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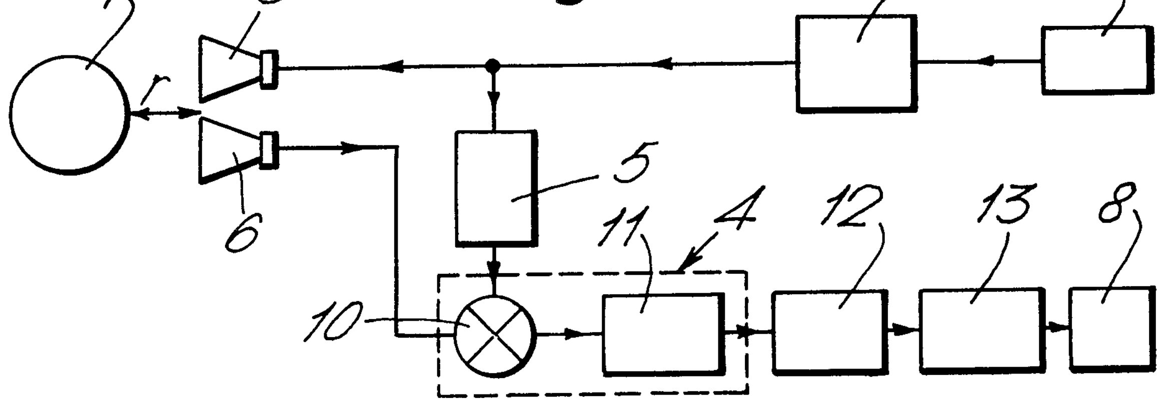
(54) Radar apparatus

(57) A microwave proximity detector system has a microwave noise source 2 that supplies signals to a transmitting aerial 3 and to a delay unit 5. Microwave energy reflected off external objects 7 is received by a second aerial 6 which supplies signals directly to a correlator 4. The correlator 4 also receives signals from the delay unit 5 and produces output signals that are dependent on the degree of correlation between the two input signals and the amplitude of the received energy. This gives a response that decreases sharply beyond a predetermined distance, dependent on the delay introduced by the unit 5. The microwave signals may be converted to a lower intermediate frequency prior to correlation, (Fig. 5).

Fig.1.



The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

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Fig.1.

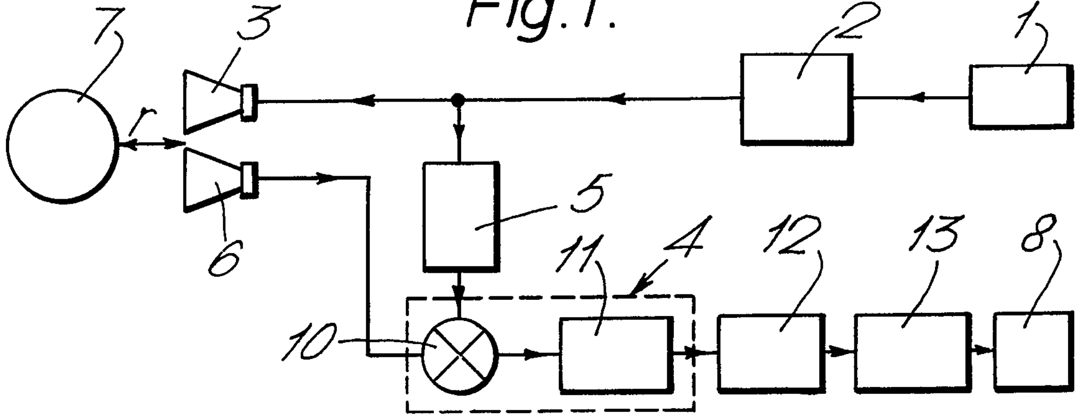


Fig.2.

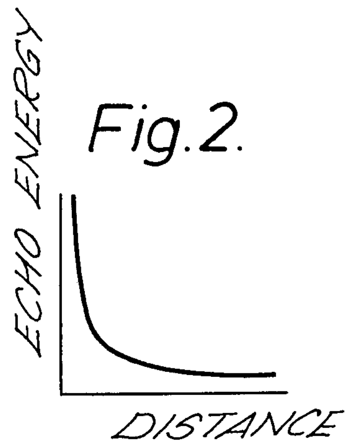


Fig.3.

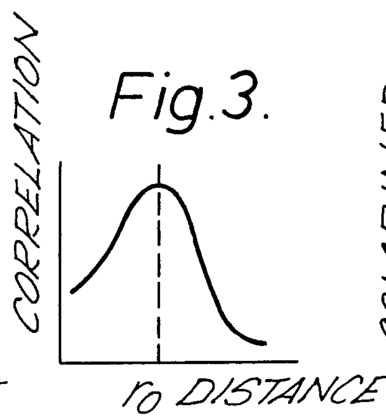


Fig.4.

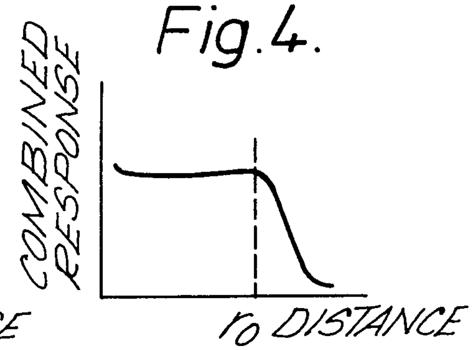
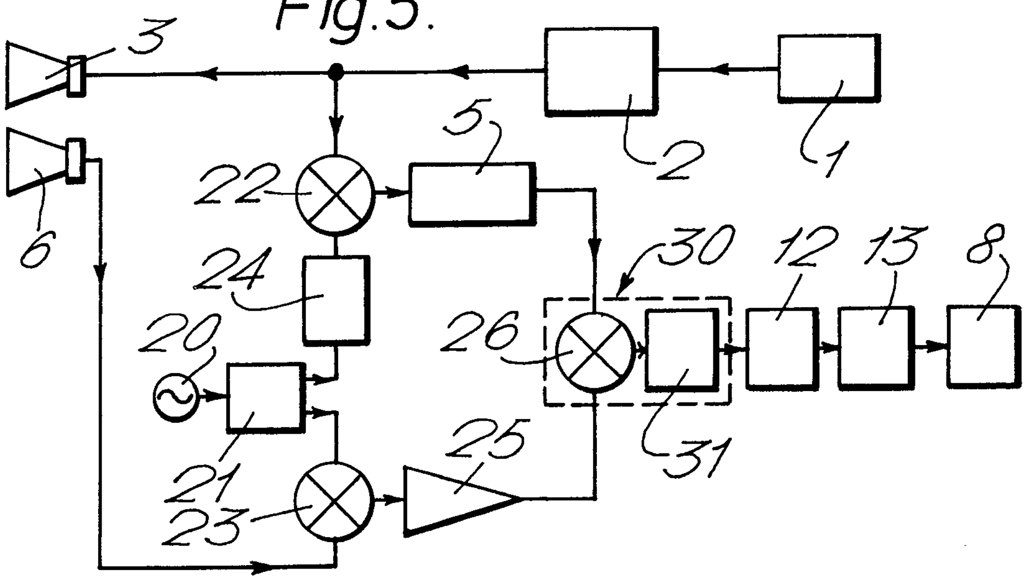


Fig.5.



SPECIFICATION

Radar apparatus

This invention relates to radar apparatus.

The invention is concerned more especially with microwave noise radar apparatus of particular, but not exclusive, application in proximity detecting equipment.

Microwave radar proximity detectors which employ pulse or continuous sine-wave energy are known. These previous detectors include means for transmitting microwave energy and means for receiving energy reflected from an object located in the transmitted beam. The time difference or phase difference between the transmitted and received energy provides an indication of the distance of the object from the detector. Detectors responsive solely to movement of an object are also known, such detectors being sensitive to the Doppler shift in frequency of the reflected energy. Previous systems, however, suffer from several disadvantages in that their performance may be impaired by interference from nearby electrical equipment such as fluorescent tubes or other proximity detectors. It is also difficult to control the range of such detectors and prevent them responding to objects beyond the distance within which it is desired to sense objects.

It is an object of the present invention to provide apparatus that may be used to overcome the above-mentioned disadvantages.

According to one aspect of the present invention there is provided radar apparatus including microwave transmitting means; electrical noise generator means, said noise generating means being arranged to supply electrical noise signals both to said microwave transmitting means, such that said transmitting means transmits microwave noise energy in response to said electrical noise signals, and to delay means; microwave receiving means arranged to receive microwave noise energy reflected off an external object; correlator means arranged to receive electrical noise signals from said receiving means and to receive electrical noise signals from said delay means, said correlator means being arranged to provide an output signal that is dependent both upon the degree of correlation between the received noise energy and the transmitted energy, and upon the amplitude of the received noise energy, the sensitivity of the apparatus decreasing sharply for energy reflected off external objects beyond a predetermined distance.

The degree of correlation will depend on the time difference between the two signals supplied to the correlator means, being a maximum when it is equal to the delay provided by the delay means. The amplitude of the received noise energy will depend inversely on the fourth power of the distance of the external object to the apparatus. The combined result of this is that the apparatus will, in general, be highly sensitive to objects within a distance substantially equal to that corresponding to the predetermined time delay but will be considerably less sensitive to objects beyond this distance.

The apparatus may be arranged to be sensitive only to displacement of objects within said predetermined distance.

A proximity detector system including radar apparatus according to the present invention, will now be described, by way of example, with reference to the accompanying drawing, in which:

Figure 1 is a circuit diagram illustrating the detector system schematically;

Figure 2 is a graph showing the variation in amplitude of received echo signals with distance;

Figure 3 is a graph showing correlation response with distance;

Figure 4 is a graph showing the combined response with distance; and

Figure 5 is a circuit diagram illustrating a modification of the detector system of Fig. 1.

The proximity detector system includes an electrical noise modulator 1 that supplies a continuous random noise signal to a microwave source 2. The microwave noise signal generated by the source 2 is supplied to a transmitting aerial 3 and to a correlator unit 4 via a time delay unit 5. The system also has a receiving aerial 6 that receives echo signals originating from the transmitting aerial and reflected off an external object 7. The output of the correlator unit 4 is supplied to an alarm 8 or other utilising equipment and is dependent upon the distance of the object 7 from the system and on movement of the object.

The noise generator 1 may be of the kind described in the specification of the Applicant's co-pending application No. 80 22829 and is arranged to supply a continuous random noise signal to the microwave source 2. The aerial 3 may be a microwave horn or other radiating means and is arranged to propagate microwave energy in a narrow or broad beam, according to the particular application. Noise signals from the microwave source 2 are also supplied to the time delay unit 5 which delays the signals for a predetermined time t. After the delay, the signals are supplied to a radio frequency mixer 10 within the correlator unit 4. The receiving aerial 6 may be of the same form as the transmitting aerial 3 and is directed to receive energy reflected from the object 7 when it is located in the path of the beam of transmitted radiation. The output of the receiving aerial 6 is supplied to a second input of the mixer 10 which functions as a multiplier and supplies output signals to an integrating band-pass filter 11 within the correlator unit 4.

The output of the band-pass filter 11 is in turn supplied to a motion detector 12 which produces an output of the amplitude of which is representative of the degree of movement of the object 7 towards or away from the system. The detector 12 supplies its output to the alarm 8 via a threshold detector 13.

In operation, when the object 7 is located in the path of energy propagated from the transmitting aerial 3, it reflects echo signals to the receving aerial 6. If the object 7 is located at a distance r in front of the transmitting aerial 3, the path travelled by the microwave energy between the transmitting aerial and the receiving aerial 6 is 2r and the time delay t' is given by:

$$t' = 2r/c \qquad \text{(I)}$$

where c is the velocity of the microwave energy in the propagating medium.

The amplitude of the echo energy received by the receiving aerial 6 is inversely proportional to the fourth power of the distance r to the object 7 as shown in Fig. 2.

Because the transmitting signal generated is random noise, the signal will not in general be the same at any two different times. The degree of correlation between the two signals supplied to the mixer 10 will therefore vary, maximum correlation occurring when the time delay t produced by the delay unit 5 equals the delay t' or

$$t = t' \qquad \text{(II)}$$

The distance r from the system at which this occurs is r_0. When r is greater than or less than r_0 the degree of correlation will be correspondingly less, as shown in Fig. 3.

The output of the integrating band-pass filter 11 is thereby dependent both on the correlation response and on the fourth power radar range law. The correlator unit 4 is so arranged to give a combined response with distance of the kind shown in Fig. 4 in which the system response is substantially constant for distances up to r_0 and then decays rapidly, becoming highly insensitive to objects having ranges greater than r_0.

If the object 7 is moving relative to the system, there will be a Doppler shift in the echo signals which will result in an output from the correlator unit 4 which oscillates at the Doppler frequency. The detector 12 is responsive to an alternating output of the correlator unit 4, passing signals to the threshold detector 13 the amplitude of which are indicative of the degree of movement of the object 7. The threshold detector 13 is adjusted to be responsive only to signals above a predetermined amplitude and to pass output signals to the alarm 8 for signalling the presence of a moving object within the range r_0. The alarm 8 could be arranged to provide a visual or audible warning.

A modification of the system is shown in Fig. 5, employing intermediate frequency detection. This modified system has a noise modulator 1, microwave source 2, transmitting aerial 3, delay unit 5, receiving aerial 6, motion detector 12, threshold detector 13, and alarm 8 of similar kinds to those in the system of Fig. 1 but instead converts the transmitted and received radio frequency signals to a lower, intermediate frequency before correlation. To do this, the modified system includes a local oscillator 20 that supplies signals via a power divider 21 to two radio frequency mixers 22 and 23. The signals from the local oscillator 20 are supplied to the first mixer 22 via an isolator 24, the mixer also receiving reference signals directly from the microwave source 2. The first mixer 22 acts to convert the radio frequency noise signals down to a lower intermediate frequency, in the usual way, and supplies these intermediate frequency signals to the time delay unit 5 of a similar kind to that in the system of Fig. 1. The other mixer 23 receives the radio frequency echo signals from the receiving aerial 6 and similarly converts these down to an intermediate frequency by mixing with signals from the local oscillator 20. The intermediate frequency signals are supplied via an amplifier 25 to an intermediate frequency mixer 26 together with the delayed signals from the unit 5. The intermediate frequency mixer 26 forms part of an intermediate frequency correlator unit 30 which also includes an integrating band-pass filter 31 and which functions in the same way as the radio frequency correlation unit 4 of Fig. 1.

Either system is thereby highly sensitive to movement within the range r_0 but relatively insensitive to movement outside the range r_0. This has advantage in making the system insensitive to external interference and has particular application in such fields as intruder alarms, where the system could be arranged to be triggered when someone comes close to the system but be unresponsive to movement at the far side of a room.

In place of the alarm 8, some other form of utilising equipment could be used. For example, the system of Fig. 1 or 5 could supply signals to a motor operable to open a door on the approach of a pedestrian. The system could also be used in counters, speed sensors and fuses. A variable time delay could be provided, the delay being increased until an object is detected. In this way, the system could be used to determine the range of an object.

CLAIMS

1. Radar apparatus including: microwave transmitting means; electrical noise generating means, said noise generating means being arranged to supply electrical noise signals both to said microwave transmitting means,

such that said transmitting means transmits microwave noise energy in response to said electrical noise signals, and to delay means; microwave receiving means arranged to receive microwave noise energy reflected off an external object; and correlator means arranged to receive electrical noise signals from said receiving means and to receive electrical noise signals from said delay means, said correlator means being arranged to provide an output signal that is dependent both upon the degree of correlation between the received noise energy and the transmitted energy, and upon the amplitude of the received noise energy, the sensitivity of the apparatus decreasing sharply for energy reflected off external objects beyond a predetermined distance.

2. Radar apparatus according to Claim 1, wherein said correlator means includes multiplier means that is arranged to receive output signals from said microwave receiving means and said delay means.

3. Radar apparatus according to Claim 2, wherein said correlator means includes filter means that receives output signals from said multiplier means.

4. Radar apparatus according to any one of the preceding claims including motion sensing means that is arranged to respond to movement of an external object within said predetermined distance.

5. Radar apparatus according to any one of the preceding claims including means for converting the microwave noise energy to a lower intermediate frequency before supply to said correlator means.

6. Radar apparatus according to Claim 5, wherein said apparatus includes a local oscillator, the output of which is mixed with said microwave noise energy.

7. Radar apparatus substantially as hereinbefore described with reference to Figs. 1 to 4 of the accompanying drawings.

8. Radar apparatus substantially as hereinbefore described with reference to Figs. 2 to 5 of the accompanying drawings.

9. Proximity detector system including radar apparatus according to any one of the preceding claims, said system being arranged to provide an alarm signal when said microwave receiving means receives energy reflected off an external object within said predetermined distance.

10. Proximity detector system according to Claim 9, wherein said alarm signal is initiated only by movement of an external object within said predetermined distance.

11. Proximity detector system substantially as hereinbefore described with reference to Figs. 2 to 4 and Fig. 1 or 5 of the accompanying drawings.

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