ULTRASONIC INTRUSION DETECTION SYSTEM SIGNAL PROCESSING CIRCUIT

Inventors: John H. Lee, Township of Woodbury, Washington County, Thomas E. Collins, East Oakdale, both of Minn.

Assignee: Minnesota Mining and Manufacturing Company, St. Paul, Minn.

Filed: Nov. 17, 1969

Appl. No.: 877,173


Int. Cl. G08b 13/00

Field of Search 340/258, 258 A, 261

References Cited

UNITED STATES PATENTS
2,767,393 10/1956 Bagno ........................................ 340/258

2,782,405 2/1957 Weisz et al........................................ 340/258


Primary Examiner—John W. Caldwell

Assistant Examiner—Michael Slobasky

Attorney—Kinney, Alexander, Sell, Steldt & Delahunt

ABSTRACT

An electronic device for processing the amplitude modulations of a received ultrasonic carrier wave to produce an alarm signal when the pattern of the amplitude modulations is characteristic of an alarm condition. The device produces an electrical signal which is representative of the amplitude modulations of a received wave. When the electrical signal has a frequency within a predetermined pass-band, is of at least a predetermined amplitude, and persists for a minimum time interval, an alarm signal is produced.

8 Claims, 3 Drawing Figures
ULTRASONIC INTRUSION DETECTION SYSTEM SIGNAL PROCESSING CIRCUIT

BACKGROUND OF INVENTION

Systems for detecting conditions corresponding to a fire or an intruder within a protected space by sensing for changes in ultrasonic acoustic waves radiated into the space are well known in the art. In such systems, ultrasonic acoustic energy of a fixed frequency (the carrier frequency) is radiated into the space to be protected. An acoustic energy receiver is stationed in the space. When there is no movement within the space, the radiated acoustic energy exists as a standing wave pattern. Disturbances within the space, such as those caused by an intruder, a fire, or environmental noise such as the ringing of a telephone and air turbulences caused by exhaust fans, vehicular traffic passing near the protected space or even vibrating window blinds or water pipes will disturb the standing wave pattern to cause a variation in the energy sensed by the receiver.

Many analyses have been made to determine the characteristic variations of the different types of disturbances. A long sought after objective of these analyses has been to unambiguously distinguish between variations characteristic of a fire or an intruder and variations characteristic of environmental noise.

Many such analyses, and systems predicated upon the conclusions of these analyses, considered the frequency composition of the received wave to be the criteria for unambiguously identifying different types of disturbances. Such a prior art system shall hereafter be referred to as a “frequency demodulated” system, i.e., one in which an electrical signal corresponding to a received acoustic wave is frequency demodulated.

Such frequency demodulated systems are disclosed in U.S. Pat. Nos. 2,655,645; 2,794,974; and 3,111,657. An objective of each of the latter two of these patents is to solve the problem of false alarms. A premise of both patents is that the amplitudes of the different frequency components of valid alarm signals (caused by a fire or an intruder) are essentially the same whereas the corresponding amplitudes of turbulence signals vary inversely with frequency. These patents thus each include circuits for separating a received signal into a low frequency component and a high frequency component together with additional circuitry for comparing the amplitudes of the two signals. A circuit is included for attenuating the low frequency component so that the comparison produces a difference signal only for valid alarm signals. The two components of a turbulence signal, after attenuation of the low frequency component, are approximately equal and thus do not produce a difference signal when compared. U.S. Pat. No. 3,111,657 also includes additional circuitry for preventing false alarms when the composition of a turbulence signal does not simultaneously include both a high and a low frequency component as is sometimes the case. This additional circuitry comprises integrators for time-averaging the high and low frequency components and will prevent a turbulence signal having only a high or a low frequency component from producing a false alarm for those cases when the time-averaging of the high and low frequency components over a pre-selected period is approximately equal.

We have discovered that it is not necessary to frequency demodulate the received signal. We thus are able to eliminate all of the circuitry for separating a received signal into two components and for comparing and otherwise processing these components. Instead, we merely amplitude demodulate received signals. We have found that the frequency, duration, and amplitude of the amplitude demodulation signal of a received wave is a reliable criteria for distinguishing between environmental noise and valid alarm condition disturbances. Specifically, we have found that signals of relatively low frequency correspond to turbulence disturbances whereas a higher frequency signal is characteristic of a valid alarm disturbance, i.e., both fire and intrusion type disturbances. We have also found that environmental noises other than turbulence, e.g., the ringing of a telephone, are characterized by amplitude modulations of still higher frequencies.

In a preferred embodiment, the ultrasonic motion detector device of the present invention comprises a circuit for producing an electrical signal corresponding to amplitude modulations of a received ultrasonic wave. The received waves comprise reflections of a wave both radiated into a space to be protected and modulated according to disturbances within the area. The electrical signal is applied to another circuit which produces an alternating signal. The alternating signal is produced to have a first value (i.e., the difference between the high and low amplitudes of a signal excursion) when the absolute value of the electrical signal amplitude is greater than a predetermined reference amplitude and to have another value less than the first value when the absolute value of the electrical signal amplitude is less than the predetermined reference amplitude. The alternating signal is applied to a further circuit which passes the alternating signal as an output signal when the frequency of the alternating signal is within a predetermined pass-band. Another circuit receives the output signal and produces an alarm signal when the output signal corresponds to a train of alternating signal excursions of the first value occurring within a predetermined or minimum time. By blocking passage of alternating signals of low and high frequency and by requiring that an alternating signal pass for a minimum time, the signal processing circuit of the present invention avoids false alarms while reliably indicating valid alarm conditions.

In another embodiment, an additional circuit is provided for effectively varying the predetermined reference amplitude in direct proportion to changes in the time average of the output signal amplitude to compensate for changes in the ambient level of environmental noise signals.

Specific embodiments of the invention chosen for purposes of illustration and description are shown in the accompanying drawings wherein:

FIG. 1 is a block diagram of an ultrasonic intrusion detector system employing the processing circuit of the present invention;

FIG. 2 is a schematic circuit diagram of a preferred embodiment of the signal processing circuit of the present invention;

FIG. 3 is a schematic circuit diagram of a circuit for use with the processing circuit of FIG. 2 to compensate for variations in the ambient environmental noise signal level.

With reference to the block diagram of FIG. 1 there is shown a transmitter 10 which radiates ultrasonic waves 12 at an essentially constant amplitude and frequency (a “carrier” frequency) into a space to be protected. The transmitter 10 is not considered a part of the present invention. Reflected waves 14 impinge upon and are demodulated by a receiver 16. The output of the receiver is an electrical signal which is a representation of the amplitude modulations of the received wave. An illustrative representation of the electrical signal produced by the receiver is illustrated as waveform 18. The output of receiver 16 is shown to be applied to a saturation amplifier 20 which converts the electrical signal 18 to an alternating signal, shown as waveform 22. Waveforms 18 and 22 have the same time base. Thus it is apparent that the saturation amplifier 20 provides a signal the excursions of which have a first amplitude whenever the electrical signal of waveform 18 exceeds a predetermined reference amplitude. Otherwise, for amplitudes of waveform 18 less than a predetermined amplitude, the signal excursion (i.e., the peak-to-peak amplitude) is less than the first amplitude excursion.

In the waveform 18, zero reference is indicated by solid line 24 and the predetermined amplitude is represented by the equidistant displacements of dashed lines 23 and 25. In waveform 22, the first amplitude excursions, corresponding to waveform 18 signal equal or greater than the predetermined amplitude limits of dashed lines 23 and 25, are shown to occur between reference lines 27 and 29. The alternating signal of saturation amplifier 20 is applied to an active filter 26. Active
filter 26 passes as an output signal, shown as waveform 28, those alternating signals having a periodicity within a predetermined pass-band. The lower limit of the pass-band rejects turbulence type signals; the upper limit rejects environmental noise signals like those from a ringing telephone. The output signal 28 from active filter 26 is applied to an alarm and indicator circuit 30 which generates an alarm signal in response to an output signal corresponding to a train of first amplitude alternating signal excursions occurring within a predetermined time. The foregoing describes a basic embodiment of the present invention. A further improvement of the device of Fig. 1 is shown in dashed lines as a feedback circuit 32. Feedback circuit 32 effectively varies the predetermined reference amplitude 23 and 25 in direct 22 in changes in the time average of the output signal amplitude.

FIG. 2 is a schematic diagram of the basic embodiment of FIG. 1. Receiver 16 is shown to comprise a transducer 34 which is responsive to variations in the received acoustic wave to correspondingly vary the base current applied to the base lead of transistor 36. Transistor 36 is the amplifier of one stage of the two-stage common emitter amplifier shown generally as 38. The combination of transducer 34 and amplifier 38 are tuned to the carrier wave frequency, which for the present example shall be assumed to be 40 KHz. The output of the two-stage common emitter amplifier 38 is applied to an emitter follower 40. The emitter follower output is an electrical signal representative of amplitude demodulation of a received wave. The emitter follower 40 output is shown to be applied as the input to saturation amplifier 20. Saturation amplifier 20 comprises a first common emitter amplifier, shown generally as 42, and a second common emitter amplifier, shown generally as 44. The combination of the amplifiers 42 and 44 provides an alternating signal representation of the electrical signal output of receiver 16. This alternating signal is provided as the input to active filter 26 which is shown to comprise an active network, shown generally as 45, and a twin-T network shown generally as 46. The output 45 is shown to comprise a common emitter amplifier 48 coupled in series with an emitter follower 50, the output of which is the input to twin-T network 46. The output of twin-T network 46 is fed back via coupling capacitor 52 to the input of common emitter amplifier 48. The output of active filter 26 is provided through coupling capacitor 54 as the input signal to alarm and indicator circuit 30. The alarm and indicator circuit 30 is shown to generally comprise an emitter follower 56 and integrator circuit 58, a Schmidt Trigger 60 and a relay output 61.

The path for charging capacitor 62 of integrator 58 is through transistor 64, and resistor 66. The discharge path of capacitor 62 is through resistor 70. The charge time constant of integrator 58 is chosen so that random, short duration disturbances characteristic of environmental noise do not cause an alarm. The discharge time constant is selected to be much larger than the charge time constant so that a long duration disturbance characteristic of a valid alarm condition will cause an alarm. We have found a ratio of the discharge to charge time constants of about 30 to be acceptable.

FIG. 3 illustrates a circuit which would provide compensation for variations in the ambient level of turbulence signals. The connection points A through E of the circuit of FIG. 3 would be connected at the similarly identified points in FIG. 2. In addition to providing a slightly different integrator circuit, shown generally as 74, the circuit of FIG. 3 includes a feedback network shown generally as 76. Integrator 74 is essentially the same as the integrator 58 having a charge path through transistor 64 and resistor 66 to capacitor 62. The integrator 74 has a discharge path through resistors 80 and 82. The relationship between the charge and discharge time constants of integrator 74 is the same as that previously discussed for integrator 58. Feedback network 76, as shown, may conveniently be a Miller integrator. The transistor 84 of the integrator is shown to have its collector lead coupled to the output of the first common emitter amplifier of the saturation amplifier 20. The Miller integrator of feedback network 76 time-averages the charge stored by capacitor 62 of integrator 74 to sink current from, i.e., to load, the output of common emitter amplifier 42 in direct proportion to the charge stored in capacitor 62.

Briefly, the operation of a circuit of FIG. 2 is as follows. Transducer 34 receives reflected waves of the carrier waves that are fed into active filter 26 which produces an input alternating signal. The input alternating signal is applied to the base of transistor 36 in a manner corresponding to variations of the received wave. Emitter follower 40 strips the carrier frequency from the output signal of amplifier 38 to provide an electrical signal which is representative of the amplitude modulation of the received wave. The amplifier 20 produces an electrical signal which is input into a twin-T network which is driven into saturation whenever the amplitude of the input signal exceeds a predetermined reference amplitude. Returning to FIG. 1 momentarily, it is seen that when the signal 18 exceeds the reference amplitude indicated by dashed lines 23 and 25, an alternating signal is produced having an excursion (a first excursion) extending between reference lines 27 and 29. On the other hand, if the amplitude of signal 18 is less than the reference amplitude of lines 23 and 25, the excursion of the corresponding alternating signal of amplifier 20 is less than the first excursion. The alternating signal of amplifier 20 is applied to the input of active filter 26 which rejects a pass-band of from about 50 Hz. to 200 Hz. In FIG. 1, the portion of waveform 22 corresponding to periods 1a and 1b of the time scale corresponds to a frequency between 50 Hz. and 200 Hz. and thus are passed by active filter 26 as an output signal. Portions of the waveform 22 of period 1c and 1f, however, correspond to frequencies resonant with below the pass-band of filter 26 and thus their passage is essentially blocked.

The active filter output is applied to the base of emitter follower 56 the emitter current of which flows through resistor 66 and into capacitor 62. Schmidt Trigger 60 is coupled between resistor 66 and capacitor 62 as an amplitude detector to produce an alarm signal by switching states when the charge stored in capacitor 62 reaches a predetermined level, i.e., the trigger level of the Schmidt Trigger. The trigger level is chosen to be sufficiently greater than the quiescent charge of capacitor 62 that neither a half excursion, nor even several successive full excursions, of the output signal will raise the charge in capacitor 62 to the trigger level for it has been found that environment noise can generate several successive first amplitude excursions within the frequency pass-band characteristic of valid alarms. Assuming a carrier frequency of 40 KHz., a frequency of the amplitude demodulated signal (corresponding to an intruder) of 100 Hz. and to simplify analysis, an idealized waveform, approximately 40 excursions would be required to raise the quiescent charge (about 1.2 v.) on capacitor 62 to the trigger voltage (1.5 v.) of Schmidt Trigger 60. Feedback network 32 compensates for variations in the ambient noise level which would change the quiescent charge of capacitor 62 (and thus also change the differential charge required to reach the trigger level). As the charge on capacitor 62 increases above the quiescent level, the Miller integrator time-averages the charge and sinks or draws current from the output of common emitter amplifier 42 in proportion to the time-averaged charge. The current drawn off by Miller Integrator 76 is thus diverted from the output of common emitter amplifier 44 which effectively increases the amplitude of the input signal required to drive amplifier 20 into saturation, i.e., it effectively increases the predetermined reference amplitude.

Typical values of components of the circuits of FIGS. 2 and 3 are given in the following table.

<table>
<thead>
<tr>
<th>TABLE 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. FIG. 2</td>
</tr>
<tr>
<td>R1 56 Kf</td>
</tr>
<tr>
<td>R2 4.7 Kf</td>
</tr>
<tr>
<td>R3 47 Kf</td>
</tr>
</tbody>
</table>
3,662,371

5

R5 1 KΩ C5 22 µf
R6 56 KΩ C6 22 µf
R7 470 KΩ C7 22 µf
R9 10 KΩ C8 125 µf, 16 v
R10 470 C9 10 µf, 16 v
R11 1 KΩ C10 0.047 µf
R12 3.3 megΩ C11 125 µf, 4 v
R13 470 KΩ C12 22 µf
R14 10 KΩ C13 0.015 µf
R15 47 KΩ C14 125 µf, 4 v
R16 10 KΩ C15 125 µf, 4 v
R17 15 KΩ C19 0.1 µf
R18 220 C19 1 µf
R19 3.3 KΩ C20 22 µf
R20 150 KΩ C21 10 µf, 16 v
R21 2.2 KΩ C24 22 µf
R22 33 KΩ C62 125 µf 4 v
R23 22 KΩ all transistors GE 2N3394
R24 100Ω
R25 4.7 KΩ Transducer 34
R26 56 KΩ 40 KHz ceramic transducer,
R27 4.7 KΩ commercial type number
R28 10 KΩ MK-109 offered for sale by
R29 470 MASSA DIVISION of
R30 1 KΩ Dynamics Corporation of
R31 15 KΩ America
R32 15 KΩ
R33 15 KΩ
R34 8.2 KΩ
R35 47 KΩ
R39 1.2KΩ
R40 391
R41 820 KΩ
R42 15 KΩ
R66 680Ω
R70 100 KΩ

II. FIG. 3

Resistor Capacitor
R80 27 KΩ C88 125 µf @ 10 v
R82 47 KΩ
R86 2.2 KΩ Transistor 84 GE 2N3394

35

It will be appreciated that, while certain specific embodiments have been shown and described, various changes and modifications may be resorted to without departing from the true spirit and scope of the invention as defined in the appended claims.

What is claimed is:

1. An ultrasonic motion detector device which receives an ultrasonic acoustic wave radiated into a space to be protected at an essentially constant carrier frequency and amplitude and which produces an alarm signal when the modulations of a received wave are characteristic of an alarm condition, comprising:

A. means for producing an electrical signal which is representative of the amplitude modulations of a received ultrasonic wave;

B. means for producing an alternating signal in response to said electrical signal, said alternating signal having a frequency corresponding to the frequency of said electrical signal but the difference between the high and low amplitudes of an excursion of said alternating signal being a first value when the absolute value of the electrical signal amplitude is greater than a predetermined reference amplitude and being another value less than the first value when the absolute value of the electrical signal amplitude is less than the predetermined reference amplitude;

C. means for passing said alternating signal as an output signal when the frequency of said alternating signal is within a predetermined passband;

D. means for producing said alternating signal in response to an output signal which corresponds to a train of a predetermined number of alternating signal excursions of said first value occurring within a predetermined time.

2. An ultrasonic motion detector device according to claim 1 further comprising means for effectively varying said predetermined reference amplitude in direct proportion to the time average of the output signal amplitude.

3. An ultrasonic motion detector device which receives an ultrasonic acoustic wave radiated into a space to be protected at an essentially constant carrier frequency and amplitude and which produces an alarm signal when the modulations of a received wave are characteristic of an alarm condition, comprising:

A. means for producing an electrical signal which is representative of the amplitude modulations of a received ultrasonic wave;

B. a saturation amplifier for producing an alternating signal in response to said electrical signal, said alternating signal having a frequency corresponding to the frequency of said electrical signal but the difference between the high and low amplitudes of an excursion of said alternating signal being a first value when the absolute value of the electrical signal amplitude is greater than a predetermined reference amplitude and being another value less than the first value when the absolute value of the electrical signal amplitude is less than the predetermined reference amplitude;

C. an active filter for passing the alternating signal as an output signal having a pass-band of from about 50 Hz. to 200 Hz.; and

D. means for producing an alarm signal in response to an output signal which corresponds to a train of a predetermined number of alternating signal excursions of said first value occurring within a predetermined time, which means comprises an integrator having a charge time constant and a discharge time constant greater than said charge time constant, which integrator is responsive to one-half of each output signal corresponding to one-half of an alternating signal excursion to store a charge at a rate determined by said charge time constant and responsive to the other one-half of each output signal to reduce the stored charge at a rate determined by said discharge time constant and an amplitude detector responsive to the stored charge reaching a predetermined level to produce an alarm signal.

4. An ultrasonic motion detector according to claim 3, wherein the saturation amplifier comprises a first common emitter amplifier which receives the electrical signal as its input, a second common emitter amplifier coupled in series with the first common emitter amplifier, and wherein the means for effectively varying the predetermined amplitude comprises a feedback network for time-averaging the charge stored in said integrator and for loading the output of said first common emitter in direct proportion to said time-averaged charge.

5. An ultrasonic motion detector according to claim 4, wherein said feedback network loads the output of said first common emitter amplifier relatively lightly when said first integrator is storing less than a predetermined charge but abruptly changes to load said output relatively heavily when the charge stored in said first integrator exceeds a predetermined charge.

6. An ultrasonic motion detector according to claim 4, wherein said feedback network is a current sink which draws current from the output of said first common emitter amplifier in direct proportion to the charge stored in said first integrator.

7. An ultrasonic motion detector according to claim 5, wherein said active filter comprises a third common emitter amplifier having its input coupled to the output of said saturation amplifier, an emitter follower having its input coupled to the output of said third common emitter amplifier, and a twin-T filter having its input coupled to the output of said emitter follower and having its output fed back to the input of said third common emitter amplifier.

8. An ultrasonic motion detector device which receives an ultrasonic acoustic wave radiated into a space to be protected at an essentially constant carrier frequency and amplitude and which produces an alarm signal when the modulations of a received wave are characteristic of an alarm condition, comprising:
A. means for producing an electrical signal which is representative of the amplitude modulations of a received ultrasonic wave;

B. a saturation amplifier for producing an alternating signal in response to said electrical signal, having a frequency corresponding to the frequency of said electrical signal, the excursions of which have a first amplitude whenever said electrical signal exceeds a predetermined reference amplitude and have a second amplitude less than said first amplitude whenever said signal is less than said predetermined reference amplitude;

C. an active filter for passing said alternating signal as an output signal having a frequency, the periodicity of which is within a predetermined pass-band, said pass-band having a lower limit which will reject turbulence type signals and an upper limit which will reject environmental signals like those of a ringing telephone; and

D. an alarm and indicator circuit for producing an alarm in response to said output signal, corresponding to a train of said first amplitude alternating signal excursions occurring within a predetermined time.