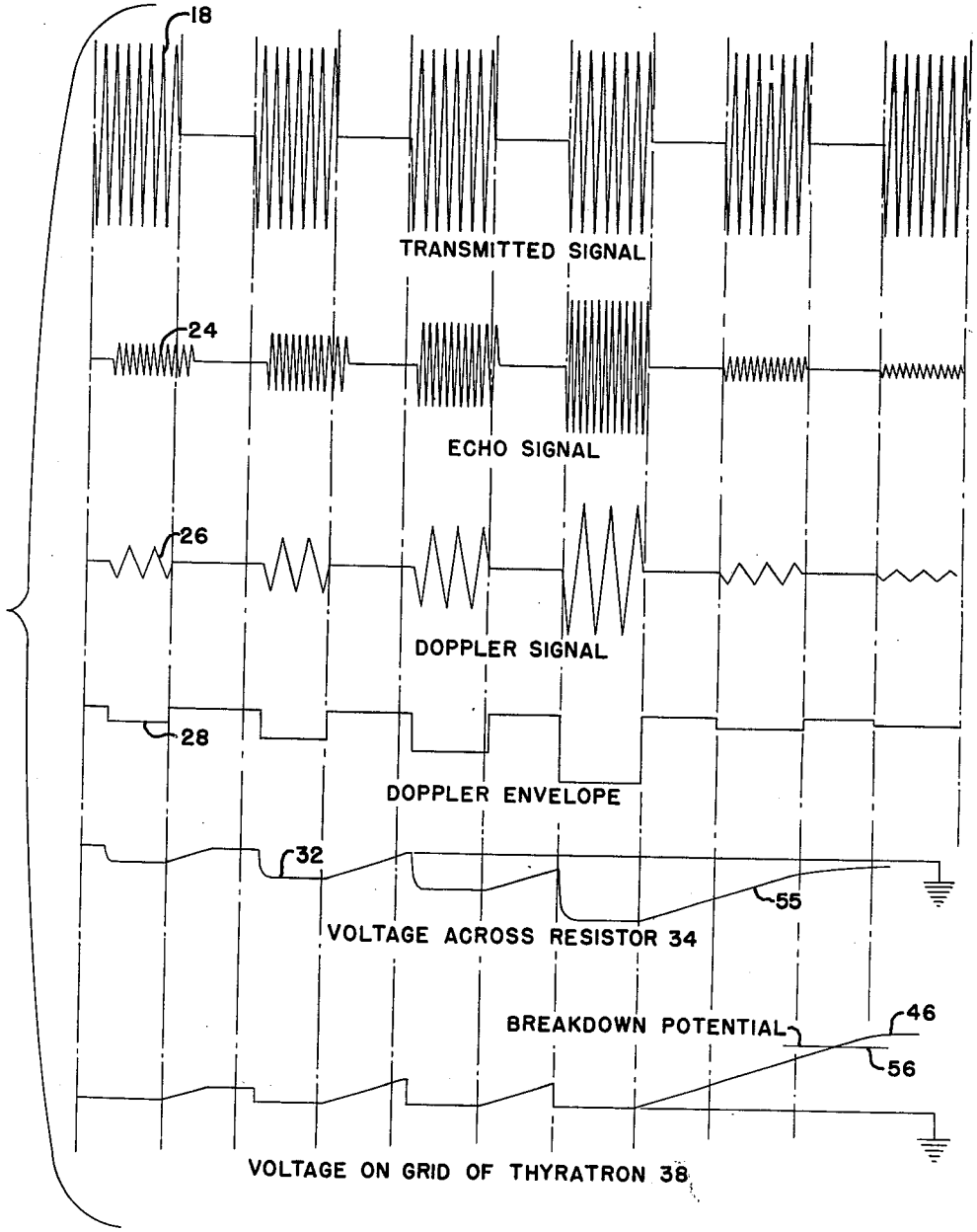
Filed May 4, 1951 2 Sheets-Sheet 2

FIG. 4.



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SEMI-ACTIVE PROXIMITY FUZE

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Filed May 4, 1951, Ser. No. 224,632
13 Claims. (Cl. 343—7)
(Granted under Title 35, U.S. Code (1952), sec. 266)

This invention relates generally to a new and improved proximity fuze for a projectile or the like and more particularly to a semi-active proximity fuze which has improved operational characteristics.

Prior art proximity fuzes such, for example, as that disclosed and claimed in the copending application of L. W. Erath and G. N. Plotkin, Serial No. 197,962, filed November 28, 1950, while providing many advantages over conventional time fuzes have certain inherent disadvantages which are difficult to overcome. Such prior art fuzes are comparatively susceptible to jamming by small frequency swept transmitters carried by the target aircraft and by friendly radars the field patterns of which are traversed by the projectile in its flight toward the target aircraft and salvo effects in which the radiation from one shell coacts with that of another shell to cause mutual interference with the operation of the adjacent shells fired in salvo at a target aircraft as well as spurious responses resultant from echo signals received from the ocean or terrain over which the projectile passes in a low angle trajectory.

The semi-active proximity fuze of the present invention possesses all the advantages of the prior art devices and overcomes to a great extent the disadvantages associated therewith. This is accomplished by separating the transmission and reception function of the radiation system to provide only the receiving system on the proximity fuzed projectile and providing a transmission function at the ground or vessel near the source of the projectile's trajectory. In accordance with the teaching of this invention a transmitter preferably of the type which radiates in a narrow beam pattern operates with the gun laying radar and thus tracks the target and the projectiles fired thereat. Signals from this radar reach the projectile and are received thereby by a high-gain antenna system which is incorporated in the body of the projectile to supply the mixer circuit contained therein with local oscillator power directly from the shipborne radar. These same ship originated signals, of course, impinge upon the target aircraft and a small portion of the energy is reflected back to the projectile. A forward looking lobe of the antenna pattern of the projectile's antenna system receives a small amount of the energy reflected by the target aircraft and the antenna system mixes the echo signal with the energy received directly from the shipborne radar to produce a beat frequency characterized by the Doppler shift resulting from the projectile-target velocity. The frequency range of these signals is well known for a given type of projectile and the amplifier and firing circuit contained in the projectile fuze are of the conventional type with a selected passband for the range of frequencies to be encountered. The firing circuit, if desired, can be adapted to detonate when the signal supplied has reached a predetermined maximum value and preferably is made responsive to a predetermined time rate of decrease in amplitude of the signal, after the latter has reached a maximum value, as would be caused by the forward lobe of the antenna pattern sweeping past the target.

It is an object of this invention to provide a new and improved proximity fuze for a projectile.

A further object of this invention is to provide a projectile fuze of the semi-active type.

A further object of this invention is to provide a proximity fuze projectile which is free from operational difficulties due to jamming, salvo and ocean or terrain noise.

Another object of this invention is to provide a proximity fuze for a projectile which receives its local oscillator power from a source not located on a projectile.

A further object of this invention is to provide a proximity fuze the frequency of operation of which can be readily altered during the flight of projectile, if desired.

Yet another object of this invention is to provide a proximity fuze projectile which will be detonated when the angle between the shell trajectory and the target reaches a specified range of values corresponding to the direction of maximum fragmentation.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

FIG. 1 is a view showing the system of the present invention;

FIG. 2 is a block diagram showing functionally the circuits which are employed within the projectile in a preferred embodiment thereof;

FIG. 3 is a circuit diagram of a portion of the block diagram of FIG. 2 for producing a firing signal when the Doppler signal is decreasing in magnitude;

FIG. 4 is a timing diagram showing the relation between the transmitter, echo, Doppler and firing signals; and

FIG. 5 is a block diagram of a slightly modified form of the invention for use with a continuous wave signal.

Referring now to FIG. 1 there is shown the system of the invention employed to activate a proximity fuze projectile or missile 11 launched by gun 12 toward a target aircraft 13. The gun 12 may be controlled by a gun laying radar or any other training device, as is well known in the art, to project the missile 11 to the general proximity of the target aircraft 13. Associated with the gun 12 is a radar 14 which has a high gain antenna 15 which moves with the tracking radar to illuminate the target 13. The gain of the antenna 15 may be made extremely high at microwave frequencies, which are preferable for this application, and preferably has, for example, a gain of 10,000. The antenna 15 also has an extremely narrow beam width 16 such, for example, as 2° thereby providing high concentrations of the radio frequency energy in a single direction and is useful to prevent the projectile from being energized by the beam in the initial portion of the trajectory 17 which will be more fully described hereinafter. The radar 14 may put out energy continuously or preferably in the form of intermittent pulses represented at 18 which have, for example, 100 microseconds duration and have a repetition rate of 1000 pulses per second.

The projectile 11 has associated therewith, preferably near the rear portion of the projectile an antenna system, more fully described hereinafter, which has a backward directed lobe 19 and a forwardly directed lobe pattern 22, preferably of conical shape, which surrounds the shell and may be obtained by a properly designed slot antenna array 23. Energy, such as the pulses 18, which emanates from the antenna 15 is received directly by the projectile antenna system by the backward directed lobe 19 and echo signals of this energy such as 24 are received by the forwardly directed lobes 22 after reflection from any target which lies ahead of the projectile such as aircraft 13.

Referring now to FIG. 2 there is shown in block diagram the circuits contained in the projectile which utilize the signals received by the antenna system to detonate the projectile upon its approach to a position in which the angle between the shell trajectory and the target such

as an aircraft reaches a specified range of values corresponding to the direction of maximum fragmentation.

The pulses 18 received directly from the antenna 15 by the rearwardly directed lobe 19, and the echo pulses 24 received by the forwardly directed lobes 22 of the antenna array 23 are fed to a crystal mixer 25 and produce at the output thereof a beat frequency signal 26. This beat frequency signal is in the form of pulses, the repetition rate of which is substantially equal to the repetition rate of the pulses transmitted from antenna 15, the duration of the beat frequency pulses being dependent upon the duration of the transmitted and echo pulses and the relative phase relation between the latter, as is apparent from FIG. 4. Obviously, as the projectile approaches the target, the phase difference between the transmitted and echo pulses will approach zero and, consequently, the duration of the beat frequency pulses 26 will approach that of the transmitted pulses as the projectile approaches the target.

The amplitude of the echo pulses 24 reaches a maximum as the directional forward lobe 22 of the antenna array sweeps past the target, and, similarly the amplitude of beat frequency pulse signals produced by the heterodyning of the transmitted and echo pulses 18 and 24, respectively, also reach a maximum, and then rapidly diminish, as the lobe 22 of the antenna array sweeps past the target. The beat frequency signals 26 are then amplified by suitable amplification means. This amplification means preferably is in two parts, the first stage or stages 27 having a band pass just sufficient for the range of beat frequencies expected. The beat frequency signal 26 is then rectified or detected as at 28' with suitable time constants to produce the envelope 28 of the beat frequency pulse signals, which envelope preferably is passed through another amplifier stage 29' with a pass band sufficient to accommodate the pulse repetition rate of the envelope 28, which is substantially equal to the pulse repetition rate of the transmitted signals 18, proper consideration being given in the design of the transmitting and receiving antennas to the rotation of the projectile and its effect on the received pulses.

The envelope 28 of the beat frequency pulses could be applied directly to a firing circuit 31 to produce a firing signal at the moment a predetermined maximum signal is received. In the preferred embodiment illustrated, the envelope 28, which for reasons which will later become apparent as the description proceeds, includes only the negative portion of the pulse and is applied to a differentiating circuit 30 which supplies a firing signal to the firing circuit when the envelope 28 of the pulses passes a maximum and begins to decrease rapidly in magnitude as the forward looking lobe 22 of the projectile antenna array passes the target aircraft. Thus, the firing circuit 31 actuates the detonator 32 to explode the projectile's explosive charge when the angle between the shells trajectory corresponds to the direction of maximum fragmentation.

The differentiating circuit in FIG. 3 receives its input from either the beat frequency band pass amplifier 27 or the beat frequency pulse envelope band pass amplifier 29', dependent upon whether the latter amplifier and its associated detector is utilized in the circuit to discriminate against signals having a repetition rate differing from the repetition rate of the transmitted pulses 18. In either case, the diode detector 33 is so connected as to pass only the pulses of negative polarity, which pulses are impressed upon the RC load formed by resistor 34 and condenser 35 and produce the voltage 32 (see FIG. 4), of negative polarity, of the envelopes 28 of the input pulses. Since the amplitude of the beat frequency pulses increases and then decreases as the forward lobe 22 sweeps past the target, the voltage 32 produced by the detector 33 and its associated RC load increases negatively in steps of alternate charge and discharge cycles of condenser 35 to a negative maximum value and then decreases to ground potential at a rate determined by the RC load.

The output of the detector 33 is connected by a coupling condenser 36 to the control grid 37 of a thyratron tube 38, and as will be noted, the condenser 36 keeps the negative DC bias produced by the detector 33 and its RC load circuit off the grid of the thyratron. The cathode 39 of the thyratron is suitably grounded, and its plate 40 connected by a coupling resistance 41 to a source of positive plate potential (not shown). The thyratron 38 is such that it will fire in response to a small positive grid bias, and for this purpose there is provided a grid biasing resistor 42. A diode 43 has its cathode 44 coupled to the grid of the thyratron, and its plate 45 suitably grounded and thereby maintains the thyratron grid 37 at substantially ground potential. The side of condenser 36 which is connected to grid bias resistor 42 is therefore maintained at substantially ground potential, while the side of condenser 36 which is connected to detector 33 becomes increasingly negative with respect to ground as the envelope of the beat frequency pulses reach a negative maximum. The last mentioned envelope, however, decreases at a rapid rate as the forward lobe 22 of the antenna system sweeps past the target, and consequently the detector side of condenser 36 rapidly rises toward ground potential, as indicated at 55 in FIG. 4, causing a rapid increase in potential above ground on the thyratron side of the condenser producing a positive signal 46 (see FIG. 4) which is sufficient to fire the thyratron, the firing threshold thereof being indicated by the line 56 (see FIG. 4). The resistance 42 is sufficiently large as compared to resistance 34 to substantially maintain the potential across condenser 36 as condenser 35 discharges, thereby to develop the firing potential across resistance 42 when the condenser discharges rapidly as indicated at 55 (FIG. 4). A condenser 47 is shunted between the resistor 41 and ground and charged from the aforementioned source through resistor 41 so that, when the thyratron fires, the condenser discharges through the detonator 48 disposed in the plate circuit of the thyratron. It will therefore be noted that the detonator is actuated only when the echo pulse passes a maximum and then decreases at a predetermined rate which is greater than the rate of discharge of condenser 35 through resistor 34.

The antenna array 23 may be of any desired configuration which will produce the forwardly and backwardly directed lobe pattern previously described. One such antenna array is illustrated in FIG. 2 and includes a pair of coaxial annular wave guides 49 and 50 having circumferentially spaced slot antennas 51 and 52, respectively, therein. The individual slot antennas 51 and 52 are arranged in pairs which are disposed in radial planes through the axis of the shell, and circumferentially spaced from each other. In order to produce the desired lobe pattern, the slot antennas in each pair are spaced apart a distance equal to slightly more than ½ the wavelength of the received energy in air so that the fields of the individual antennas of each pair will reinforce in relatively opposite directions which are less than 180° apart. The antenna array is adapted to the boat tailing 53 of the shell so that the pairs of antennas are inclined relative to the axis of the shell whereby the rearwardly directed lobes of the array will be disposed substantially parallel to the axis of the shell, and the forwardly directed lobes will diverge relative to the axis of the shell. Obviously, the circumferential spacing of the pairs of antennas on each of the guides will be such that proper phase relation of the received signals within the guide will be achieved and for this purpose, the spacing between slot antenna centers may be a multiple of the wavelength, in the guide, of the range of transmission frequencies from antenna 15.

The wave guides 49 and 50 are suitably coupled by a connecting guide 54, and the crystal mixer 25 is electrically coupled in any conventional manner to the connect-

ing guide to receive the signal voltage, the mixer, for example, being mounted in guide 54. The operation of the system of the present invention in accordance with the preferred embodiment thereof disclosed in FIGS. 1, 2, and 3 will now be described with reference to the timing diagram of FIG. 4. Assume that the search and gun laying radars, not shown, have positioned the gun 12 for firing at the target 13. The radar 14 will have its antenna 15 directed to illuminate the target within the energy of the narrow beam 16. Successive projectiles are launched by the gun 12, of which only one is shown in FIG. 1, and after leaving the muzzle of the gun the conventional arming circuits not shown, contained in the projectile operate to supply operative voltages to all the tubes contained thereon. During the initial part of the trajectory 17 the main receiving lobe 19 of the projectile antenna will not receive sufficient energy from the radar antenna lobe 16 to be operative, thereby rendering the armed projectile 11 ineffective against friendly aircraft which may be in the area and adjacent to the line of fire between the gun 12 and the target 13. As the projectile proceeds along its trajectory it comes within the beam width of lobe 16 and receives sufficient power on lobe 19 to energize the mixer in the manner in which conventional mixers are normally energized by a local oscillator. Energy from the antenna 15 which strikes the target aircraft 13 is reflected, in part, in a direction toward the oncoming missile 11 and this reflected energy received by the lobe 22 of the antenna system of the projectile and fed into the mixer. Since the energy fed into both channels of the mixer originates from the same source the apparent frequency difference which exists between these two signals is controlled only by the relative velocity between the projectile and the target aircraft in accordance with the well known Doppler principle.

Assuming now that the projectile has travelled far enough along its trajectory so that it is within the beam 16 of the radar and that the missile to target range is sufficiently short so that the wave front of energy which is received by the projectile at the lobe 19 may travel to the target aircraft 13 and back again to the projectile within the time duration of one transmission pulse 18. For all ranges of this magnitude or less, transmitted and echo signals will be received by the projectile simultaneously for a portion of the pulse determined by the amount of overlap of the signals 18 and 24 received at the projectile as shown in the timing diagrams of FIG. 4. For the duration of the overlap of signals 18 and 24 the mixer will be energized by two signals of slightly different frequencies and produce in its output a beat note which is the Doppler signal 26. The frequency of the Doppler signal 26 will be well known for all conventional target and missile encounters and may be for example, 150,000 cycles per second. Knowing that the frequency of the Doppler signal will be within a definite range, the passband of the amplifier 27 is selected to pass only those signals thereby improving the immunity of the fuze to spurious signals.

The amplified Doppler signals are then detected to recover the video signal which will be in the form of envelope pulse 28 and further discrimination against unwanted signals preferably is obtained by providing the pulse amplifier 29' with the proper response to selectively amplify the pulse repetition rates which will be encountered. The amplified pulses are supplied to the differentiating circuit which provides a firing impulse to the firing circuit when the signal has reached a maximum and is decreasing at a predetermined rate, as when the forward lobe 22 of the antenna pattern sweeps past the target.

By detonating the shell when the beat frequency signal is falling, i.e., when the forward looking lobe 22 passes the target, the optimum burst position may be attained with considerable consistency since firing is dependent upon the rate of change of amplitude of the Doppler, and

not upon a magnitude thereof. Since the rate of change of amplitude is dependent upon the forward looking lobe pattern 22, it will be appreciated that by proper adjustment of the angle between the rear edge of the lobe 22 and the axis of the projectile, in the manner previously described, the optimum damage probability can be achieved.

It is contemplated that the frequency of transmission from the antenna be at extremely high microwave frequencies, such as 25,000 mc., at which frequency the Doppler between the transmitted and echo signals due to a projectile target velocity in the range of 3000 ft./sec. will be 150 kc. Thus the Doppler is low in comparison to the transmitted frequency, and since the Doppler frequency is substantially proportional to the transmitted frequency, for a given projectile-target velocity such as 3000 ft./sec., it will be noted that a change in the transmitted frequency of 5000 mc., which produces a like change in the echo frequency, will only produce a frequency change in the Doppler of about 30 kc. The band pass amplifier 27 is designed to pass the range of Doppler frequencies encountered due to changes in the transmission frequency and the projectile-target velocity while being selective within a somewhat narrow range of 100–200 kc. Thus, the control of the projectile fuze with a variable frequency transmitted pulse, improves the immunity of the fuze to attempted jamming.

One possible jamming technique would be to supply a simulated reflected signal from the target, which signal would be received by the forwardly directed lobes 22, while energy from the shipboard antenna would be received by the rearwardly directed lobe 19. The beat frequency between the simulated reflected signal would not only be a function of the projectile target velocity and the transmitted frequency, but also a function of the difference in the frequency of the transmitted signal and the simulated reflected signal. Because of the high transmitted frequencies, it will be appreciated even a very small percentage difference between the frequency of the transmitted signal 18 and a simulated reflected signal would, in itself produce a beat frequency of a very high order which would not be passed by the amplifier 27. This method of jamming would, therefore, require that the simulated signal be, at all times, at almost the same frequency as that of the transmitted signals 18. However, the frequency of the transmitted signals could be varied at any time during the flight of the projectile, within a comparatively wide range, and consequently the probability that the target could produce a suitable simulated signal having the essential characteristics for firing, is further minimized.

Another possibility of jamming the fuze would be to supply a signal, as from the target, which is amplitude modulated to simulate the Doppler frequency, which modulated signal would be received by the forward looking lobes 22. Obviously, the frequency of the carrier and the amplitude modulation thereof must correspond respectively to the frequency of the transmitted signals 18 and the range of Doppler frequencies which the amplifier 22 is designed to pass, and, in addition, the power supplied by the jammer to the fuze must be of the same order of magnitude as that supplied by the transmitter 14. However, the antenna 15 tracks the target and consequently can be made highly directional with a gain of about 10,000, and unless the jammer is also adapted to track the projectile, it cannot be made as directional in which case it can only have a gain of the order of 10. Further, if the jamming transmitter is on the target, it must get its power into the forward looking lobes 22. The directional character of the lobes 22 further necessitates either high powered jamming signals, or a comparatively small projectile-target distance, to properly actuate the fuze control circuit. Since, as previously indicated, the jammer cannot be directional, and have a high gain antenna, unless it tracks the projectile, the

projectile-target distance at which the jammer will become effective to detonate the fuze will be short, and in the range of damage possibility. It will, therefore, be noted that jamming of the fuze by the use of a carrier which is amplitude modulated to simulate the Doppler frequencies expected, will be of limited effectiveness, due to the directional characteristics of the antenna array 23.

Since the Doppler signal is dependent upon the projectile-target velocity, no difficulty is introduced due to salvo effects, since the Doppler between two or more projectiles travelling at the same speed, and in the same direction, is zero. Therefore one projectile would not cause detonation of other projectiles fired in salvo therewith.

The subject invention has been described in detail with regard to the operation thereof when activated by a pulse type signal such as that shown at 18 in FIG. 1, however, as pointed out hereinbefore, the subject invention may be used equally well in conjunction with a continuous wave activating signal in lieu of pulse signal 18. In this event, the structure and operation remain identical to that set forth hereinabove except that, since there are no pulses 18, there is no need to incorporate pulse amplifier 29' between detector 28' and differentiator 30. Thus, when it is desired to utilize a continuous wave signal in lieu of pulse signal 18, the circuitry contained in projectile 11 remains identical to that illustrated in FIG. 3 and that shown in FIG. 2 except that pulse amplifier 29' may be removed from the latter and the output signal from detector 28' may be fed directly into differentiator 30 as illustrated in FIG. 5. The structure and operation thereof otherwise remain substantially identical to that previously set forth in regard to pulse signal 18.

Obviously, many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

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

What is claimed as new and desired to be secured by Letters Patent of the United States is:

1. A semi-active detonating missile system comprising a source of electromagnetic radiation adapted to illuminate a target with said radiation, and a missile adapted to pass in proximity to said target, said missile including means for receiving said radiation directly from said source, means for receiving reflections of said radiation from said target, a mixer for heterodyning the received radiation and reflections to produce heterodyne signals, and utilization means for the heterodyne signals so produced, said utilization means being a firing circuit adapted to detonate the missile when said heterodyne signals decrease from a predetermined value at a predetermined rate.

2. An ordnance fuze system for exploding a missile in proximity of a target comprising, means located external of said missile for transmitting a continuous electromagnetic signal to both said missile and said target, means in said missile for receiving said transmitted signal and a signal reflected from said target, means in said missile for detecting said received signals to produce a beat signal therefrom, means for selectively amplifying said beat signal, and a firing circuit connected to said last means for utilizing said amplified signal to explode said missile.

3. A system for obtaining the optimum burst position of an anti-aircraft projectile with respect to a target comprising a gun for launching said projectile toward said target, means for generating energy of a predetermined frequency, an antenna associated with said gun for radiating said energy in the direction of said target, said projectile including an antenna system having a rearwardly directed lobe for receiving substantial amounts of said energy directly from said first mentioned antenna and a generally forwardly directed lobe for receiving echoes of said energy reflected from said target, a mixer operably connected to said antenna system for heterodyning the energy received by said forwardly and rearwardly directed lobes, and utilization means for the heterodyne signals operable to explode said projectile for a predetermined rate of change of said signals.

4. The system according to claim 3 in which said utilization means includes a firing circuit for firing said projectile, and circuit means responsive to a predetermined time rate of decrease of said signals from a predetermined amplitude for actuating said firing circuit.

5. A semi-active missile detonating system comprising a source of electromagnetic energy, an antenna for radiating said energy in a narrow beam, means for directing said beam to include a selected target therein, means for launching said missile to come within said beam and into proximity with said target, and an annular antenna system on said missile having one response pattern of cylindrical configuration extending coaxially in one direction therefrom and another response pattern of conical configuration extending coaxially in the opposite direction therefrom whereby energy received from said source and echoes of energy reflected from said target are utilized to detonate said missile when a predetermined condition of proximity occurs.

6. A semi-active missile detonating system comprising a source of electromagnetic energy, an antenna for radiating said energy in a narrow beam, means for directing said beam to include a selected target therein, means for launching said missile to come within said beam and into proximity with said target, an antenna on said missile comprising a pair of slotted coaxially spaced annular wave guides and an interconnecting wave guide for coupling with a mixer of a heterodyning system whereby energy received from said source and echoes of energy reflected from said target are utilized to detonate said missile when a predetermined condition of proximity occurs.

7. A semi-active missile detonating system comprising a source of electromagnetic energy, an antenna for radiating said energy in a narrow beam, means for directing said beam to include a selected target therein, means for launching said missile to come within said beam and into proximity with said target, and an antenna array on said missile comprising a pair of connected axially aligned annular wave guides each having circumferentially spaced slot antennas therein for receiving external energy and for supplying a signal heterodyning voltage to said system, said guides being spaced apart a distance such that their fields reinforce in relatively opposite directions, whereby energy received from said source and echoes of energy reflected from said target are utilized to detonate said missile when a predetermined condition of proximity occurs.

8. A semi-active missile comprising an antenna system having a rearwardly directed lobe for receiving substantial amounts of oscillatory energy and a generally forwardly directed lobe for receiving signal energy, a mixer operatively connected to said antenna system for heterodyning the signal energy received with the oscillatory energy received, and utilization means for the heterodyne signal produced by said mixer.

9. The device according to claim 8 in which said missile contains an explosive charge and said utilization means is a firing circuit operable to detonate said charge for a predetermined condition of said heterodyne signal.

10. A semi-active missile comprising an explosive charge, an antenna system having a rearwardly directed lobe and a generally forwardly directed lobe, a mixer coupled to said antenna system for heterodyning the signals received by the latter, a pass band amplifier for the output signals of said mixer, and a firing circuit coupled to the output of said amplifier and operable to explode

said charge in response to a predetermined characteristic of the amplified signals.

11. The device according to claim 10 and including amplitude rate discriminating circuit means for coupling said firing circuit to the output of said amplifier and for operating the firing circuit in time delayed relation to the maximum increase in the magnitude of said amplified signals.

12. In a heterodyning system of the character disclosed, an antenna comprising a pair of slotted coaxially spaced annular wave guides and an interconnecting wave guide for coupling with the mixer of the heterodyning system.

13. In a heterodyne receiving system, an antenna array comprising a pair of connected axially aligned annular wave guides each having circumferentially spaced slot antennas therein for receiving external energy and for supplying the signal-heterodyning voltage to said system,

said guides being spaced apart a distance such that their fields reinforce in relatively opposite directions.

References Cited in the file of this patent

UNITED STATES PATENTS

1,457,447	Mills	June 5, 1923
1,802,760	Gage	Apr. 28, 1931
2,414,266	Lindenblad	Jan. 14, 1947
2,441,030	Page	May 4, 1948
2,507,528	Kandoian	May 16, 1950
2,514,359	Allison	July 11, 1950
2,570,295	Vantine	Oct. 9, 1951
3,014,215	MacDonald	Dec. 19, 1961

FOREIGN PATENTS

573,621	Great Britain	Nov. 29, 1945
585,791	Great Britain	Feb. 25, 1947