May 4, 1948. H. C. PAGE 2,441,030

ARRANGEMENT FOR PRODUCING A TRIGGERING EFFECT IN PROXIMITY TO AN OBJECT ADAPTED TO RADIATE RADIANT-WAVE ENERGY

Filed Jan. 3, 1941

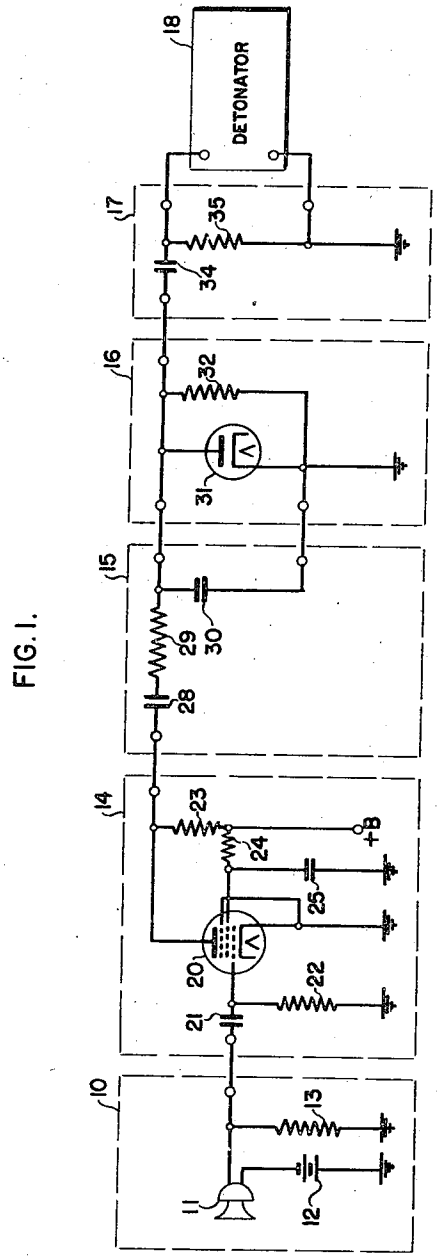


FIG. 1.

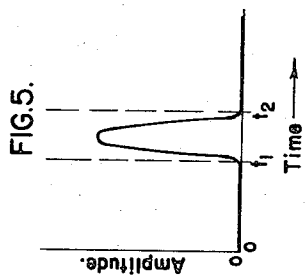


FIG. 5.

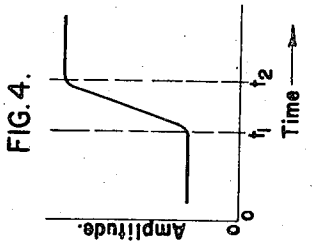


FIG. 4.

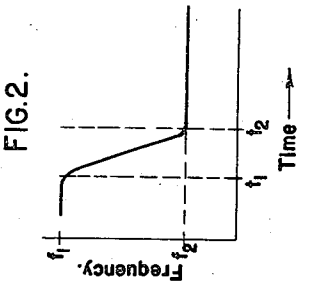


FIG. 2.

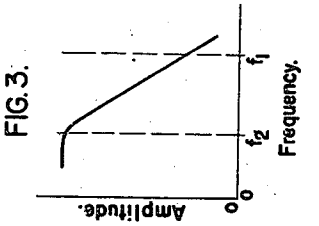


FIG. 3.

INVENTOR
HARRY C. PAGE
BY Lawrence B. Dodds
ATTORNEY

Patented May 4, 1948 2,441,030

UNITED STATES PATENT OFFICE

2,441,030

ARRANGEMENT FOR PRODUCING A TRIGGERING EFFECT IN PROXIMITY TO AN OBJECT ADAPTED TO RADIATE RADIANT-WAVE ENERGY

Harry C. Page, Scarsdale, N. Y., assignor, by mesne assignments, to Hazeltine Research, Inc., Chicago, Ill., a corporation of Illinois

Application January 3, 1941, Serial No. 372,988

12 Claims. (Cl. 102—70.2)

1

This invention relates to arrangements for exploding projectiles in proximity to sound-emitting targets and, while the invention is of general utility, it is particularly adapted for use in anti-aircraft projectiles.

It is customary, when utilizing explosive shells against aircraft, to estimate the height of the target and to adjust a timing device in the projectile to cause the projectile to explode at the desired altitude. However, many factors combine to make this system of firing very difficult and inaccurate and to cause the percentage of hits to be very much less than desired. For example, the following factors contribute to inaccurate results:

(1) Inaccuracies in estimating the range of the target;

(2) Inaccuracies in the timing arrangement of the projectile which cause the detonation to be at an undesired point even though the range is correctly estimated; and

(3) Changes in range of the target aircraft after the firing data is computed.

It is very desirable, therefore, to provide a projectile-exploding device which is not subject to these disadvantages. For instance, it is desirable to provide an arrangement by which the explosion takes place as the projectile passes the point in its trajectory closest to the target.

It is an object of the invention, therefore, to provide an improved projectile-exploding device.

It is a further object of the invention to provide an arrangement of the type under consideration which is not subject to one or more of the disadvantages of prior art arrangements mentioned above.

It is a further object of the invention to provide an arrangement for exploding a projectile in the proximity of a sound-emitting target which requires no adjustment prior to the time of firing.

In accordance with the invention, an arrangement for producing a triggering effect in proximity to an object adapted to radiate radiant-wave energy comprises means for generating a periodic control effect the frequency of which varies in accordance with the characteristic frequency of the energy radiated by the object, the means and the object having relative motion toward one another, and means responsive primarily to the change of frequency of the control effect produced as the means and the object pass one another at their closest point of approach for producing a second control effect. The arrangement includes means for utilizing the second control effect to produce the triggering effect desired.

For a better understanding of the present invention, together with other and further objects thereof, reference is had to the following description taken in connection with the accompanying drawing and its scope will be pointed out in the appended claims.

2

Fig. 1 of the accompanying drawing is a circuit diagram, partly schematic, of a projectile-exploding device in accordance with the invention; while Figs. 2–5, inclusive, comprise graphs utilized to illustrate certain of the operating characteristics of the arrangement of Fig. 1.

Referring now more particularly to Fig. 1 of the drawing, the various parts thereof comprise an arrangement for producing a triggering effect in proximity to a sound-emitting source. This arrangement, for example, is adapted to be included in a projectile to be exploded in proximity to a sound-emitting target and will be described in that connection. The unit 10 constitutes a means for generating a periodic control effect varying in accordance with the characteristic frequency of the sound produced by the target or like source, for example, by the motor of the target aircraft where the arrangement is utilized in anti-aircraft projectiles. The unit 10 includes a microphone 11, having included in circuit therewith a battery 12 and a load impedance such as resistor 13, the microphone 11 preferably being adapted to be mounted in the nose of the projectile. There are also coupled in cascade with the unit 10, a vacuum-tube amplifier and limiter 14, a frequency-responsive circuit 15, an amplitude detector 16, a differentiating circuit 17, and a detonator 18, which is responsive to the triggering effect produced by the arrangement for exploding the projectile.

The amplifier and limiter 14 may be of conventional design and, as illustrated, includes a vacuum tube 20, having input electrodes coupled to the output circuit of unit 10 through a suitable coupling condenser 21 and grid-leak resistor 22. The output circuit of tube 20 comprises a load resistor 23, while suitable operating potentials are adapted to be applied to the screen electrode of tube 20 through resistor 24 and to the anode electrode of tube 20 through resistor 23 from a source of unidirectional operating potential +B. A condenser 25 is provided for by-passing periodic currents in the screen circuit of the tube. The circuit of tube 20 is preferably designed so that both grid-circuit limiting and anode-circuit limiting are effected, the unidirectional operating potentials supplied to the tube being reduced to a suitable value to effect anode-circuit limiting and the elements 21 and 22 being so proportioned as to effect grid-circuit limiting.

The frequency-responsive circuit 15 may be of any desired type and, as shown, includes a blocking condenser 28, a series resistor 29, and shunt condenser 30. Detector 16 also may be of any desired type and, as shown, includes a diode 31 connected across the output terminals of unit 15,

that is, across condenser 30, together with a suitable parallel load resistor 32. The differentiating circuit 17 includes a condenser 34 in series in the signal-translating channel and a resistor 35 in shunt therewith. Detonator 18 includes input terminals adapted to be coupled across resistor 35 and is shown in block form for the reason that the unit, per se, forms no part of the present invention, it being understood that the arrangement is suitable for detonating an explosive in response to a triggering effect comprising an electrical input pulse thereto.

Reference is made to the curves of Figs. 2–5, inclusive, for an explanation of the operation of the present invention. In considering the operation of the arrangement of Fig. 1, it will be seen that microphone 11 is adapted to respond to the sound produced by the sound-emitting target and thus to develop a control effect varying in accordance with such sounds, for example an alternating current having a frequency corresponding to the characteristic frequency of the sound emitted by the target and having amplitudes varying in accordance with the sound amplitudes. This current flows in the circuit including battery 12 and load impedance 13 to develop across the latter a signal potential. Furthermore, it will be seen that the characteristic frequency of such sound undergoes a sudden drop when the projectile passes the point in its trajectory closest to the sound-emitting target. This sudden change in frequency is caused by the phenomenon well known as the "Doppler" effect, which is the phenomenon which causes the apparent sudden change of pitch of a locomotive whistle when passing at a high rate of speed.

Due to the fact that the position of the projectile is rapidly varying with respect to the target, the sound received by the microphone 11 correspondingly undergoes rapid variations of amplitude. Consequently, the amplitude of the signal generated across load resistor 13 will also vary and limiter-amplifier 14 is provided for amplifying the signal generated across resistor 13 and for at least partially removing such amplitude variations. The amplitude of the translated signal is limited in one direction in tube 20 by grid-circuit limiting due to reduction of the grid-cathode voltage by the grid-cathode current and is limited in the other direction by anode-circuit limiting due to the anode-current cutoff characteristic of the tube.

The frequency of the constant-amplitude signal output of limiter-amplifier 14 varies, as previously pointed out, with the characteristic frequency of the received sound and thus varies in accordance with the curve of Fig. 2; that is, the frequency is substantially constant at the frequency f_1 until the time t_1 when the projectile is in the immediate vicinity of the point in its trajectory closest to the target. As the projectile passes the target, the frequency drops, due to the "Doppler" effect previously mentioned, thus reducing the characteristic frequency of the sound impressed on the microphone 11 with consequent corresponding reduction of the frequency of the alternating current derived by the microphone 11 from the sound, for example during the time t_1—t_2 it drops to the value f_2 of Fig. 2. The arrangement of the invention is adapted to be responsive to this sudden change in frequency to explode the projectile.

The frequency-response characteristic of the circuit 15 is illustrated in Fig. 3 of the drawing and the constants of the circuit elements are so

proportioned that a decidedly drooping response characteristic is provided over the frequency range f_2—f_1. The frequency-responsive circuit 15 is designed so that the frequency range f_1—f_2 includes all of the range of variation of the characteristic frequencies usually encountered in sound emitted by targets for which the projectile is intended. The effect of translating the constant-amplitude signal output of unit 14 through the frequency-responsive circuit 15 is, therefore, to provide an output signal which varies in amplitude during the time interval when the projectile is passing the target, as indicated by the curve of Fig. 4. That is, the frequency of the signal input to circuit 15 has the f_1 value until the projectile passes fairly close to the target aircraft with the result that the signal output of circuit 15 has a low value of amplitude, as indicated in Fig. 3 by the low value of amplitude for this frequency; however, as the projectile passes the target, the frequency of the signal applied to the circuit 15 rapidly decreases to the value f_2 with the result, as indicated in Fig. 3 by the rapid increase of amplitude between the frequencies f_1 and f_2, that the signal output of the circuit 15 rapidly increases in amplitude during the time t_1—t_2 to a fairly high value. The signal output of the circuit 15 is applied to the detector 16 where the signal is rectified to derive across the resistor 32 a unidirectional potential varying in amplitude with the amplitude of the signal output of circuit 15. The amplitude of the unidirectional signal output derived from detector 16 thus also varies in substantially the manner illustrated in the curve of Fig. 4.

The differentiating device 17 is effective to derive from the unidirectional signal input thereto a pulse voltage having instantaneous amplitude values which are the corresponding differential of the signal of Fig. 4; that is, a voltage having relatively low or substantially zero amplitude until the time t_1 when the voltage amplitude suddenly increases to a high value during the rapid change of amplitude of the unidirectional signal applied to unit 17 and thereafter suddenly decreases to a relatively low or substantially zero value at the time t_2. This voltage pulse is illustrated by the curve of Fig. 5 and is utilized to detonate the projectile.

In summary, therefore, it will be seen that the arrangement of Fig. 1 is one for producing a triggering effect in proximity to a sound-emitting source, as for exploding a projectile in proximity to a sound-emitting target. The arrangement comprises the unit 10 adapted to be mounted in the projectile for generating a periodic electrical control effect, specifically a signal potential, the frequency of which varies in accordance with the frequency of the sound produced by the source or target. The units 14, 15, and 16 comprise means responsive substantially only to the change of frequency, which change is essentially a rapid reduction of frequency, of the above-mentioned control effect, produced as the unit 10 in the projectile and the sound source or target pass one another at their closest point of approach, for producing a second electrical control effect, specifically a unidirectional control signal. The unit 14 comprises an amplifier and amplitude-limiter and the unit 15 comprises a frequency-responsive circuit. The unit 17 comprises a means for differentiating the above-mentioned second control effect to derive a third control effect or triggering effect, specifically a pulse voltage, dependent upon the rate of change of amplitude thereof and,

therefore, dependent on the apparent rate of change of frequency of the received sound signal, while detonator 18 comprises means for utilizing the third control effect to explode the projectile, the detonator 18 being thus indirectly responsive to the second control effect.

From a consideration of the operating characteristics of the system described above, it will be seen that no setting for altitude is needed prior to the firing of the projectile. Furthermore, it will be seen that the detonation of the projectile depends upon a high rate of change of frequency which can only take place during the time when the projectile is passing in close proximity to the target aircraft. In other words, the passing of the projectile through a plane normal to its trajectory and including the aircraft target is effective to produce the sudden pulse voltage of the wave form of Fig. 5, which pulse voltage is utilized for detonation. It is seen, therefore, that within very wide limits the production of this pulse voltage for actuating detonator 18 is not critical with relation to either the speed of operation of the target aircraft's engine, and thus the absolute frequency of the sound, or to the speed of the projectile.

Furthermore, it will be understood that, since the arrangement of the invention need only operate for a few seconds, the various sources of potential required in the circuit can be of very short life, it being understood that the various elements of the circuit must be designed to withstand the shock incident to the firing of the projectile. The tubes utilized can, of course, be very small and, if desired, the tubes may be included within a single envelope. Also, it will be seen that, inasmuch as the detonating circuit is entirely electrical, the arrangement can be very fast-acting, thus causing the projectile to explode in a predetermined relation to the point in its trajectory closest to the target. Inasmuch as this position of detonating is ensured by the arrangement of the invention, it may be preferable to design the projectile so that the principal burst of shrapnel from the projectile is confined within predetermined limits. In this way, a considerable saving of space may be effected in the projectile to compensate for the space which is required for the detonating arrangement of the invention.

Also, it will be understood that the arrangement of the invention is particularly suitable for use in fighter aircraft for the reason that it is unnecessary to perform an adjustment upon the projectile before firing in order to ensure its explosion at the proper range.

It may be found desirable to design the unit 11 so that it is primarily responsive only to relatively low frequencies. In this way, the effect of the high-frequency noise generated by the projectile itself can be minimized. It may be desirable also to include a low-pass filter between the units 10 and 14 for the same purpose. Furthermore, it will be understood that additional stages of amplification can be provided if desired.

While the term "characteristic frequency" of the sound source or target is used in the foregoing specification and in the accompanying claims, it is to be understood that this term is intended to include the predominant frequency or frequencies of the sound which contain the major portion of the sound energy and which enable any given sound to be distinguished by the human ear from another sound. In general, any given sound source emits sound waves having one or more predominant or "characteristic" frequencies together

with a large number of other frequencies of low energy content. The predominant or characteristic frequencies of the sound generally lie relatively closely to each other in the frequency spectrum and enable it to be said that the sound has a characteristic high, medium or low pitch. It is the simultaneous change in the frequency spectrum of these predominant or characteristic frequencies of a sound resulting from the "Doppler" effect that enables one to say that a locomotive whistle, for example, appears to change pitch as the locomotive passes an observer. In the arrangement described, the frequency-response range f_1 to f_2 of unit 15 is materially broader than the range of predominant or characteristic frequencies comprising the sound received by the microphone 11 of unit 10 and thus may include such frequencies both before and after any shift thereof in the frequency spectrum such as caused by the "Doppler" effect.

While there has been described what is at present considered to be the preferred embodiment of this invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and it is, therefore, aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. An arrangement for exploding a projectile in proximity to a sound-emitting target comprising, means adapted to be mounted in the projectile for generating a periodic control effect the frequency of which varies in accordance with the characteristic frequency of the sound produced by said target, means responsive primarily to the change of frequency of said control effect produced as said projectile passes the point in its trajectory closest to said target for producing a second control effect, and means for utilizing said second control effect to explode said projectile.

2. An arrangement for exploding a projectile in proximity to an energy-emitting target comprising, means adapted to be mounted in the projectile for generating a periodic electrical control effect the frequency of which varies in accordance with the characteristic frequency of the energy produced by said target, means comprising an amplifier and amplitude-limiter for translating said generated control effect, means responsive primarily to the change of frequency of said translated control effect produced as said projectile passes the point in its trajectory closest to said target for producing a second control effect, and means for utilizing said second control effect for exploding said projectile.

3. An arrangement for exploding a projectile in proximity to an energy-emitting target comprising, means adapted to be mounted in the projectile for generating a periodic control effect the frequency of which varies in accordance with the characteristic frequency of the energy produced by said target, means responsive primarily to the rate of change of frequency of said control effect produced as said projectile passes the point in its trajectory closest to said target for producing a second control effect, and means for utilizing said second control effect to explode said projectile.

4. An arrangement for exploding a projectile in proximity to an energy-emitting target comprising, means adapted to be mounted in the projectile for generating a periodic control effect the frequency of which varies in accordance with

the characteristic frequency of the energy emitted by said target, an amplitude-limiter for deriving from said control effect a periodic wave of substantially constant amplitude, a primarily frequency-responsive circuit for deriving from said periodic wave a second periodic wave having an amplitude varying in accordance with the frequency of the energy emitted by said target, means for rectifying said second periodic wave, means for differentiating the output of said rectifying means to derive a pulse, and means for utilizing said pulse to explode said projectile.

5. An arrangement for producing a triggering effect in proximity to a sound-emitting source comprising, means for generating a periodic control effect the frequency of which varies in accordance with the characteristic frequency of the sound emitted by said source, said means and said source having relative movement toward one another, means responsive primarily to the change of frequency of said control effect produced as said means and said source pass one another at their closest point of approach for producing a second control effect, and means for utilizing said second control effect to produce said triggering effect.

6. An arrangement for producing a triggering effect in proximity to an object adapted to radiate radiant-wave energy comprising, means for generating a periodic control effect the frequency of which varies in accordance with the characteristic frequency of the energy radiated by said object, said means and said object having relative movement toward one another, means responsive primarily to the change of frequency of said control effect produced as said means and said object pass one another at their closest point of approach for producing a second control effect, and means for utilizing said second control effect to produce said triggering effect.

7. An arrangement for producing a triggering effect in proximity to an object adapted to radiate radiant-wave energy comprising, means responsive to received energy radiated by said object for generating a periodic electrical wave the frequency of which varies in accordance with the characteristic frequency of said received energy, said means and said object having relative movement toward one another, means responsive primarily to the change of frequency of said periodic wave produced as said means and said object pass one another at their closest point of approach for producing a control effect, and means for utilizing said control effect to produce said triggering effect.

8. An arrangement for producing a triggering effect in proximity to an object adapted to radiate radiant-wave energy comprising, means responsive to received energy radiated by said object for generating a periodic control effect the frequency of which varies in accordance with the characteristic frequency of said received energy, said means and said object having relative movement toward one another, means responsive primarily to the change of frequency of said control effect produced as said means and said object pass one another at their closest point of approach for producing an electrical second control effect, and means for utilizing said electrical control effect to produce said triggering effect.

9. An arrangement for producing a triggering effect in proximity to an object adapted to radiate radiant-wave energy comprising, means responsive to received energy radiated by said object for generating a periodic control effect the frequency of which varies in accordance with the characteristic frequency of said received energy, said means and said object having relative movement toward one another, means responsive substantially only to the change of frequency of said control effect produced as said means and said object pass one another at their closest point of approach for producing a second control effect, and means for utilizing said second control effect to produce said triggering effect.

10. An arrangement for producing a triggering effect in proximity to an object adapted to radiate radiant-wave energy comprising, means responsive to received energy radiated by said object for generating a periodic control effect the frequency of which varies in accordance with the characteristic frequency of said received energy, said means and said object having relative movement toward one another, means responsive primarily to the change of frequency of said control effect produced as said means and said object pass one another at their closest point of approach for producing a second control effect, means for differentiating said second control effect to derive a third control effect, and means for utilizing said third control effect to produce said triggering effect.

11. In a device for detecting passage of an object producing sound of characteristic pitch, the combination of means associated with said device for receiving such sound and translating the sound energy into electrical energy of a frequency substantially proportional to such pitch as increased by the effect of relative approach velocity between said object and said means, output means, and means associated with said device for actuating said output means, said actuating means being responsive only to a reduction of frequency of such electrical energy corresponding to the reduction in received sound pitch occurring upon close passage of either said object or said receiving means by the other.

12. A control device responsive to the reduction of received sound frequency resulting from close relative passage at substantial speed between the device and a source of sound of characteristic frequency, including a microphone, an amplifier having its input connected to the microphone, a frequency-selective network connected to the output of said amplifier to provide output change from the network responsive to rapid reduction in frequency of the amplifier output corresponding to such sound frequency reduction, and a work device operating responsive to such network output change.

HARRY C. PAGE.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,137,222	Leon	Apr. 27, 1915
1,538,316	Duffie	May 19, 1925
2,194,559	Koch	Mar. 26, 1940

FOREIGN PATENTS

Number	Country	Date
376,987	Italy	Dec. 4, 1939