United States Patent [19]

Kalmus

[11] **3,821,737**

[45] **June 28, 1974**

[54] **RATIO FUZE**

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[22] Filed: **Feb. 17, 1955**

[21] Appl. No.: **489,005**

[52] **U.S. Cl.** ..... **343/7 PF,** 102/70.2 P, 343/14

[51] **Int. Cl.** **G01s 9/24**

[58] **Field of Search** ..... 343/7, 14, 17.2, 17.5, 343/7 PF, 7 ED; 102/70.2 P

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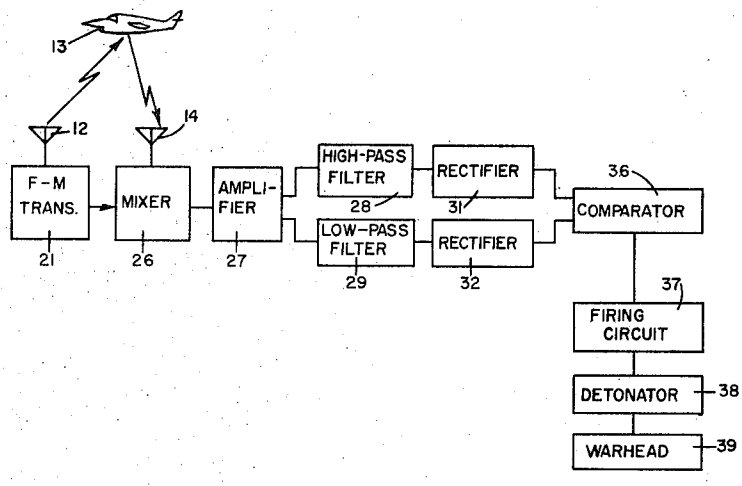
Attorney, Agent, or Firm—Edward J. Kelly; Herbert Berl; Saul Elbaum

EXEMPLARY CLAIM

6. In an electronic ordnance fuze of the class wherein the signal returned from a target is mixed with a portion of the transmitted signal to obtain a mixer output signal the energy of which is peaked at a frequency substantially proportional to fuze-to-target distance, the improvement comprising: first and second networks having different but overlapping pass bands, the inputs of both of said networks being connected to the output of said mixer; and a firing circuit responsive to the attainment of a predetermined ratio between the respective outputs of said networks.

8 Claims, 9 Drawing Figures



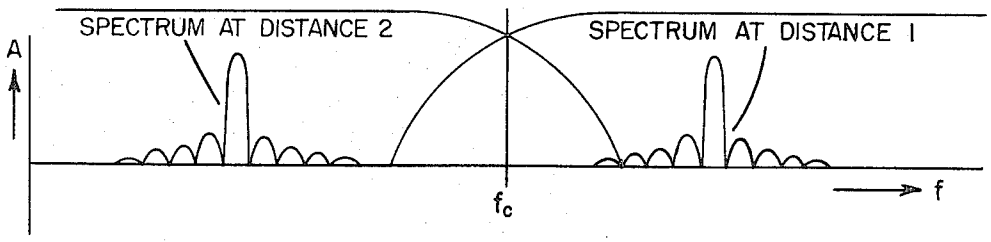


Fig. 6.

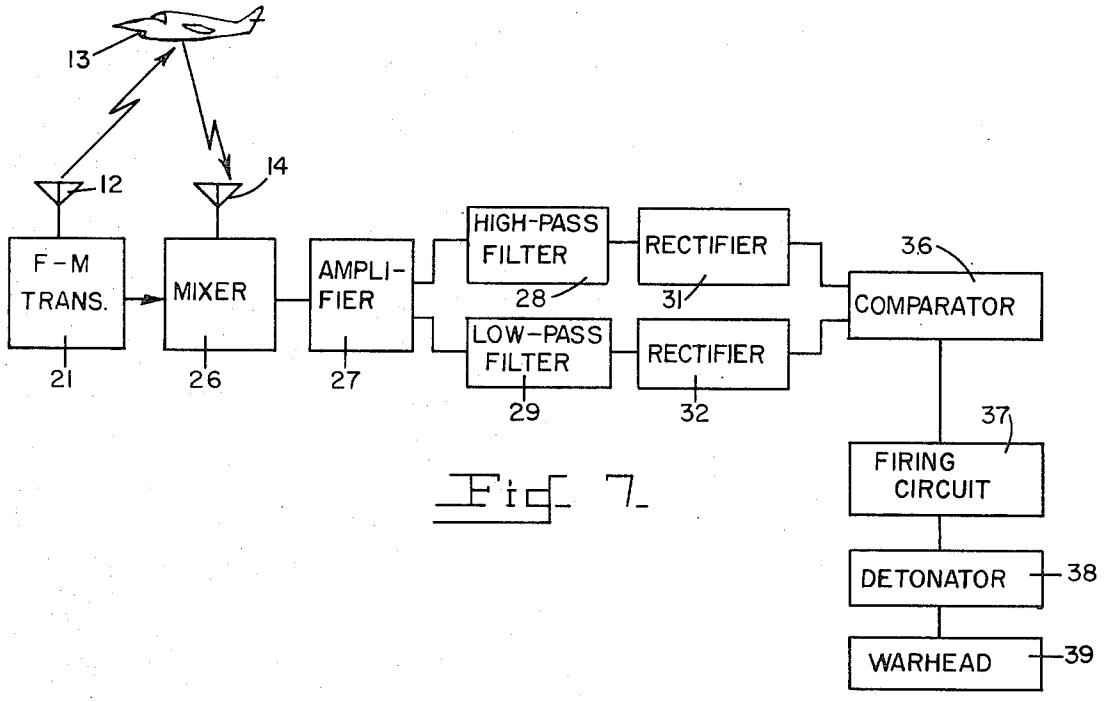


Fig. 7.

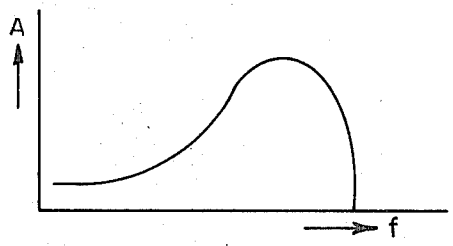


Fig. 9.

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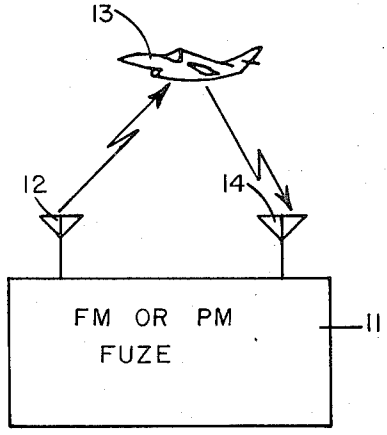

Fig. 1.

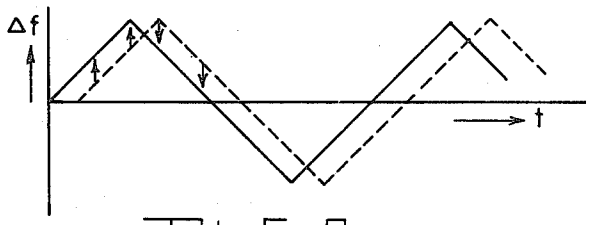

Fig. 2.

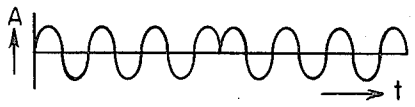

Fig. 3.

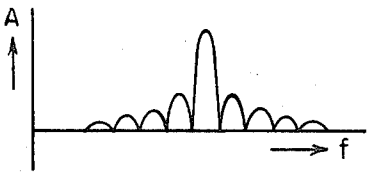

Fig. 4.

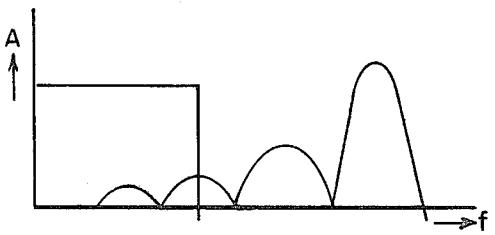

Fig. 5.

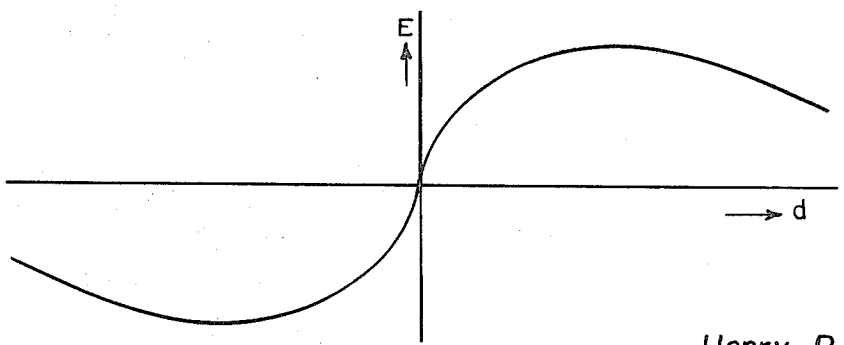

Fig. 8.

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RATIO FUZE

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

This invention relates to ordnance fuzes of the radio proximity type, and more particularly to frequency modulated or phase modulated fuzes of the so-called "altimeter" type. In a preferred embodiment of my invention I provide a "spectrum ratio" fuze in which a beat note, obtained by mixing the signal returned from a target with a portion of the emitted signal, is fed to two networks having different but overlapping pass bands. The responses of the two networks are made equal only at a frequency corresponding to the distance at which it is desired that the fuze detonate. The outputs of the two networks are fed to a utilization circuit that causes fuze detonation when the two outputs become equal. Fuzes in accordance with the invention have several important advantages. A number of variations are possible.

In altimeter-type fuzes in general, a frequency- or phase modulated radiofrequency signal is radiated from the fuze. As the fuze approaches a target, a portion of the transmitted signal is reflected by the target and returned to the fuze. This returned signal is mixed with a portion of the transmitted signal to obtain a difference-frequency signal or beat note. The principal components of this beat note are of relatively high frequency when the fuze-to-target distance is great but approach zero frequency as the fuze approaches the target.

In prior-art altimeter-type fuzes it has been usual to measure target distance by using electronic counter circuits that determine the number of beat-note cycles in a short time interval. The use of counter circuits for this measurement has several disadvantages. For one thing, although the use of high frequencies is desirable to minimize effects of microphonics, the counting rate of known counters has been limited to about 200 kilocycles. Furthermore, the use of counter circuits also necessitates accurate limiting of the beat-note amplitude, further complicating circuit design.

An object of my invention is to provide an altimeter-type electronic ordnance fuze not requiring counter circuits.

Another object is to provide a fuze having high immunity to noise and microphonics.

Still another object is to provide an altimeter fuze that will fire only at the desired predetermined fixed distance from the target, and that is immune to the premature firing that may occur in known altimeter fuzes when the mixer output signal has broad spectral distribution and high amplitude.

A further object is to provide an altimeter fuze not requiring the accurate amplitude limiting required in such fuzes of the prior art.

A still further object is to provide a fuze that will recognize the condition of "no target."

Other objects, aspects, uses, and advantages of the invention will become apparent from the following description and from the accompanying drawing in which

FIG. **1** is a diagram illustrative of the transmission of a phase-modulated or frequency-modulated radiofrequency signal from an ordnance fuze to a target, and of the reflection of a portion of the signal back to the fuze.

FIG. **2** is a plot of the instantaneous frequency deviations, as functions of time, of the emitter and returned waves in an f-m altimeter fuze system using triangular modulation.

FIG. **3** is a plot of the waveform of the beat note produced, at a particular fuze-to-target distance, by heterodyning the returned signal against a portion of the emitted signal in an f-m altimeter fuze using triangular modulation.

FIG. **4** is a plot of the Fourier equivalent spectrum corresponding to the waveform of FIG. **3.**

FIG. **5** is a plot of a portion of a Fourier spectrum, similar to that of FIG. **4,** superimposed on a plot of the response of an ideal low-pass filter.

FIG. **6** is a plot of the Fourier equivalent spectra corresponding to two values of fuze-to-target distance, superimposed on plots of the response to high-pass and low-pass filters having overlapping pass bands.

FIG. **7** is a block diagram of a preferred embodiment of a fuze in accordance with my invention.

FIG. **8** is a curve showing the variations with distance of the combined rectified output voltages of the high- and low-pass filters in an embodiment of my invention.

FIG. **9** is a curve showing the envelope of the Fourier equivalent spectrum of the beat-note signal produced in an altimeter-type fuze employing sinusoidal modulation.

In FIG. **1** a frequency-modulated or phase-modulated fuze **11** radiates a signal from a transmitting antenna **12.** A portion of the radiated signal strikes a target **13** and is returned to a receiving antenna **14.** If the modulation is of triangular waveform, the relation between the frequencies of the emitted and returned signals will be that shown in FIG. **2.** The time interval by which the returned signal (dashed line) lags the emitted signal (solid line), and thus the instantaneous frequency difference between the two signals, is proportional to the fuze-to-target distance.

If the returned and emitted signals (FIG. **2**) are mixed, a difference-frequency beat note is obtained having a waveform which may be of the type shown in FIG. **3.** FIG. **3** shows a single full beat-note cycle, the period of a full beat-note cycle being equal (ignoring the effects of motion) to the period of the modulating signal. FIG. **4** illustrates the spectral distribution that the energy of the beat note may take.

The relation between the fuze-to-target distance and the frequency at which the beat-note spectrum peaks has been recognized in the prior art, and the use of a sharp cut-off or sharply-peaked filter to trigger the fuze has been suggested. Unfortunately, the prior art has failed to recognize what my analysis now makes clear — that with such a filter the fuze may be triggered falsely at a distance much greater than the intended distance. This is because, as will be understood on consideration of FIGS. **4** and **5,** the spectrum may under some conditions contain substantial energy at frequencies far below the peak of the spectrum.

By my invention I am able to make the distance at which an altimeter-type fuze triggers practically independent of the amplitude and spectral distribution of the beat-note energy. The way I accomplish this will be understood from FIG. **6.**

In FIG. 6, a low-pass filter and a high-pass filter are designed to have pass bands that overlap, the response of the two filters being equal at a cross-over frequency f_c corresponding to the critical fuze-to-target distance at which it is desired that the fuze be triggered.

When the fuze is at a great distance from the target — for example, at distance 1 — practically all of the beat-note spectrum is within the pass band of the high-pass filter, and practically none within the pass band of the low-pass filter. When the fuze is much closer to the target — for example, at distance 2 — the situation is reversed. It will be understood that, at a certain critical intermediate distance corresponding to frequency f_c, the spectrum is such that equal amounts of energy are passed by the high-pass and low-pass filters. The point at which the output of the low-pass filter becomes equal to that of the high-pass filter can readily be sensed and utilized to trigger the fuze.

FIG. 7 is a block diagram of an embodiment of a complete fuze system in accordance with my invention. A frequency-modulated transmitter **21** with a transmitting antenna **12** radiates a signal part of which is intercepted and reflected by a target **13** and returned to a receiving antenna **14.** The received signal from antenna **14** is mixed with a portion of the signal from transmitter **21** in a mixer **26.** The difference-frequency output of mixer **26** is amplified by an amplifier **27.** The output of amplifier **27** is connected to a high-pass filter **28** and to a low-pass filter **29.** The outputs of filters **28** and **29** are connected to rectifiers **31** and **32** respectively. Filters **28** and **29** have overlapping pass bands. At a certain critical fuze-to-target distance the rectified outputs of filters **28** and **29** become equal. The point at which the outputs become equal is sensed by comparator **36,** the output of which triggers a firing circuit **37** that fires a detonator **38** causing detonation of a warhead **39.** By suitable selection of the crossover frequency of filters **28** and **29,** the fuze can be designed to function at any desired predetermined fuze-to-target distance. Also, the effects of noise and microphonics can be minimized by choosing this cross-over frequency to be at least 50,000 cycles so that operation will be out of the microphonic region.

It will be understood that the equality of the outputs of filters **28** and **29** can be sensed in any of various well known ways. For example, it may be convenient to connect their rectified output voltages in opposition, so that the combined rectified output voltage will pass through zero at the desired detonation point. FIG. **8** shows the variation in net output voltage with distance in such an arrangement. Circuits that can utilize a zero voltage for detonation are well known, as are also circuits that are triggered by a change of polarity.

The invention can readily provide a "no-target" indication. If the high-pass filter **28** is designed to pass a much wider range of frequencies than low-pass filter **29,** any noise voltage — since noise by its nature has a broad spectral distribution — will produce a larger output from high-pass filter **28** and rectifier **31** than from low-pass filter **29** and rectifier **32.** The presence of this larger high-pass output is thus an indication that (1) the fuze is operative but that (2) no target is within range.

Although I have described an embodiment of the invention in which a broad-band amplifier **27** is used in conjunction with high-and low-pass filters **28** and **29,** it will be understood that other arrangements can be used. For example, two peaked amplifiers or filters can be used; one amplifier or filter is tuned to pass frequencies above, and the other to pass frequencies below, the frequency corresponding to the detonating position. Tuned discriminator transformers similar to those used in conventional frequency-modulation receivers will serve this purpose.

Although I have spoken of using the equality of the outputs of two filters to cause detonation, it will be understood that a ratio-sensing arrangement can be used, in which the ratio of the output of the high-pass or high-peaked filter and the output of the low-pass or low-peaked filter provides a measure of the amount by which the actual position of the target differs from the signal-equality position. Adjustably ratio-responsive circuits, which are known, can then be utilized to provide a simple adjustment of the distance at which the fuze will fire.

Although my analysis has been based on triangular modulation, it is often more convenient and economical to use sinusoidal modulation. It will be understood that my invention is also applicable and advantageous in fuzes employing sinusoidal or other modulation. With a variety of modulation waveforms, my invention offers altimetertype fuzes in which the fuze-to-target distance at which detonation is — because of the balanced filter arrangement — practically unaffected by the fact that the beat-note energy is generally not limited to a single frequency. Furthermore, because my fuzes are responsive to spectrum ratio rather than to amplitude, the need for limiting circuits is eliminated. Because the need for electronic counters is eliminated, my fuzes can utilize mixer output frequencies above those to which counters will respond; microphonics problems can be practically eliminated by using these higher frequencies. And when an extended-range high-pass filter is used, my fuzes will give a positive indication of the absence of a target.

It may be noted that, other things being equal, triangular modulation produces a more sharply peaked beat-note spectrum than sinusoidal modulation. FIG. **9** shows the general form of the spectral distribution of beat-note energy when sinusoidal modulation is used.

It will be apparent that the embodiments shown are only exemplary and that various modifications can be made in construction and arrangement within the scope of the invention as defined in the appended claims.

I claim:

1. An electronic ordnance fuze comprising: a radio transmitter having a center frequency f_1; means for frequency modulating said transmitter with a periodic signal having a repetition rate f_2; means for radiating frequency-modulated energy from said transmitter; means for receiving a returned signal comprising a portion of said energy reflected from a target; mixer means for heterodyning said returned signal against a local frequency-modulated signal taken directly from said transmitter, the predominant frequencies in the output of said mixer being substantially proportional to fuze-to-target distance; first and second networks having different but overlapping pass bands, the inputs of both of said networks being connected to the output of said mixer, the output amplitude of said first network being adapted to decrease and the output amplitude of said second network being adapted to increase as the fuze-

to-target distance decreases toward the value at which the fuze is designed to detonate; and a firing circuit responsive to the attainment of a predetermined ratio between the respective outputs of said first and second networks.

2. The invention according to claim **1,** the cross-over frequency at which the outputs of said first and second networks become equal being at least 50,000 cycles, the effects of noise and microphonics thus being minimized.

3. The invention according to claim **1,** the pass band of said first network being broader than the pass band of said second network, so that noise and microphonics will give a "no-target" indication at the output of said network.

4. The invention according to claim **1,** said firing circuit being responsive to the attainment of equality between the outputs of said first and second networks.

5. The invention according to claim **1,** said firing circuit being responsive to a change in polarity of the combined outputs of said first and second networks.

6. In an electronic ordnance fuze of the class wherein the signal returned from a target is mixed with a portion of the transmitted signal to obtain a mixer output signal the energy of which is peaked at a frequency substantially proportional to fuze-to-target distance, the improvement comprising: first and second networks having different but overlapping pass bands, the inputs of both of said networks being connected to the output of said mixer; and a firing circuit responsive to the attainment of a predetermined ratio between the respective outputs of said networks.

7. The invention according to claim **6,** said ratio being 1-to-1.

8. The invention according to claim **7,** said networks being resonant circuits peaked at different frequencies.

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