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PATENT SPECIFICATION

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(54) IMPROVEMENTS IN OR RELATING TO ULTRASONIC INTRUDER ALARM SYSTEMS

(71) We, SIEMENS AKTIENGESELLSCHAFT, a German Company of Berlin and Munich, German Federal Republic, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The invention relates to ultrasonic intruder alarm systems of the type exploiting the Doppler effect.

The German Patent Specification No. 2,613,375 filed by the applicants of the present invention describes a system of this type, which will be described in detail hereinafter with reference to the drawings. It includes an amplitude limiter, known *per se* for frequency modulation, which is provided for received echo signals, and by which any amplitude modulation of received signals is eliminated, the received signals having been previously amplified to such an extent that the amplitude limited signal still has adequate intensity for further processing, and there is provided a product detector, which is supplied both with the amplitude-limited signal and a reference signal component derived from the transmitted signal, to produce a frequency difference signal which is available at an output terminal for forwarding to the device which triggers an alarm.

In special applications of ultrasonic intruder alarm systems, as described in the above mentioned German Specification, it can be necessary to select the exact location at which an ultrasonic receiving converter is to be set up, in order to ensure that interference signals do not arise because the ultrasonic converter receives a signal which possesses a phase state which is unfavourable for analysis by phase comparison with the signal fed from the oscillator to the phase detector. This problem can often be overcome in a simple manner by a relatively slight change of location of the receiving-transducer and/or the transmitting converter. However, it could be necessary, in the event of a change being made in the set up of the area to be monitored, for example in the event that a cupboard or the like is moved, to subsequently carry out a further location correction of at least one converter.

One object of the present invention is to provide a circuit arrangement for an ultrasonic intruder alarm system of improved design which substantially avoids the need for such relocation of a transducer, in all normal circumstances.

The invention consists in an ultrasonic transducer alarm system in which a transmitting transducer is fed from a frequency controlled oscillator to continuously transmit ultrasonic radiation, when operating, and a receiving transducer is provided to detect any echo signals and feed electrical output signals representative thereof to a phase detector which compares the electrical output signals with the oscillator output and produces an output having an amplitude which is dependent upon the mutual phase angle, which output is fed to an analysis circuit, which responds in the event of any a.c. components in said output being detected, said oscillator forming part of a phase-locked regulating loop which includes a further phase detector, which compares the receiving transducer output signals with the oscillator output and whose output is connected via a low-pass filter to a frequency control input of said oscillator, the cut-off frequency of said low-pass filter being such that the only signals which can pass without significant attenuation are those those frequency is lower than a critical frequency $F_c = c/E$, where c is the speed of the ultrasonic radiation in the area to be monitored, and E is the length of the path for the ultrasonic radiation from the transmitting transducer to the most remote reflective object and back to the receiving transducer.

The invention will now be described with reference to the drawing, in which:—

Figure 1 is a block schematic circuit arrangement of the system described in the above mentioned German Patent Specification;

Figure 2 is a block schematic circuit diagram of one exemplary embodiment of an intruder alarm constructed in accordance with the invention; and

Figure 3 shows circuit details of a preferred embodiment of a system very similar to that shown in Figure 2.

The intruder alarm system shown in Figure 1 possesses an oscillator 1 which supplies an output signal to an ultrasonic transmitting transducer 2 which produces ultrasonic radiation 21. Any ultrasonic radiation reflected from the walls or other surfaces in the area to be monitored, and by objects or persons in this area are returned as echo signals 31 schematically indicated by arrows. This radiation is received by an ultrasonic receiving transducer 3 and converted into electrical signals. When reflected on stationary objects, the ultrasonic frequencies of the transmitted radiation 21 and the received radiation 31 are identical. In the case of moving objects which are to be detected by the system, the known Doppler frequency shift occurs which is analysed to trigger an alarm.

The electrical signal produced by the receiving transducer 3 passes via an amplifier 4 to a phase detector 5 which is also supplied with a component of the transmitted output from the oscillator 1.

The phase detector 5 supplies an output signal whose amplitude is dependent upon the phase difference between the output signal of the oscillator 1 and the receiving signal supplied by the receiving transducer 3. The output signal of the phase detector 5 is passed via a low-pass filter 6 to an analysis circuit 7 by which an alarm signal is emitted if an a.c. component of the phase detector signal indicates radiation reflected from a moving object.

Equipping a circuit as illustrated in Figure 1 with a conventional form of phase detector involves certain difficulties, since many known phase detectors do not have a constant sensitivity. The detection sensitivity in respect of small phase fluctuations between the supplied signals is dependent upon the degree of the general phase difference between these signals supplied to the phase detector. For specific, periodic values of the phase difference, the sensitivity can even be zero. This can occur in an intruder alarm system in dependence upon the set-up and properties of the area in question, since the received echo signals can assume any phase, which remains uniform over a period of time relative to the transmitted signal. However, this can be overcome with the aid of the above mentioned measures, in particular by change of location, although this necessitates readjustment which may be difficult, time-consuming or inconvenient.

The exemplary embodiment of the present invention illustrated in Figure 2 possesses a phase-locked regulating loop, commonly known as a PLL circuit. This includes the elements 9, 10, 11 and 110, which will be explained in detail in the following. The other elements of Figure 2 correspond to elements already described with reference to Figure 1, and these are identified by use of the reference numerals allocated to the corresponding elements in Figure 1.

The oscillator 110 is controllable in its frequency, albeit only to a low extent, e.g. ±5%, and is provided with a frequency control input 102.

As already described with reference to the oscillator 1 of Figure 1, this oscillator 110 supplies an output signal to the transmitting transducer 2 and to the phase detector 5. A further component of the output signal of the oscillator 110 is fed to a further phase detector 9, which is likewise supplied with a part of any received echo signal by the receiving transducer 3, either via the preliminary amplifier 4, or via a separate amplifier 8, which may in some cases form part of the phase detector 9.

The output signal of the further phase detector 9, which signal is dependent in amplitude upon the phase difference, passes through a low-pass filter 10 which is designed in a manner yet to be described. The output signal from the low-pass filter 10 passes via a further amplifier 11 to the control input 102 of the oscillator 110.

A controllable oscillator 110 as described here is also referred to as Vco (voltage controlled oscillator).

The PLL regulating loop formed by the phase detector 9, the low-pass filter 10 and the oscillator 110 allows the frequency of the oscillator 110 to be controlled in dependence upon the phase difference established in the phase detector 9.

The mode of operation of the circuit arrangement thus far described is such that the frequency of the transmitted signal is varied in such manner that, providing there are no objects moving in the monitored area, there is a predeterminable, uniform phase angle set up between the transmitted signal and the received echo signal at the transducer 3. In accordance with the selection of the type of phase detector, the phase angle is contrived to be such that a favourable detection action is achieved.

However, for the realisation of the aim of the invention it is also necessary that there is a received signal of adequate size from the receiving transducer 3, which is not ensured if, on the reception of echo signals from non-moving objects, conditions favourable to interference of the ultrasonic radiation in the monitored area cause the received signal to be so weak that the PLL regulating system comes to a halt. This circumstance is taken into account by a further feature of the invention. In fact, as a result of the special application of the invention periods of time exist in which there may be received ultrasonic echo signals which are based on reflection from non-moving objects. For such time as no movements of the reflecting objects take place, the frequency of the received ultrasonic radiation conforms with that of the transmitted signal. This means that during this length of time the PLL circuit does not require to carry out regulation so that the low-pass filter 10 provided in the PLL circuit can possess an unusually high time constant, e.g. $\tau > 1$. The operating range of the PLL circuit having a low-pass filter 10 of such a low cut-off frequency is now reduced to fractions of 1 Hz., for example. This has no disadvantageous influence in a normal operating situation in which no movement of objects to be detected takes place. However, it ensures that the phase-locked regulatation in this stationary state influences the oscillator 110 in such manner that a permanently constant phase deviation, e.g. 90° exists between any received echo signal and the transmitted signal. Thus this fulfills a first condition for a sensitive detection, namely that no phase indetermination should exist in respect of the signals to be analysed.

Thus this high time constant of the low-pass filter 10 fulfills the second condition, namely the avoidance of quenching of intensity on the receiving transducer 3. In fact if a situation of this kind should by chance occur, the oscillator 110 would not longer receive a defined control voltage and would change its own oscillator frequency in an uncontrolled fashion. Due to the very high time constant of the PLL circuit, this takes place very slowly, however, i.e. in periods of time which are long relative to the transit time of the ultrasonic radiation in the area to be monitored.

In the event of this independent change in frequency of the oscillator 110, changes occur in the interference conditions in the area, and there is always one of an arbitrary number of possible new frequencies for the transmitted signal for which a receiving amplitude of adequate magnitude is formed in the receiving transducer 3. However, as a result the oscillator 110 again automatically enters a phase control state. The cut-off frequency which is to be selected for the low-pass filter 10 is such that the only signals which can pass without significant attenuation are those whose frequency is lower than a critical frequency $F_c = c/E$, where c is the speed of the ultrasonic radiation in the area in question, and E is the path of an ultrasonic radiation which has been emitted from the transmitting transducer 2 and reflected by an object located at a maximum range to return to the receiving transducer. Calculation of the value E is non-problematic and relatively non-critical. For an ultrasonic intruder alarm system it is generally known how large an area to be monitored is. Thus the value E cannot exceed double the maximum distance in the area in question (area diagonal). However, this does not impose a limitation to the effect that the range of application of a system constructed in accordance with the invention is subject to a special condition. The value E can readily be selected to be one order of magnitude greater, even up to two orders of magnitude, than the path length which subsequently constitutes the maximum path length for ultrasonic radiation in the individual, actual application.

However, the design of the low-pass filter 10 differs quite decisively from filter values in PLL circuits normally prevailing in such regulating circuits.

In the event of the reception of frequency shifted echo signals which have been reflected by any moving object, the PLL circuit does not always directly operate as such a circuit. The superimposed Doppler frequency modulation, e.g. of 40 to 400 Hz, is itself too rapid for the inert reaction of this PLL circuit due to the above described design, i.e. due to the low cut-off frequency of the low-pass filter 10. However, the PLL circuit continues to operate for the average adherence to the phase relationship, and even in the event of the detection of a movement, i.e. the presence of a Doppler frequency shifted received signal, it avoids unfavourable general phase states.

It is not necessary to discuss the fact that special attenuation should be given to received echo signals, prevailing for a longer period of time, exhibiting equal like-directed Doppler shift. A situation of this kind could in fact bring the rigid phase regulation out of step. Doppler frequency shifted received signals of this type are, however, always so strong in intensity that an unstrict adherence to the phase regulation could lead to the breakdown of the detection as received signals of this kind are always sufficiently strong in intensity.

Figure 3 shows a complete circuit diagram illustrating a preferred embodiment of the invention. The expert will not require any special explanations of this exemplary embodiment. However, an explanation will be given in respect of the use of a commercially available, integrated

PLL circuit, the Signetics PLL tone decoder type NE 576. This provides the oscillator 110, and circuit means which can be influenced from the input 102 and serve to control the frequency of the oscillator. This oscillator 110 is contained in this integrated circuit together with the amplifier 11 and a resistor of the low-pass filter 10. A capacitor 100 in Figure 3 serves as a frequency-determining capacitor for the low-pass filter 10 of the PLL circuit. The further phase detector 9 is also contained in the integrated circuit. The amplifier 8 of the circuit shown in Figure 2 is replaced by the amplifier 4 of the circuit shown in Figure 2. The phase detector 5 is formed by a logic NAND-gate.

WHAT WE CLAIM IS:—

1. An ultrasonic transducer alarm system in which a transmitting transducer is fed from a frequency controlled oscillator to continuously transmit ultrasonic radiation, when operating, and a receiving transducer is provided to detect any echo signals and feed electrical output signals representative thereof to a phase detector which compares the electrical output signals with the oscillator output and produces an output having an amplitude which is dependent upon the mutual phase angle, which output is fed to an analysis circuit, which responds in the event of any a.c. components in said output being detected, said oscillator forming part of a phase-locked regulating loop which includes a further phase detector, which compares the receiving transducer output signals with the oscillator output and whose output is connected via a low-pass filter to a frequency control input of said oscillator, the cut-off frequency of said low-pass filter being such that the only signals which can pass without significant attenuation are those whose frequency is lower than a critical frequency $F_c = c/E$ where c is the speed of the ultrasonic radiation in the area to be monitored, and E is the length of the path for the ultrasonic radiation from the transmitting transducer to the most remote reflective object and back to the receiving transducer.

2. A system as claimed in Claim 1, in which the echo signal to be fed to the further phase detector is taken from the output of an amplifier connected between the receiving transducer and the phase detector that is connected to the analysis circuit.

3. A system as claimed in Claim 1, in which the echo signal fed to the further phase detector is fed from the receiving transducer via a further amplifier.

4. An ultrasonic transducer alarm system substantially as described with reference to Figure 2 or Figure 3.

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Fig. 1

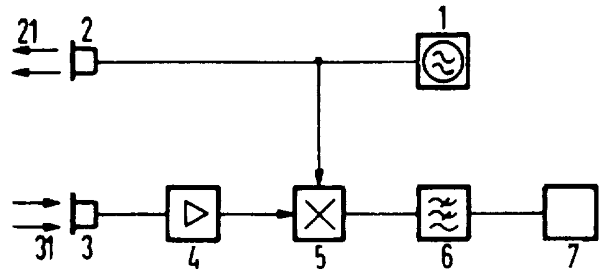
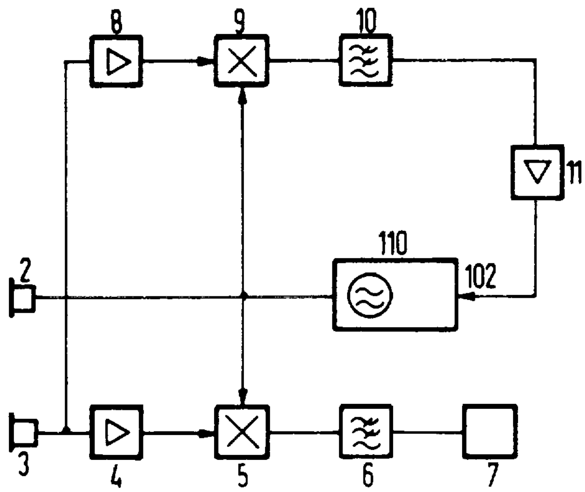
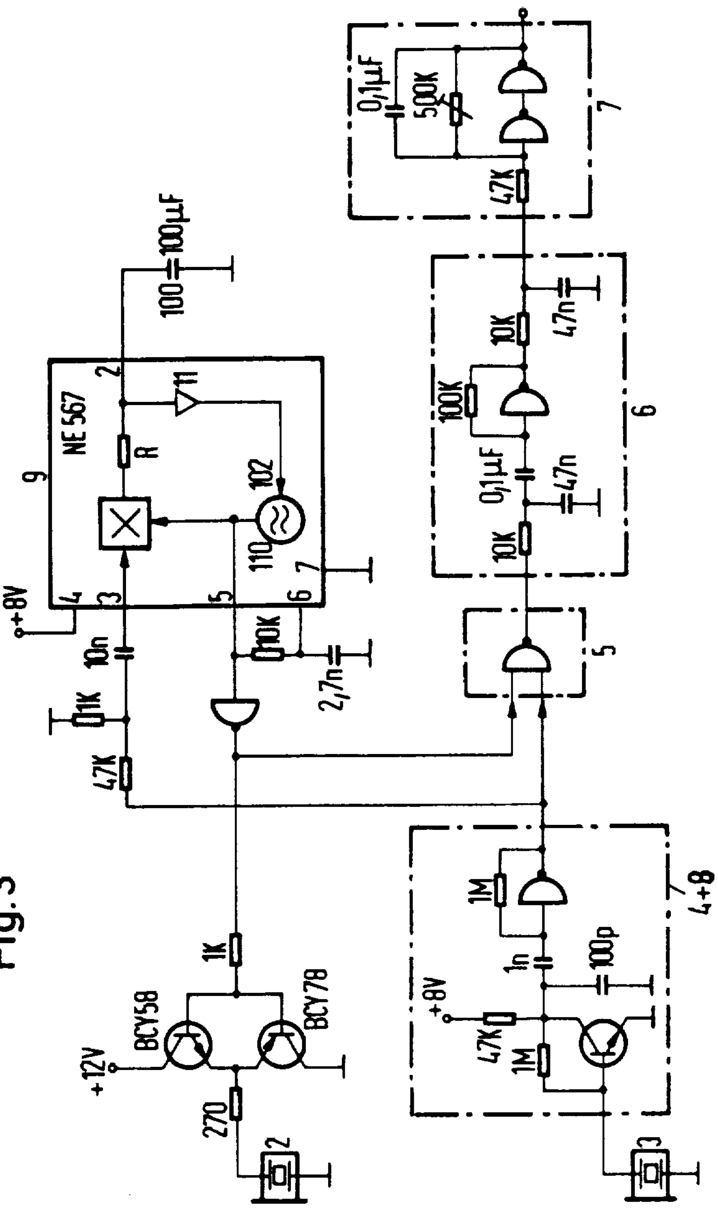


Fig. 2

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100
100µF
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BCY78
+12V
270
1M
1n
100p
4+8
0,1µF
500K
47n
100K

Fig.3