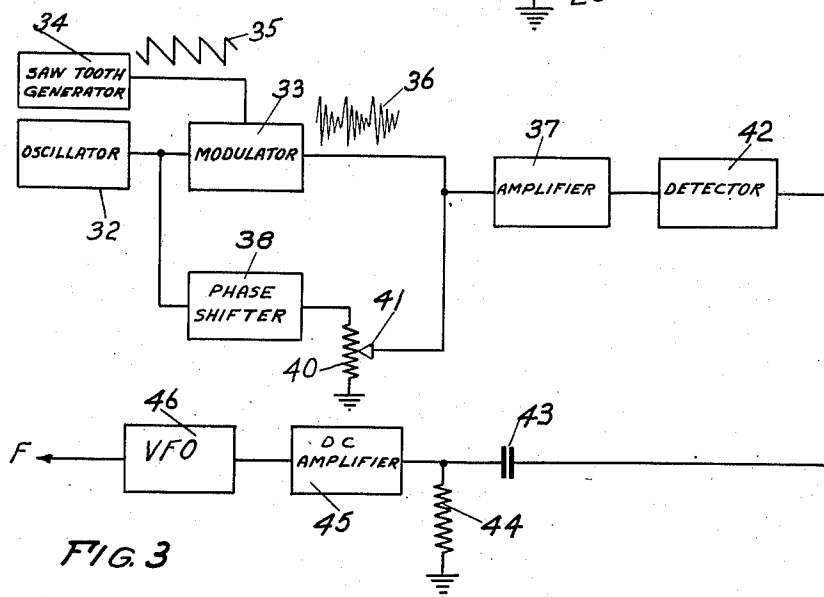
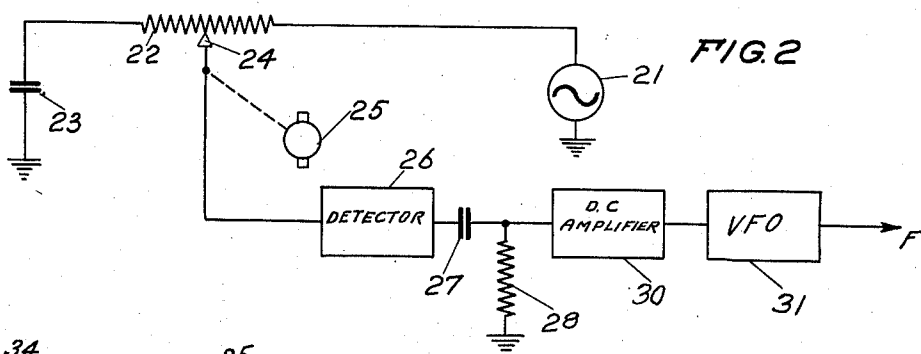
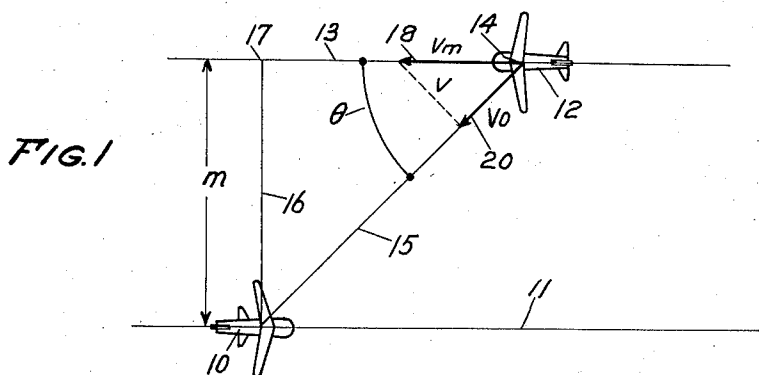


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DOPPLER MISS SIMULATOR

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This invention relates to an apparatus for simulating by an electrical analogue quantity the distance of a missile from a target at the closest point of approach in terms of the frequency of oscillation of an electrical current.

In the design of guided missiles directed to their target by radar, the problem arises of detonating the charge of such a missile at the proper moment. This should be done when the missile is closest to the target. The rate of approach of the missile to the target will pass through zero at the point of closest approach. This would indicate the desirability of detonating the charge under control of the Doppler frequency generated by a radar system operated on this principle. The point at which the Doppler frequency passes through zero could be used to trigger the detonation equipment. This direct system was found to be impractical because the antenna of the radar system could not track the target closely enough during this period and the change in the Doppler frequency could be as great as a million cycles per second. This would be too great for a practical computer set to follow.

It was thus necessary to calculate the time to the point of closest miss (T) at some earlier time and to use this value for setting a timing mechanism which will operate the detonator at $T=0$. In the course of testing in the laboratory equipment designed for such a system, it is necessary to simulate the Doppler effect that would be obtained from a Doppler radar in a missile traveling toward a target at a certain relative velocity along a certain course. By the present invention, this is accomplished by representing the distance between the missile and the target by a frequency varying from some maximum value to zero as determined by the vector sum of two voltages in quadrature phase relationship.

Other and further advantages of this invention will be apparent as the description thereof progresses, reference being had to the accompanying drawings, wherein:

Fig. 1 is a diagrammatic illustration of the problem to be simulated by the apparatus of the invention;

Fig. 2 is a schematic diagram of one embodiment of the invention; and

Fig. 3 is a schematic diagram of another embodiment of the invention.

In Fig. 1 the numeral 10 represents the target, in this case an airplane flying a course designated by the line 11. A missile or vehicle 12 is guided along a course 13 and is shown at a point 14. It will be seen that the shortest distance between the missile 12 and the target 10 will be measured along the line 15 at an angle θ to the missile course 13, which line 15 becomes the perpendicular 16 of length m , the minimum distance between the missile and target when the missile reaches the point 17.

The missile is assumed to have a velocity V_m along its course as represented by the arrow 18. This velocity is taken as the algebraic sum of the velocity of the missile and the component of the velocity of the target projected on the course of the missile. The missile is also approaching the target at a velocity V_0 represented by the

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arrow 20. The velocity V_0 becomes zero when the missile reaches the point 17, its nearest point to the target 10. The distance it is desired to represent by a frequency is m measured along the line 16.

By the present invention, the problem shown in Fig. 1 may be represented by the electromechanical analogue of Fig. 2 or the electronic analogue of Fig. 3. The embodiment of Fig. 2 more clearly demonstrates the principle of the invention, but the electronic analogue of Fig. 3 is preferable for actual use.

In the embodiment shown in Fig. 2, a source of high frequency energy 21 is applied across a potentiometer 22 and a capacitor 23 connected in series.

It will be apparent that taking the component of the voltage due to the drop across the potentiometer 22, or any part of it, as a reference, the component of the voltage due to the drop across the capacitor 23 will be 90 degrees out of phase. The vector sum of these voltages appears between the arm 24 of the potentiometer 22 and ground. The total resistance of the potentiometer 22 is proportional to the maximum range of the radar used in the proposed control system. The voltage across the capacitor 23 is proportional to the miss distance m . The resistive component of the voltage on the arm 24 is proportional to the distance along the lines 13 from the missile 12 to the point 17. The distance along the line 15 is equal to the square root of the sum of the squares of the distance m and the distance from the missile 12 to the point 17. In voltage this represents the vector sum of the resistive and capacitive components of the voltage at the arm of the potentiometer 22.

If the arm 24 is swept along the potentiometer 22 by the motor 25 at a rate proportional to the velocity V_m of the missile along its course, the in-phase voltage at the arm 24 also varies directly at a rate proportional to the velocity V_m . The vector sum of the out-of-phase and in-phase voltages at this point (the square root of the sum of the squares of the two voltages) varies at a rate proportional to the velocity V_0 , the rate of change of the distance between the missile 12 and the target 10.

This voltage is rectified in a detector 26 of standard design. The output of the detector is differentiated in the circuit comprising a capacitor 27 with a resistor 28 shunted across it. The output of this circuit is proportional to the velocity V_0 .

This voltage is then amplified in an amplifier 30 of conventional design. The output of the amplifier is used to vary the frequency of an oscillator 31.

In a Doppler system, zero frequency represents zero speed, and frequency is a function of the relative speed of the radar and the target. In this system, the voltage at the output of the amplifier 30 is proportional to this speed. This voltage varies from a maximum value to zero. This variation in voltage is applied to the oscillator 31 to produce a variation in the frequency of its output from a maximum value for maximum voltage input and speed to zero for zero voltage input and zero speed. Preferably the frequency produced should be directly proportional to the voltage applied.

This can be done in several known ways. The voltage may be applied to the control grid of a reactance tube connected across the tank circuit of the oscillator, or it may be applied to a servomotor to produce a change in the adjustment of a tuning element of the oscillator to produce the desired frequency of the output of the oscillator.

This varying frequency output may also be obtained by the use of the electronic system shown in Fig. 3. In this system, an oscillator 32, which may be of any conventional design, produces an oscillatory current of any convenient frequency. Part of this current is applied to a device, such as a modulator 33, where it is cyclically

varied in amplitude from some large value to zero. This may be done by applying the output of a saw-tooth voltage generator 34 having the wave form 35 to the modulator 33 to give the output of the oscillator 32 the modulated form 36. The wave form 35 is made to vary at a rate proportional to the velocity V_m of the missile. Thus the envelope of this modulated output 36 is made to vary at a rate proportional to the velocity V_m of the missile.

This modulated output is applied to an amplifier 37 of conventional design where it is mixed with the remaining portion of the oscillator output which has passed through a 90 degree phase shifter 38, which may be of any conventional design. This phase shifter 38 replaces the capacitor 23 of the circuit shown in Fig. 2.

The output of the phase shifter is then applied to a potentiometer 40 where a portion proportional to the desired miss distance is selected by the arm 41 and applied to the input of the amplifier 37. There the two signals, that from modulator 33 and that from the phase shifter 38, in quadrature, are mixed and the resulting signal is subsequently rectified in the detector 42, which may be of a design similar to that of the detector 26 of Fig. 2.

The rectified signal is applied to the differentiating circuit comprising a capacitor 43 and a resistor 44 similar to the circuit in Fig. 2 comprising capacitor 27 and resistor 28.

This differentiated signal is then applied to the input of a direct current amplifier 45, the output of which is used to control the frequency of the output of a variable frequency oscillator 46 to produce a frequency F proportional to the miss distance m of Fig. 1.

The output of the amplifier 45 may be utilized for this purpose in much the same manner as the output of the amplifier 30 of the circuit shown in Fig. 2 is used to control the oscillator 31 of that circuit. The modulator 33 could, of course, be a motor driven potentiometer.

In operation, the potentiometer arm 41 is adjusted to select the desired miss distance, and the repetition rate and slope of the saw-tooth wave 35 produced by the generator 34 is adjusted to select the speed of the missile desired to be represented. The result will be a frequency of the output of the oscillator 46 proportional or equal to the Doppler frequency to be expected from a radar system used in a guided missile under the selected conditions. In the circuit of Fig. 2, the capacitor 23 could be made variable to represent any of several desired miss distances, while the speed of the motor 25 could be varied to represent the desired velocity V_m of the missile 12. The result of either circuit is a laboratory instrument that is capable of producing a frequency equal to that to be expected from a Doppler radar operating in a guided missile under a range of conditions. Such an apparatus permits the laboratory study of the operation of guided missile control devices depending upon a Doppler frequency for their operation. The signal produced by such an equipment varies directly as the factors that would determine it in the completed control system of a guided missile. Its use avoids the expense and inconvenience of conducting the tests with an actual guided missile.

This invention is not limited to the particular details of construction, materials and processes described, as many equivalents will suggest themselves to those skilled in the art. It is accordingly desired that the appended claims be given a broad interpretation commensurate with the scope of the invention within the art.

What is claimed is:

1. In an apparatus for producing oscillatory electrical energy at a frequency proportional to the relative velocity between an object and a distance measuring device; the combination of a source of oscillatory electrical energy, with means to control the frequency of said source in accordance with the derivative of the amplitude of a varying unidirectional voltage proportional to the vector sum of two alternating current voltages in phase quadrature

relationship, a first said voltage proportional to the projection of the miss distance on the course of the missile and a second voltage proportional to the distance between the sources of the missile and the target, means for continuously varying the amplitude of the first of said voltages in a linear manner and means to shift the phase of the second of said voltages 90 degrees with respect to the first, said continuously varying means comprising a motor driven potentiometer and said phase shifting means comprising a capacitor.

2. Apparatus for producing oscillatory electrical energy of a frequency proportional to the relative velocity between an object and a distance measuring device, comprising a first source of oscillatory electrical energy, a second source of oscillatory electrical energy, means to select a portion of the output of said first source proportional to the miss distance, means to vary a second portion of the output of said first source in amplitude with relation to time in a linear manner at a repetition rate proportional to the velocity of the missile desired to be represented, means to combine the two portions of the output of the first source as modified, means to rectify the combined output, means to differentiate the combined output, and means to utilize the resulting varying unidirectional voltage to control the frequency of the output of the second source so that the frequency of this output is proportional to the relative velocity between the object and the distance measuring device.

3. Apparatus for producing oscillatory electrical energy of a frequency proportional to the relative velocity between an object and a distance measuring device, comprising a first source of oscillatory electrical energy, a second source of oscillatory electrical energy, means to select a portion of the output of said first source proportional to the miss distance, means to shift this portion of the output in phase by ninety degrees, means to vary a second portion of the output of said first source in amplitude with relation to time in a linear manner at a repetition rate proportional to the velocity of the missile desired to be represented, means to combine the two portions of the output of the first source as modified, means to rectify the combined output, means to differentiate the combined output, and means to utilize the resulting varying unidirectional voltage to control the frequency of the output of the second source so that the frequency of this output is proportional to the relative velocity between the object and the distance measuring device.

4. Apparatus for producing oscillatory electrical energy of a frequency proportional to the relative velocity between an object and a distance measuring device, comprising a first source of oscillatory electrical energy, a second source of oscillatory electrical energy, means to select a portion of the output of said first source proportional to the miss distance, means to vary a second portion of the output of said first source in amplitude with relation to time in a linear manner at a repetition rate proportional to the velocity of the missile desired to be represented comprising a modulator and associated sawtooth voltage generator, means to combine the two portions of the output of the first source as modified, means to rectify the combined output, means to differentiate the combined output, and means to utilize the resulting varying unidirectional voltage to control the frequency of the output of the second source so that the frequency of this output is proportional to the relative velocity between the object and the distance measuring device.

5. Apparatus for producing oscillatory electrical energy of a frequency proportional to the relative velocity between an object and a distance measuring device, comprising a first source of oscillatory electrical energy, a second source of oscillatory electrical energy, means to select a portion of the output of said first source proportional to the miss distance, means to vary a second por-

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tion of the output of said first source in amplitude with relation to time in a linear manner at a repetition rate proportional to the velocity of the missile desired to be represented, means to combine the two portions of the output of the first source as modified in series, means to rectify the combined output, means to differentiate the combined output, and means to utilize the resulting varying unidirectional voltage to control the frequency of the output of the second source so that the frequency of this output is proportional to the relative velocity between the object and the distance measuring device.

6. Apparatus for producing oscillatory electrical energy of a frequency proportional to the relative velocity between an object and a distance measuring device, comprising a first source of oscillatory electrical energy, a second source of oscillatory electrical energy, means to select a portion of the output of said first source proportional to the miss distance, means to vary a second portion of the output of said first source in amplitude with relation to time in a linear manner at a repetition rate proportional to the velocity of the missile desired to be represented, means to combine the two portions of the output of the first source as modified in parallel, means to rectify the combined output, means to differentiate the combined output, and means to utilize the resulting varying unidirectional voltage to control the frequency of the output of the second source so that the frequency of this output is proportional to the relative velocity between the object and the distance measuring device.

7. Apparatus for producing oscillatory electrical energy of a frequency proportional to the relative velocity between an object and a distance measuring device, comprising a first source of oscillatory electrical energy, a second source of oscillatory electrical energy, means to select a portion of the output of said first source proportional to the miss distance, means to shift this portion of the output in phase by ninety degrees, means to vary a second portion of the output of said first source in amplitude with relation to time in a linear manner at a repetition rate proportional to the velocity of the missile desired to be represented comprising a modulator and associated sawtooth voltage generator, means to combine the two portions of the output of the first source as modified, means to rectify the combined output, means to differentiate the combined output, and means to utilize the resulting varying unidirectional voltage to control the frequency of the output of the second source so that the frequency of this output is proportional to the relative velocity between the object and the distance measuring device.

8. Apparatus for producing oscillatory electrical energy of a frequency proportional to the relative velocity between an object and a distance measuring device, comprising a first source of oscillatory electrical energy, a second source of oscillatory electrical energy, means to select a portion of the output of said first source proportional to the miss distance, means to shift this portion of the output in phase by ninety degrees, means to vary a second portion of the output of said first source in amplitude with relation to time in a linear manner at a repetition rate proportional to the velocity of the missile desired to be represented, means to combine the two portions of the output of the first source as modified in series, means to rectify the combined output, means to differentiate the combined output, and means to utilize the resulting varying unidirectional voltage to control the frequency of the output of the second source so that the frequency of this output is proportional to the relative velocity between the object and the distance measuring device.

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9. Apparatus for producing oscillatory electrical energy of a frequency proportional to the relative velocity between an object and a distance measuring device, comprising a first source of oscillatory electrical energy, a second source of oscillatory electrical energy, means to select a portion of the output of said first source proportional to the miss distance, means to shift this portion of the output in phase by ninety degrees, means to vary a second portion of the output of said first source in amplitude with relation to time in a linear manner at a repetition rate proportional to the velocity of the missile desired to be represented, means to combine the two portions of the output of the first source as modified in parallel, means to rectify the combined output, means to differentiate the combined output, and means to utilize the resulting varying unidirectional voltage to control the frequency of the output of the second source so that the frequency of this output is proportional to the relative velocity between the object and the distance measuring device.

10. Apparatus for producing oscillatory electrical energy of a frequency proportional to the relative velocity between an object and a distance measuring device, comprising a first source of oscillatory electrical energy, a second source of oscillatory electrical energy, means to select a portion of the output of said first source proportional to the miss distance, means to shift this portion of the output in phase by ninety degrees, means to vary a second portion of the output of said first source in amplitude with relation to time in a linear manner at a repetition rate proportional to the velocity of the missile desired to be represented comprising a modulator and associated sawtooth voltage generator, means to combine the two portions of the output of the first source as modified in series, means to rectify the combined output, means to differentiate the combined output, and means to utilize the resulting varying unidirectional voltage to control the frequency of the output of the second source so that the frequency of this output is proportional to the relative velocity between the object and the distance measuring device.

11. Apparatus for producing oscillatory electrical energy of a frequency proportional to the relative velocity between an object and a distance measuring device, comprising a first source of oscillatory electrical energy, a second source of oscillatory electrical energy, means to select a portion of the output of said first source proportional to the miss distance, means to shift this portion of the output in phase by ninety degrees, means to vary a second portion of the output of said first source in amplitude with relation to time in a linear manner at a repetition rate proportional to the velocity of the missile desired to be represented comprising a modulator and associated sawtooth voltage generator, means to combine the two portions of the output of the first source as modified in parallel, means to rectify the combined output, means to differentiate the combined output, and means to utilize the resulting varying unidirectional voltage to control the frequency of the output of the second source so that the frequency of this output is proportional to the relative velocity between the object and the distance measuring device.

References Cited in the file of this patent

UNITED STATES PATENTS

2,170,487	Soler	Aug. 22, 1939
2,486,265	Dennis	Oct. 25, 1949
2,600,264	Proctor	June 10, 1952