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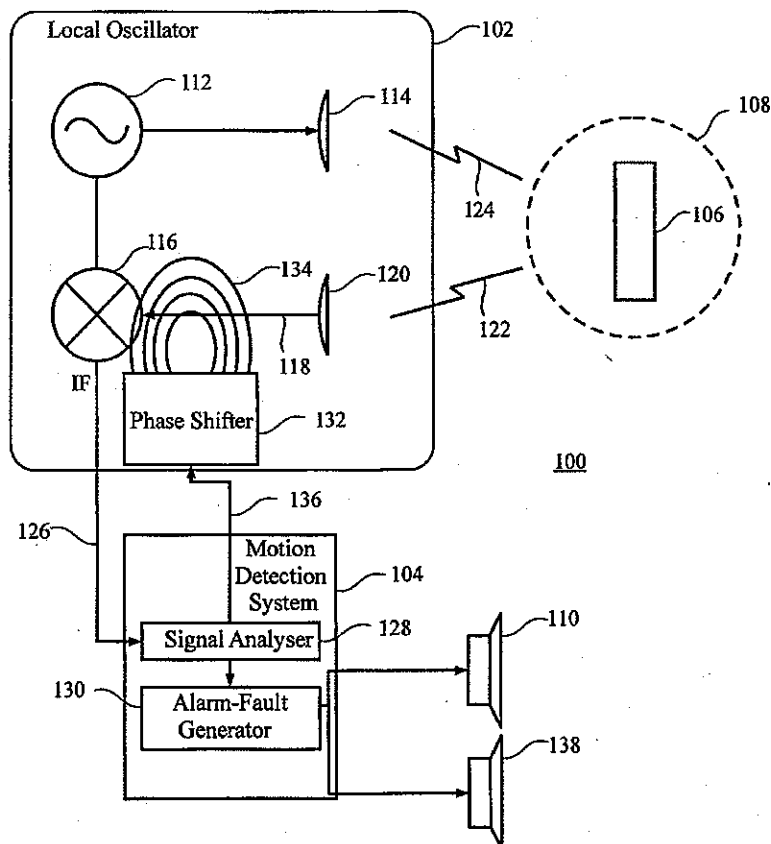
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(54) Title: MOTION DETECTOR



(57) Abstract: The present invention relates to a motion detector using the Doppler shift principle. The received signal may be a Doppler shifted version of a transmitted signal. Combining the phase and/or amplitude shifted version of the received signal and the signal from the local oscillator produces an IF signal that is indicative of the phase and/or amplitude shift.

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MOTION DETECTOR

Field of the Invention

The present invention relates to a detector and, more particularly, to such a detector comprising a self-
5 diagnosis capability.

Background to the Invention

Present day motion detectors rely upon the Doppler principle, as is well known within the art, to detect the presence of a moving object within a protected volume or
10 volume to be surveyed. Conventionally, such motion detectors use at least microwave technology, that is, typically X-band or K-Band signals transmitted and received via a transceiver. Post-reception, the received signals are suitably processed to identify the presence
15 of a Doppler signal that can be attributed to movement within the protected volume.

Relatively sensitive devices such as, for example, the mixer, which typically takes the form of a mixer diode, can be easily damaged by inappropriate handling or
20 excessive signal strengths. Therefore, care needs to be taken in the fabrication and the installation of the motion detectors. Notwithstanding any such care, the mixer diodes may, post-installation, be inappropriately exposed to signals or handling that may cause damage. It
25 will be appreciated that any such damage may, in the worst case, prevent the motion detector from operating correctly in that, from the perspective of the output of the mixer diode, there will be no change in the signal due to any Doppler shifted received signal.
30 Alternatively, the performance of the mixer diode may be degraded in some way so that it produces excessive noise, which reduces the sensitivity of the motion detector.

It is an object of the present invention at least to mitigate some of the problems of the prior art.

Summary of Invention

In accordance with an aspect of the present invention, there is provided a detector comprising a mixer for combining at least the first and second electro-magnetic signals to produce a combined signal having a predetermined characteristic; a conductor for coupling at least the first electro-magnetic signal to the mixer; and a device, disposed relative to the conductor, to impose, in response to an input signal, a variable load on the conductor to thereby vary at least one of the phase and magnitude of the first electro-magnetic signal; the variation being manifested in the predetermined characteristic of the combined signal.

In accordance with another aspect of the present invention, there is provided a method of operating a detector comprising a mixer for combining at least first and second electro-magnetic signals to produce a combined signal having a predetermined characteristic; a first conductor for coupling at least the first electro-magnetic signal to the mixer; and a device, disposed relative to the conductor, to impose, in response to an input signal, a variable load on the conductor to thereby vary at least one of the phase and magnitude of the first electro-magnetic signal; the variation being manifested in the predetermined characteristic of the combined signal; the method comprising the steps of generating first and second electromagnetic signals; applying the input signal to the device to vary the load imposed by the device on the conductor; and deriving a measure of the correct operation or otherwise from the combined signal.

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Preferably, embodiments of the present invention provide a detector a detector in which the device is physically unconnected with the conductor. Alternative embodiments are provided in which the device is physically connected with the conductor.

Preferably, an embodiment is provided in which the device comprises a semi-conductor device disposed adjacent to the conductor carrying the first signal. It will be appreciated that the semi-conductor device should be positioned sufficiently close to the conductor so as to be able to influence the electro-magnetic field of the signal being carried by the conductor.

In a preferred embodiment, the degree of influence exerted by the device varies with variations in the input signal. Preferably, the input signal is modulated at a predetermined frequency. The predetermined frequency is preferably between 10Hz and 80Hz, which frequencies are

typical Doppler frequencies that would be generated by a human moving within a protected volume. Furthermore, these are frequencies that the IF amplifiers in such a detector would pass. Additionally, the input signal is
5 arranged to switch the device between substantially open and substantially closed circuit conditions. Furthermore, the device is operable in response to the input signal to present substantially closed or open circuit conditions to the first electro-magnetic signal
10 carried by the conductor.

In preferred embodiments, the device does not radiate or generate an electro-magnetic field in response to the input signal. The device merely represents a variable load on the conductor.

15 In a preferred embodiment the semi-conductor device is a diode.

It will be appreciated that the output of the mixer, having had one of the input signals influenced by the device, can be used by a signal analysis system
20 comprising, for example, a micro-processor and associated software, to determine whether or not the mixer and/or the device as a whole is functioning correctly. Suitably, an embodiment additionally comprises a signal analyser for analysing the combined signal to determine
25 whether that combined signal has predetermined characteristics. In preferred embodiments, the predetermined characteristics include at least an oscillation having a frequency that is associated with the frequency of the input signal.

30 To test the operation of the mixer an appropriate input signal should be applied to the device. Suitably, an embodiment provides a signal generator for generating the input signal to be applied to the device for

influencing the electro-magnetic field.

It will be appreciated that the second signal fed into the mixer is conventionally a divided portion of the output of a local oscillator; the other portion having been, in operation, radiated by a transmit antenna. In the absence of motion, the RF signal on the input to the mixer is at the same frequency as the LO signal. The mixer then operates as a phase detector and produces a DC voltage at its output that is related to the phase difference between the LO and RF signals and the magnitude of the RF signal. Hence, by disturbing at least the phase and, preferably, the phase and magnitude of the RF input signal to the mixer, an output signal indicative of that disturbance will be produced by the mixer.

Brief Description of the Drawings

Embodiments of the present invention will now be described, by way of example only, with reference to the accompanying drawings in which:

figure 1 illustrates schematically a motion detection system having a self-diagnosis capability in accordance with a first embodiment of the present invention;

figure 2 illustrates a detector for use in such a motion detection system in accordance with an embodiment; and

figure 3 illustrates a detector for use in such a motion detection system in accordance with a further embodiment.

Description of the Preferred Embodiments

Referring to figure 1 there is shown schematically a motion detection system 100 comprising a detector 102 which co-operates with a detection system 104 to detect relative motion between the device and a body 106 within a monitored volume 108 and to produce a corresponding alarm signal via an output device 110 in response to the detection of any such relative motion. The output device may be an audio-visual output device.

The detector 102 comprises a local oscillator 112 for generating K or X-band microwave signals that are radiated into the monitored or protected volume 108 via a transmit antenna 114. A portion of the output of the local oscillator signal 112 is directed towards a mixer 116 which combines that portion with an RF input signal 122, carried on a conductor 118, that has been received by a receive antenna 120. Typically, in the presence of relative motion between the device and the body, the RF input signal 122 is a reflected and Doppler shifted version of the transmitted signal 124. The output of the mixer, that is, the IF signal 126, is input into the detection system 104 which, if appropriate, can instruct an alarm-fault generator 130 to generate an appropriate alarm signal to be output via the audio-visual output device 110.

The detector also comprises a device 132 for influencing the electro-magnetic field of the RF input signal being carried by the conductor 118. The device 132 is operable to present a variable load to the nearby microstrip 118 in response to an applied signal 136. As the signal 136 is applied to the device, its loading effect upon the nearby microstrip 118 changes, which, in turn, changes the electrical characteristics of the line 118 from the perspective of the RF signal. Preferably, the device 132 takes the form of a diode that, in

response to the applied signal 136, causes a change in the electro-magnetic field carried by the conductor 118. In particular, the device influences the phase of the RF input signal (at the RF input port) of the mixer 116.

5 In the absence of motion, the mixer 116 acts as a phase detector and produces a DC output signal in response to receiving an input signal on the port that would ordinarily receive the received signal 122, that is, on the RF input port of the mixer. This input signal
10 is a combination of the received signal 122 reflected from static objects within the protected volume 108 and signals generated within the detector 102 due to internal reflections.

Referring to figure 2 there is shown in greater
15 detail a circuit 200 for realising an embodiment of the detector 102. The circuit 200 comprises a local oscillator circuit 202, that is coupled, via a decoupling capacitor 204, to a transmit antenna feed portion 206 and a receive antenna portion 208 of the circuit. The device
20 also comprises a test portion 210. The various portions 202 to 210 are screened via appropriate planar metalisations 212 having holes drilled therein to suppress unwanted spurious electro-magnetic emissions from the various circuit elements.

25 A series of connection tabs 214 are provided to allow power to be supplied to the circuit elements 202 to 210 and to allow the IF signal to be received as well as to allow a test signal, that is, input signal, to be applied to the test portion 210. The connection tabs 214
30 comprise a ground connection tab 216 and an IF output connection tab 218. The IF output connection tab 218 also serves as the output for the signal generated as a result of testing the operation of the receive portion

208. It will be appreciated that the test diode 242 tests the whole of the operation of the detector, that is, the local oscillator, the mixer and the transmit and receive antennas. A test signal connection tab 220 is
5 arranged to provide the test signal to the test portion 210 of the device. Power is supplied to the local oscillator circuit 202 via a power connection tab 222.

The local oscillator circuit 202 comprises, in a preferred embodiment, a dielectric puck 224 disposed
10 adjacent to a pair of strip lines 226 and 228 that are connected to one another via the gate and drain of a FET transistor. Power is supplied to the transistor via the power connection tab 222 and a resistor 230. The output of the transistor is coupled via the decoupling capacitor
15 204 to the transmit and receive portions 206 and 208 where that power is divided in a predetermined ratio. The power carried by a microstrip line 232 of the transmit portion 206 is coupled via a slot in a ground plane (not shown), preferably, to a pair of patch
20 transmit antennas (not shown) as is well known within the art. An example of a detector within which embodiments of the present invention can be incorporated is shown in UK patent application no. GB2253108, the content of which is incorporated herein for all purposes.

25 Similarly, power is coupled to a microstrip line 234 of the receive portion via a corresponding slot in a ground plane (not shown) and an associated pair of patch receive antennas (not shown).

It can be appreciated that the diode mixer 236 of
30 the receive portion 208 receives power from the local oscillator via a corresponding microstrip line 238 and also from the microstrip line 234. The output of the mixer diode 236 is fed to the IF output tab 218 for

further processing by the detection system 104 and, more particularly, by a signal analyser 128.

The test portion 210, in a preferred embodiment, comprises the series arrangement of a resistor 240 and the test diode 242. The diode 242 is disposed within close proximity to a conductor or microstrip line 244 which couples power from the receive microstrip line 234 to the receive RF input of the diode mixer 236. The diode 242 is positioned sufficiently close to the microstrip line conductor 244 such that, in the presence of the input signal applied to the test signal connection tab 220, the variation in diode 242 characteristics is sufficient to vary the degree of influence experienced by the electro-magnetic field of the signal being coupled from the receive microstrip line 234 to the receive RF input of the diode mixer 236 in the vicinity of microstrip line 244. In a preferred embodiment, the electro-magnetic field perturbation caused by the change in diode characteristics in response to the applied signal imparts at least a phase change to the signal carried by the microstrip line 244. As the microstrip line 244 couples power to the RF port of the mixer, that is, the receive RF input of the diode mixer 236, a corresponding phase change occurs at the RF port of the mixer.

It will be appreciated in the absence of motion, that is, in the absence of the received signal being a Doppler shifted version of the transmitted signal, that the mixer diode 236 operates as a phase detector which generates a DC voltage that is dependent upon the relative phases and magnitudes of the signals present at the local oscillator input port and the RF input port of the mixer. The two signals are in fact each the resultant of a vector summation of all signals appearing at each of

the two ports. Therefore by influencing one of those signals, as in the preferred embodiment, the phase of the resultant signal at the RF input port could be changed. In turn this will change the DC voltage present on the IF
5 output tab 218.

Preferably, the test signal applied to the test signal connection tab 220 is arranged to be a TTL signal (0V to +5V) at a frequency that is within the bandwidth of the amplifiers contained within the signal analyser
10 128 that is connected to the IF output tab 218. For example, embodiments may use a test signal having a frequency of 30Hz.

The detection system 104 uses the signal analyser 128 to monitor the IF output 218 to determine whether or
15 not an intrusion into the protected volume 108 has been detected during conventional operation of the system 100. In the event that the signal analyser 128 determines that an intrusion into the protected volume 108 has been detected, the signal analyser 128 instructs the alarm-
20 fault signal generator 130 to produce at least one of an audible or visual alarm signal via the output device 110 or to output an alarm condition signal for further processing by, for example, a central control centre.

However, during a test mode of operation of the
25 detection system, the signal analyser 128 supplies an appropriate test signal to the test signal connection tab 220 during the normal operation of the detector 102, that is, during the conventional transmit and receive operations of the detector 102. The signal analyser 128,
30 again, monitors the IF output tab 218 and in the absence of the IF output signal meeting predetermined criteria, the signal analyser 128 instructs the alarm-fault generator 130 to produce a fault indication signal that

is output via a fault indicator 138. It will be appreciated that the testing preferably takes place in the absence of motion of a body within the protected volume. The predetermined criteria include the magnitude of the IF signal being disposed above or below a particular threshold. The fault indication signal can equally well or additionally be output to a central control centre.

Preferably, the test signal generated in the embodiments of the present invention does not saturate any IF amplifiers that may be present. For example, the input signal may be arranged to produce a $3V_{pk-pk}$ signal at the output of the IF amplifier. It will be appreciated that the signal output by the mixer will vary according to whether or not an object enters the protected volume. Therefore, by applying the test signal and looking for a deviation from an anticipated peak-to-peak voltage output signal from the IF amplifiers, a change in the presence or otherwise of an object within the protected volume may be detected. Therefore, if an object enters a protected volume and becomes stationary, when the testing is applied, rather than the monitoring system detecting the anticipated, or previous equilibrium, voltage level, a new voltage level will be detected. The change in the voltage provides an indication that the scene has changed, that is, that one or more objects have been removed from or introduced into the protected volume since the last investigation by the monitoring system 104.

Advantageously, the correct operation or otherwise of the detector 102 can be monitored in a predetermined and controlled manner and also in the absence of external test equipment that is conventionally used to monitor such operation.

Figure 3 illustrates a detector 300 for use in such a motion detection system in accordance with a further embodiment. The detector 300 of figure 3 is substantially similar to that of figure 2, with like reference numerals being associated with like elements, which perform substantially the same functions. Figure 3 illustrates a number of possible positions for the loading device, that is, the diode, in preferred embodiments. It can be appreciated that the diode can be positioned at one of five locations D1-1 to D1-5 associated with the RF receive path and two additional locations D1-6 and D1-7 associated with the local oscillator signal path. One skilled in the art will realise that these diodes may be selectively used or selectively provided as part of the circuit as they see fit. Therefore, in some embodiments, the monitoring system has the option of using one or more diodes in a testing procedure both jointly and severally. The two diodes positions D1-2 and D1-3 adjacent to the RF microstrip 244 are used to provide increased loading on that microstrip 244. The diode positions D1-4 and D1-5 adjacent to the slot 234 are arranged to have a significant influence on the RF signal passing through the slot. The final RF diode position D1-1 is adjacent to the "U" of the mixer.

Two diode positions are provided adjacent to the LO input. These positions are D1-6 and D1-7. Preferably, these diode positions are orthogonal to each other.

The diodes in the various positions may be used jointly or severally in testing the detector or investigating the protected volume.

It will be appreciated that a conventional diode, such as a BAS 16, can be used in the preferred

embodiments. However, the embodiments are not restricted to such an arrangement. Embodiments can equally well be realised in which other devices could be used such as, for example, a microwave diode, a FET, a further mixer or the like, providing the characteristics of the device vary in response to an applied test signal in such a manner as to influence the electro-magnetic field carried by the microstrip lines to the RF input of the mixer.

Although the above embodiments have been described with reference to detecting movement within a protected volume, the present invention is not limited to such an application. It will be appreciated by those skilled in the art that the invention is equally applicable to relative motion between the detector and a body whether the body is stationary and the detector is moving or both the body and detector are moving relative to each other.

The above embodiments have been described with reference to a device that influences or modifies the electro-magnetic field carried by the conductor. It does not radiate electro-magnetic energy as a microwave oscillator would for example, at least not intentionally or not to a sufficient degree to influence the field carried by the conductor. However, it will be appreciated that embodiments of the present invention can be realised in which the device does radiate an electro-magnetic field, in response to an input signal or otherwise, which influences the signal or electro-magnetic field present at the RF input port of the mixer. The field present at that port will be generated by superposition of the generated field and the received RF field. This superposition may be in addition to the influencing of the field described above in the preferred embodiments.

Although the above embodiments have been described with reference to influencing the RF signal, embodiments are not limited to such arrangements. Embodiments can equally well be realised in which the device is disposed sufficiently close to one of the other microstrip lines leading to the mixer to influence electro-magnetic signals carried by those lines. Again, any such influence will manifest itself in a change in the output signal of the IF port of the mixer. For example; the device may be disposed so as to influence the signals carried by the local oscillator microstrip line that leads to the local oscillator port of the mixer. By influencing the characteristics of this line, the return loss or reflection coefficients for this line may be influenced. This, in turn, may lead to corresponding variations in the conversion loss for the mixer. That is, if the conversion loss of the mixer varies due to the influence exerted by the diode on the conductor, then the dc output at the IF port, due to the mixer acting as a phase detector, when there is no movement within the protected volume, will also vary thereby providing an indication that the detector is functioning correctly.

The reader's attention is directed to all papers and documents which are filed concurrently with or previous to this specification in connection with this application and which are open to public inspection with this specification, and the contents of all such papers and documents are incorporated herein by reference.

All of the features disclosed in this specification (including any accompanying claims, abstract and drawings) and/or all of the steps of any method or process so disclosed, may be combined in any combination, except combinations where at least some of such features and/or steps are mutually exclusive.

Each feature disclosed in this specification (including any accompanying claims, abstract and drawings) may be replaced by alternative features serving the same, equivalent or similar purpose, unless expressly stated otherwise. Thus, unless expressly stated otherwise, each feature disclosed is one example only of a generic series of equivalent or similar features.

The invention is not restricted to the details of any foregoing embodiments. The invention extends to any novel one, or any novel combination, of the features disclosed in this specification (including any accompanying claims, abstract and drawings), or to any novel one, or any novel combination, of the steps of any method or process so disclosed.

CLAIMS

1. A detector comprising a mixer for combining at least the first and second electro-magnetic signals to produce a combined signal having a predetermined characteristic; a first conductor for coupling at least the first electro-magnetic signal to the mixer; and a device, disposed relative to the conductor, to impose, in response to an input signal, a variable load on the conductor to thereby vary at least one of the phase and magnitude of the first electro-magnetic signal; the variation being manifested in the predetermined characteristic of the combined signal.
2. A detector as claimed in claim 1, in which the device is physically unconnected with the conductor.
3. A detector as claimed in either of claims 1 and 2, in which the device is operable to change the phase of the first electro-magnetic signal.
4. A detector as claimed in any preceding claim, in which the device comprises a semi-conductor device, preferably a diode.
5. A detector as claimed in any preceding claim, further comprising a signal generator for generating the input signal.
6. A detector as claimed in any preceding claim, further comprising a transceiver for transmitting and receiving electro-magnetic signals.
7. A detector as claimed in claim 6, in which the transceiver comprises at least one of a transmit

5 antenna and a receive antenna for transmitting an electro-magnetic signal and receiving a received signal respectively; the received signal being derived from the transmitted electro-magnetic signal.

8. A detector as claimed in claim 7, in which the first electro-magnetic signal is derived from the received signal.
9. A detector as claimed in claim 7, in which the first electro-magnetic signal is derived from the transmitted signal.
10. A detector as claimed in any of claims 7 to 9, in which the second signal is derived from the received signal.
11. A detector as claimed in any of claims 7 to 9, in which the second signal is derived from an oscillator for generating the transmit signal.
12. A detector as claimed in any preceding claim, further comprising a signal analyser for monitoring the predetermined characteristic of the combined signal to determine the correct operation or otherwise of at least one element of the detector.
13. A detector as claimed in claim 12, in which the at least one element is at least one of a mixer, transmitter, oscillator and receive portion.
14. A detector as claimed in any preceding claim, in which the device does not radiate an electro-magnetic field in response to the input signal.
15. A detector as claimed in any of claims 1 to 14, in which the device is arranged to radiate an electro-

magnetic field in response to the input signal.

- 5 16. A detector as claimed in any preceding claim, in which the conductor is an RF conductor leading to an RF port of the mixer and the first electro-magnetic signal is an RF signal.
- 10 17. A detector as claimed in any preceding claim, in which the conductor is a local oscillator conductor leading to a local oscillator RF port of the mixer and the first electro-magnetic signal is a local oscillator signal.
18. A detector device as claimed in claim 17 in which the device is operable, in response to the input signal, to influence a conversion loss of the mixer
- 15 19. A detector substantially as described herein with reference to and/or as illustrated in the accompanying drawings.
- 20 20. A motion detection system comprising a detector as claimed in any preceding claim.
21. A method of operating a motion detection device substantially as described herein with reference to and/or as illustrated in the accompanying drawings.
- 25 22. A method of operating a detector comprising a mixer for combining at least first and second electro-magnetic signals to produce a combined signal having a predetermined characteristic; a first conductor for coupling at least the first electro-magnetic signal to the mixer; and a device, disposed relative to the conductor, to impose, in response to an input signal, a variable load on the conductor to thereby vary at least one of the phase and magnitude of the first electro-magnetic signal; the variation being
- 30

manifested in the predetermined characteristic of the combined signal; the method comprising the steps of generating first and second electromagnetic signals; applying the input signal to the device to
5 vary the load imposed by the device on the conductor; and deriving a measure of the correct operation or otherwise from the combined signal.

23. A method as claimed in claim 22, in which the first electromagnetic signal is a received RF signal and
10 the second electromagnetic signal is a local oscillator signal.

24. A method as claimed in either of claims 22 and 23, in which the predetermined characteristic is a phase characteristic.

15 25. A method as claimed in any of claims 22 to 24 in which the mixer is operable as a phase detector.

26. A method as claimed in any of claims 22 to 25 further comprising the step of operating the device, in response to the input signal, to produce a
20 predetermined circuit condition experienced by at least one of the first and second electromagnetic signals.

27. A method as claimed in claim 26, in which the predetermined circuit condition is an open circuit
25 condition.

28. A method as claimed in claim 26, in which the predetermined circuit condition is a closed circuit condition.

29. A method as claimed in any of claims 22 to 28,
30 further comprising the step of applying the input signal to influence a performance characteristic of

the mixer.

30. A method as claimed in claim 29 in which the performance characteristic is a conversion loss.

5 31. A method as claimed in any of claims 22 to 30, in which the detector comprises a second conductor for coupling at least the first electro-magnetic signal to the mixer; and a second device, disposed relative to the second conductor, to impose, in response to a second input signal, a variable load on the
10 conductor to thereby vary at least one of the phase and magnitude of the first electro-magnetic signal; the variation being manifested in the predetermined characteristic of the combined signal; the method further comprising the step of applying the second
15 input signal to the device to vary the load imposed by the device on the conductor.

32. A method as claimed in claim 31, further comprising the step of selectively applying the first and second input signals to the device and second device
20 respectively.

33. A method as claimed in either of claims 31 and 32, in which the first and second conductors are one and the same.

25 34. A method of detecting the presence of an object within a monitored volume using a detector as claimed in any of claims 1 to 19; the method comprising the steps of generating first and second electromagnetic signals; applying a first input signal to the device to vary the load imposed by the
30 device on the conductor; storing first data representing at least one characteristic of the combined signal; applying a second input signal to

the device to vary the load imposed by the device on the conductor; storing second data representing at least one characteristic of the combined signal; comparing the first and second data to detect the presence or otherwise of the object within the protected volume; and determining whether or not the object is present from the comparison.

35. A method as claimed in claim 34, in which the first and second input signals are substantially identical.

36. A method of operating a detector substantially as described herein.

37. A method of operating a detector substantially as described herein with reference to and/or as illustrated in the accompanying drawings.