

[54] TRANSMISSION LINE PRESENCE SENSOR

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[73] Assignee: **Sperry Rand Corporation**, New York, N.Y.

[22] Filed: **Oct. 20, 1971**

[21] Appl. No.: **190,842**

[52] U.S. Cl. **340/258 C, 324/52, 340/38 R**

[51] Int. Cl. **G08b 13/26**

[58] Field of Search **340/258 R, 258 C, 340/258 D, 38 R, 38 L, 250 R; 343/5 PD; 324/52; 325/43**

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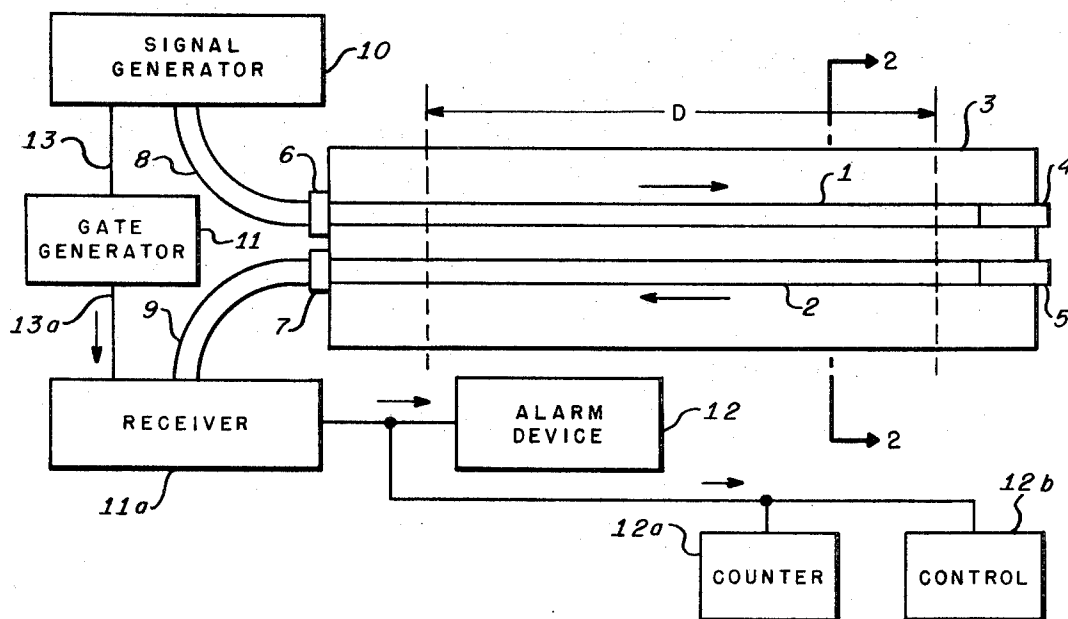
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[57] ABSTRACT

A pulse generator-receiver system for detecting the presence or proximity of objects including persons employs transmission of short base-band or subnanosecond electromagnetic pulsed signals and reception thereof within a dispersionless, broad band transmission line energy coupling system with a receiver circuit cooperating with a biased semiconductor device located within the transmission line coupling system for instantaneously detecting substantially the total energy of each coupled base-band pulse and for providing corresponding outputs suitable for indication of the presence of such proximate objects.

18 Claims, 16 Drawing Figures



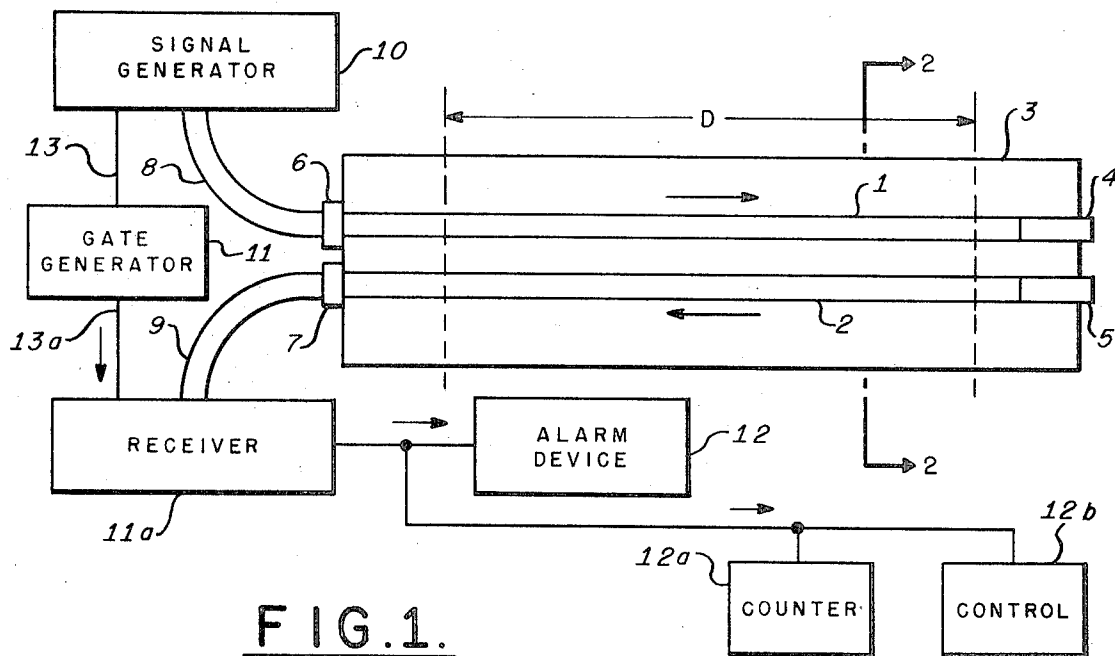


FIG. 1.

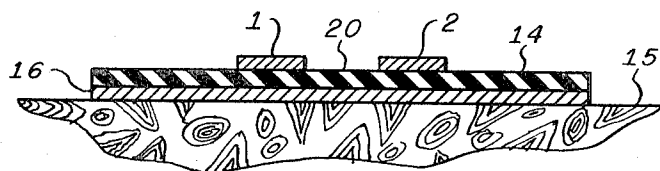


FIG. 2.

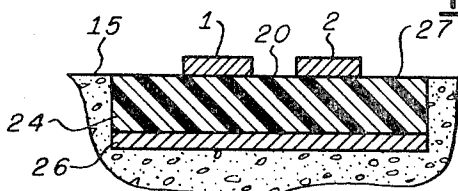


FIG. 3.

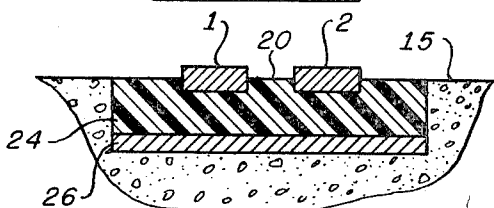


FIG. 4.

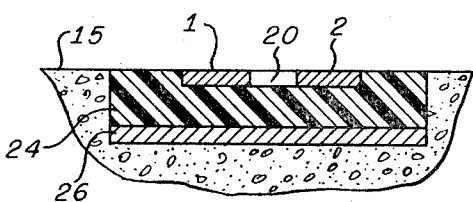


FIG. 5.

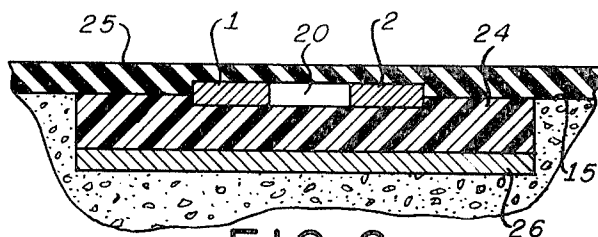


FIG. 6.

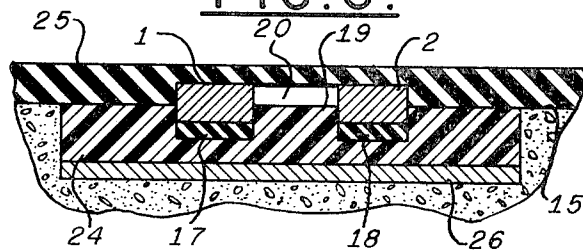


FIG. 7.

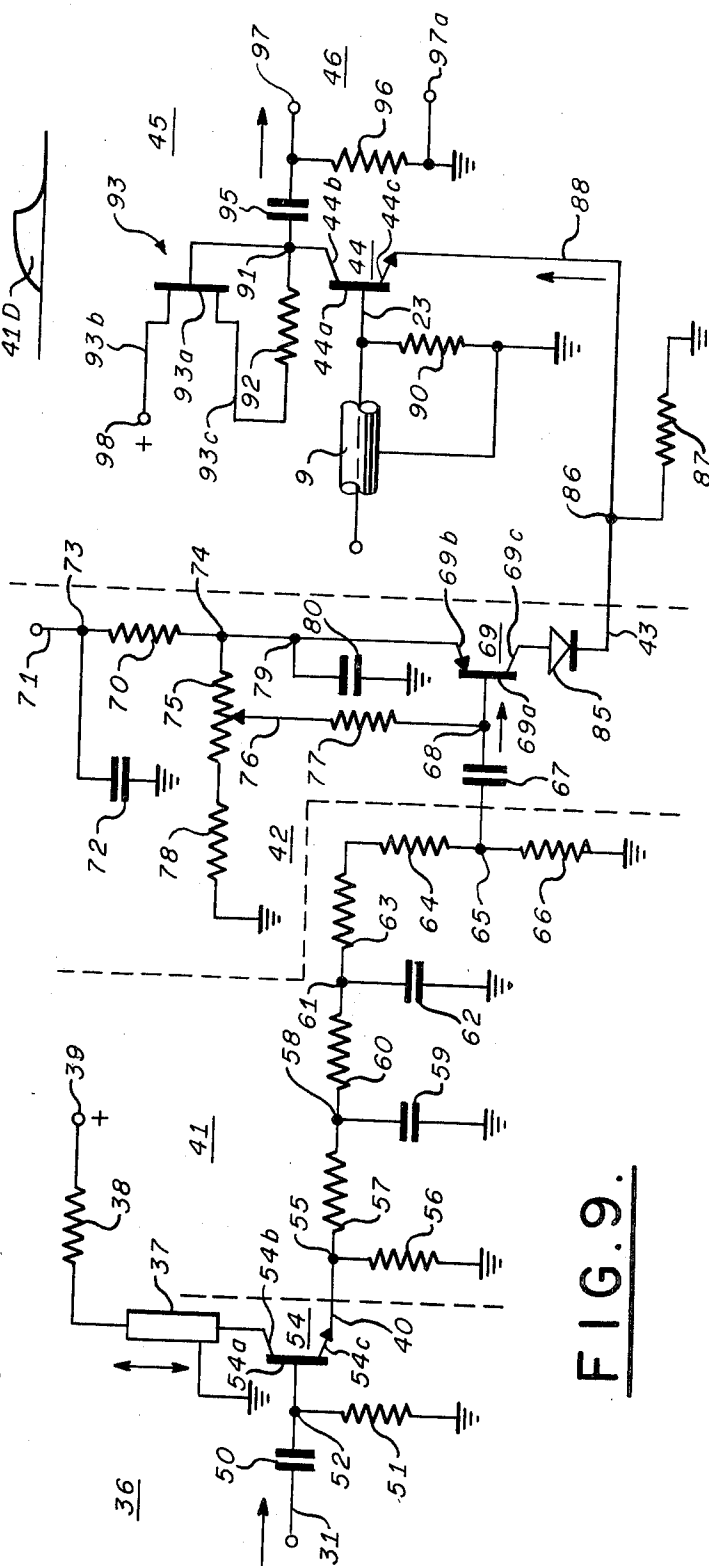
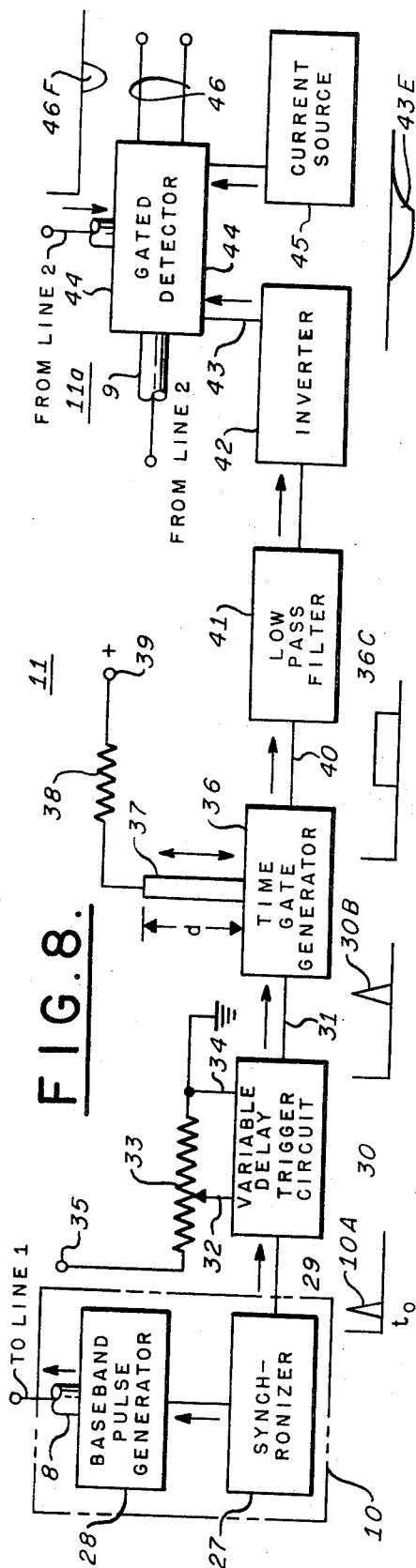


FIG. 10.
RESPONSE WITH
NO OBJECT PRESENT

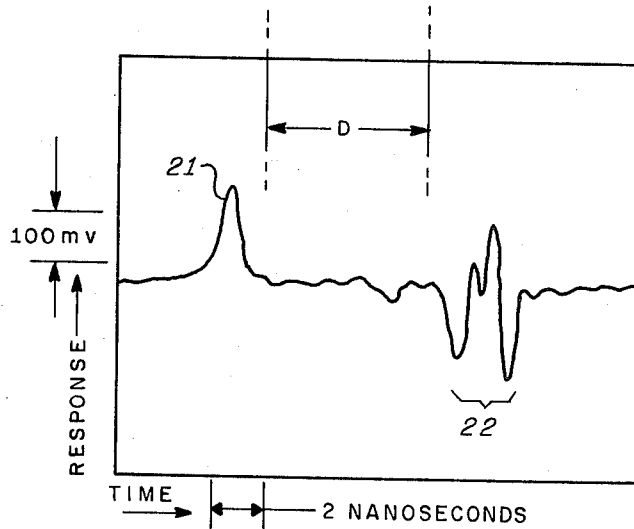


FIG. 11.
RESPONSE WITH
TIRE ON SENSOR GAP

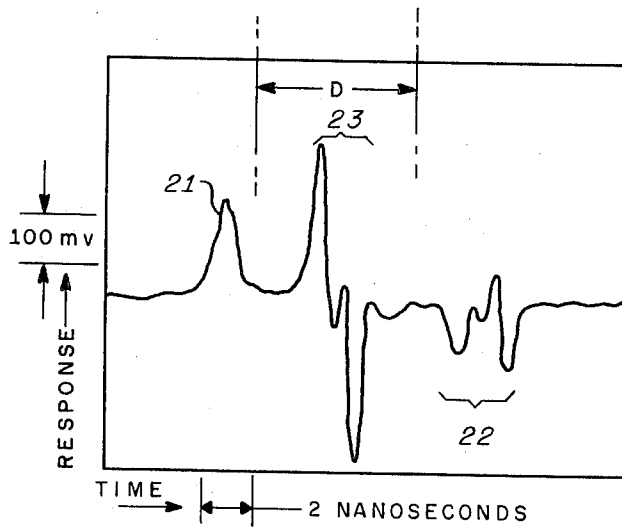
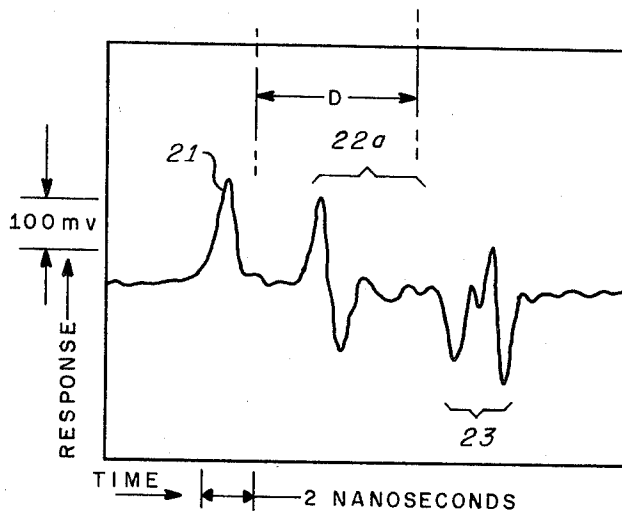


FIG. 12.
RESPONSE WITH
LEATHER SOLE OF SHOE
ON SENSOR GAP



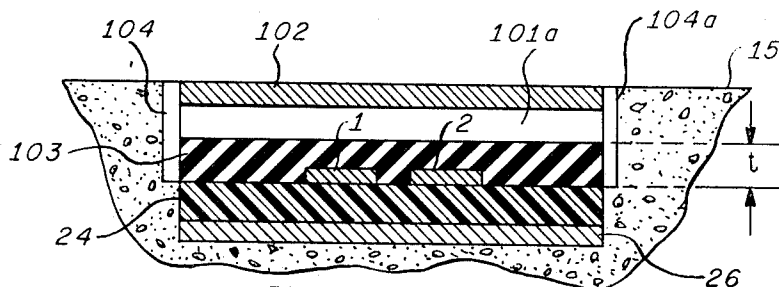


FIG. 13.

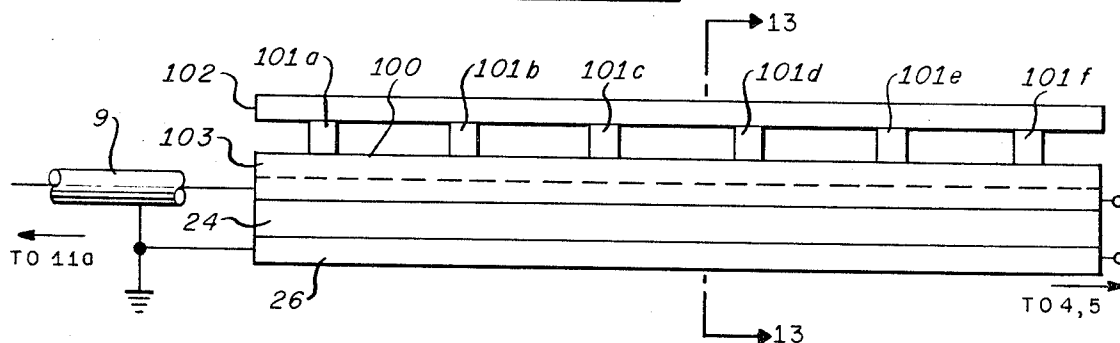


FIG. 14.

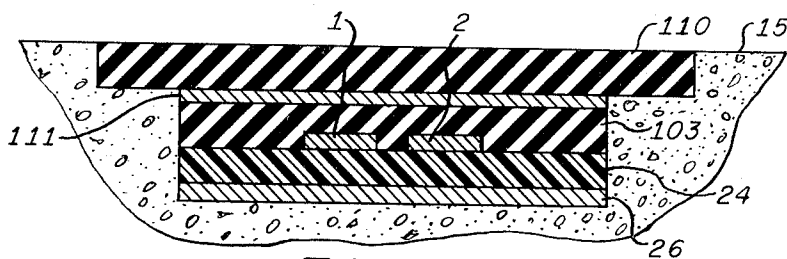


FIG. 15.

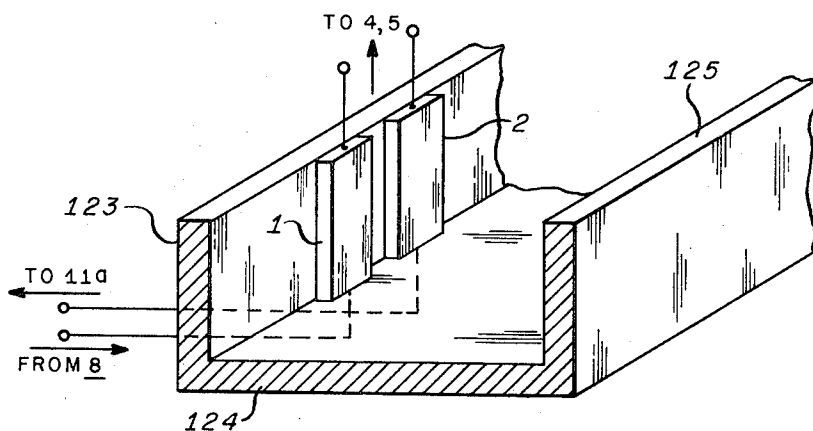


FIG. 16.

TRANSMISSION LINE PRESENCE SENSOR

CROSS REFERENCE TO COPENDING APPLICATIONS

This application relates to subject matter disclosed in application Ser. No. 123,720, filed Mar. 12, 1971, now U.S. Pat. No. 3,662,316, and applications Ser. Nos. 134,990, filed Apr. 16, 1971, and 137,355, filed Apr. 26, 1971.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to radio systems for the detection of the presence or of other characteristics of objects such as persons or vehicles and more particularly relates to the sensing of the presence of such objects as may move through a door or passage way or along a traffic lane. Detection is accomplished by a novel transmission line energy coupling system, excited by base-band or subnanosecond electromagnetic signals, wherein changes in the level of energy coupling are caused by the passage of the object to be sensed.

2. Description of the Prior Art

In prior art presence detectors operating with radio frequency signals, it is common practice to employ relatively high radio energy signal levels to ensure that the passage of an object such as a person or vehicle is detected without failure. Such systems tend to be expensive to operate, requiring radio frequency generators which consume considerable power. In consequence of the level of the power, undesired leakage radiation in excess of government standards may occur. A further consequence is that such prior art systems are often susceptible to interference because of radiations generated by neighboring radio frequency signal sources.

Accordingly, prior art presence detector systems may not generally be operated in a wave band already allotted to conventional transmitters and receivers. More particularly, there is not known in the prior art a radio frequency presence detector system of the just described type which can operate at very low or legal power levels in such wave bands without it itself being the victim of intolerable interference. Furthermore, there is not known in the prior art a radio frequency presence detector system such as described in the foregoing and also capable of employing signals having an extremely wide frequency spectrum without interfering with the transmission of ordinary radio communication signals.

SUMMARY OF THE INVENTION

The invention pertains to radio object presence detection systems of a novel kind so constructed and arranged as to afford sensing of objects without interference with conventional types of radio communication systems, and, in turn, being substantially unaffected in normal operation by the radiations of other radio frequency systems or by ambient electrical noise signals.

While continuous wave or pulsed radio frequency signals may also be used with advantage in the novel presence detector, it will be preferred in many applications to use very short impulse signals. For example, a transmitter appropriate for exciting the transmission line coupling system may employ a non-dispersive transmission line and a charging-discharging system for the cyclic generation of such base band pulses. The

novel coupling or sensing system is also constructed of similarly non-dispersive transmission line elements.

Cooperating with the sensor is a receiver suitable for detecting and utilizing such coupled short base-band electromagnetic pulses the receiver also employing a dispersionless transmission line, with a utilization circuit cooperating with a semiconductor element located within the receiver transmission line for instantaneously detecting substantially the total coupled energy of the base-band pulse and for supplying a corresponding output suitable for application in presence indicating or control circuits. The receiver transmission line system supplies substantially the total energy of each undistorted coupled base-band pulse directly to the receiver detector; thus, the receiver is adapted to operate successfully with base-band pulse signals having a very wide spectral extent. Further, the receiver may operate with base-band pulse signals having spectral components each of such low individual energy content as to escape detection by conventional relatively narrow band receivers. The total energy in each base-band pulse can, however, be relatively larger than the level of noise or other interfering pulses or signals in the vicinity of the novel receiver. Thus, by appropriately adjusting the output level of the base-band pulse signal generator and the sensitivity or threshold of the detector receiver, base-band signals not affecting other receivers are readily generated, coupled, and detected without the receiver, in turn, being affected in any substantial degree by other radio energy transmissions. The coupling and processing of the coupled signals is accomplished, according to the invention, by simple base-band signal processing circuits, thus avoiding the need for signal frequency conversion and avoiding the problems associated with alignment and operation of conventional radio and intermediate frequency amplifiers.

The novel base-band object presence sensing system operates with very low energy consumption, so that power supply cost and size are minimized. Furthermore, with such low power operation, inexpensive components find long life use throughout the pulse generator. The receiver circuits are similarly categorized, all constituent elements being of simple nature and otherwise inexpensive of installation, maintenance, and operation, adapting readily to cooperative use with conventional alarm, display, or control equipment.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a plan view of a preferred embodiment of the invention showing components thereof and their electrical interconnections.

FIG. 2 is an elevation cross section view taken at the line 2—2 of FIG. 1.

FIGS. 3 through 7 illustrate alternative forms of the structure of FIG. 2.

FIG. 8 is a block diagram of the receiver 11 of FIG. 1.

FIG. 9 is a detailed circuit diagram of a portion of the receiver apparatus of FIG. 8.

FIGS. 10 to 12 are graphs showing representative wave forms useful in explaining the operation of the system.

FIG. 13 is an elevation cross section view taken at the line 13—13 of FIG. 14.

FIG. 14 is an elevation view of an alternative form of FIG. 1.

FIG. 15 is an elevation cross section view of an alternative form of the construction shown in FIG. 13.

FIG. 16 is a fragmentary perspective view, partly in cross section, showing a further application of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The transmission line object-presence sensor shown in FIG. 1 detects the actual presence of an object traversing it in contacting, substantially contacting, or other relation by measuring a change caused by the presence of the object in the amplitude of the signal coupled between the substantially parallel high frequency transmission line conductors 1 and 2. The transmission line system comprising conductors 1 and 2 may be of the parallel plate or strip transmission line type conventionally used in the high frequency art. In particular, the preferred transmission line system will be one capable of propagating electromagnetic energy in the low loss transverse electromagnetic or TEM mode.

The high frequency conductors 1 and 2 are affixed to the top surface of a substrate sheet 3 of low loss dielectric material. A metallic ground conducting plane (not seen in FIG. 1) is affixed to the bottom of sheet 3. At one end of the transmission line conductors 1 and 2 are respectively located conventional impedance matching connectors 6 and 7 for coupling to respective conventional input and output transmission lines 8 and 9, which latter lines may be coaxial transmission lines. At the end of the substrate sheet 3 opposite connectors 6 and 7, the strip conductors 1 and 2 are coupled to impedance matched terminating resistors or energy absorbers 4 and 5 for preventing reflections. Signal generator 10 is adapted to supply excitation signals to transmission line conductor 1 via coaxial line 8 and also to supply synchronizing signals, if required, to the gate generator 11 over conductor 13. The output of gate generator 11 may be supplied via lead 13a to control the receiver 11a. Receiver 11a is coupled to transmission line conductor 2 via coaxial line 9 and supplies useful output signals to utilization device 12 when an object contacts conductors 1 and 2 or otherwise distorts the coupling between conductors 1 and 2. It is recognized that utilization device 12 may be any conventional type of alarm, latchable or otherwise. Simultaneously or alternatively, a counter 12a or other display may be employed as the utilization device. Similarly, a control device 12b may be used, including an actuator for opening a door or other servo devices.

Although other types of apparatus, such as pulsed or continuous wave oscillator systems, may be used to play the role of signal generator 10, it is preferred to employ a short or base-band pulse generator for that purpose. One such generator for producing short base-band pulses is disclosed by G. F. Ross in the U.S. Pat. No. 3,402,370 for a "Pulse Generator," issued Nov. 30, 1965 and assigned to the Sperry Rand Corporation. Switching systems adapted for generating base band pulses are described in the H. C. Maguire U.S. Pat. No. 3,564,277 for a "Coaxial Line Reed Switch Fast Rise Signal Generator with Attenuation Means Forming Outer Section of the Line," issued Feb. 16, 1971 and in the K. W. Robbins, G. F. Ross U.S. Pat. No. 3,569,877 for a "High Frequency Switch," issued Mar.

9, 1971, both patents being assigned to the Sperry Rand Corporation.

The receiver 11a of FIG. 1 is a receiver again preferably designed for operation with short base-band electromagnetic pulses; it may be of the general type described by K. W. Robbins in the U.S. Pat. Application Ser. No. 123,720 for a "Short Base-Band Pulse Receiver," filed Mar. 12, 1971, issued as U.S. Pat. No. 3,662,316 May 9, 1972 and assigned to the Sperry Rand Corporation. A preferred base-band receiver system, adapted for synchronous operation with generator 10, is disclosed by G. F. Ross in the U.S. Pat. application Ser. No. 137,355 for an "Energy Amplifying Selector Gate for Base Band Signals," filed Apr. 26, 1971 and also assigned to the Sperry Rand Corporation.

As noted above, the presence sensor may consist of two spaced parallel strip conductors 1 and 2 placed across the path of the object to be detected. Detection of the object (a wheel or a vehicle or a shoe on a human foot, for example, occurs when the presence of the object causes a change or distortion in the electromagnetic-field-coupling pattern between conductors 1 and 2. The sensor elements may, for instance, be placed in a shallow groove in the surface of a road or walk or it may be fastened directly to such a surface by a non-conducting cement such as an epoxy or other similar cement. A similar material may be used to form a protective coating over conductors 1 and 2.

In a simple arrangement, the sensor may take the form shown in FIG. 2, where conductors 1 and 2 are thin flexible conducting foils affixed to a flexible low-loss sheet 14 of material such as rubber or cloth that may be unrolled across the path to be monitored and even fastened to the surface 15 of the flooring material. A thin film 16 of conductive foil is generally fastened to the bottom of the sensor before it is placed on floor 15. It will be recognized that the dimensions and proportions shown in the various figures are exaggerated for convenience in making the drawings clear, and that the dimensions and proportions are therefore not necessarily those that would be used in actual practice. For example, the vertical dimensions in the cross section of FIG. 2 are exaggerated, since conductors 1, 2, and 16 may be made of relatively thin metal foil. While conventional cloth strip transmission line is lossy, it may be successfully used according to the invention to monitor a relatively narrow passage way.

Conventional low loss strip transmission line is readily available in rigid form and may be laid in a shallow groove across the path to be monitored, as in FIG. 3. Such conventional strip lines have good thermal stability and relatively little susceptibility to environmental effects. Evidently, strip transmission lines of superior quality may be constructed by a suitable choice of preferred conductive and dielectric materials, of which a wide variety is readily available.

In the system of FIG. 3, the dielectric slab 24 may constitute a solid non-flexible low loss material such as a ceramic material coated on one side with a conductive ground plane 26 made of copper and supporting on an upper surface 27 the spaced copper strip lines 1 and 2. The upper surface 27 of dielectric slab 24 is arranged to be flush with the surface 15 of a non-conducting floor or roadway surface. It is seen that an object such as a vehicle tire rolling over conductors 1 and 2 changes or distorts the electromagnetic-field-coupling pattern between strip lines 1 and 2. To the extent that

the pressure on the tire due to the weight of the vehicle causes the tire to flex into the gap 20 between conductors 1 and 2, the degree of electromagnetic-field-coupling may be additionally altered over that when gap 20 is occupied only by air. In FIGS. 4 and 5, it is illustrated that the strip conductors 1 and 2 may be partially or totally inlaid within the surface of dielectric slab 24, leaving gaps 20 of corresponding shape. In some applications, the configuration of FIG. 5 may be preferred, since the upper surfaces of strip conductors 1 and 2 are flush with the surface 15 of a floor or walk or road pavement.

In many instances, it may be desirable to protect the strip transmission line sensor from water or dirt or the like. In others, such as those in which the sensor is used to monitor the passage of people, it may be particularly desirable to hide the transmission line conductors 1 and 2 from view, as is accomplished in the apparatus of FIGS. 6 and 7.

In FIG. 6, for example, the arrangement of ground plane 26, dielectric slab 24, and strip transmission lines 1 and 2 is similar to the arrangement used in FIG. 4, lines 1 and 2 being partly inlaid within dielectric slab 24. A flexible rubber or other covering sheet or rug 25, such as made of carpeting or other material, may be used to hide the sensor from view. The sheet 25 may be used without modification, or may be provided with a groove for accommodating conductors 1 and 2 and for covering gap 20. It is clear that the weight of a person stepping on the carpet above conductors 1 and 2 will depress sheet 25 into gap 20, changing the character of the dielectric within gap 20 and consequently altering the electromagnetic-field-coupling pattern between strip conductors 1 and 2. In FIG. 7, the same end result is accomplished by employing strips 17, 18 of sponge rubber or other readily compressible material underlying strip transmission conductors 1 and 2. A weight placed on the rubber mat or carpet 25 above conductors 1 and 2 will compress the strips 17 and 18, permitting strip transmission lines 1 and 2 to be pressed farther into dielectric slab 24. Consequently, more of the dielectric ridge 19 of slab 24 is projected into the gap 20 between conductors 1 and 2, again significantly altering the electromagnetic-field-coupling pattern between conductors 1 and 2. Other transmission line configurations which will respond to the presence of an object having at least a predetermined weight according to the invention will be apparent to those with skill in the high frequency art.

As noted above, the transmission line systems may be constructed of flat metal, electrically-conducting strips 1 and 2 placed parallel to each other on a suitable dielectric substrate. The widths of the conductor strips 1 and 2 are determined by the desired impedance of the transmission lines. For example, if the connecting coaxial cables 8 and 9 are 50 ohm lines, 50 ohm strip lines 1 and 2 will be chosen. The width of gap 20 is selected according to the desired degree of coupling between conductors 1 and 2 and primarily upon the type of devices chosen for generator 10 and receiver 11a. For example, gap widths of from 1/32 to 11/16 inches have been found useful in various circumstances.

As noted above, the apparatus of FIGS. 1 to 7 may be operated with continuous wave or pulsed excitation. In order to discuss fully a preferred form of the sensor system and its operation, it will be assumed that signal generator 10 is a base-band pulse generator having a

convenient repetition rate and producing electromagnetic impulses of subnanosecond duration. In this kind of system, a base-band pulse is generated and is coupled through line 8 to propagate down strip line 1. In a typical application, the pulses are of about 10 volts amplitude and are 0.3 nanoseconds in duration. The transmission line system including lines 1 and 2 acts in a manner similar to a conventional microwave directional coupler. A pulse from generator 10 is coupled into receiver 11a at the point near connectors 6 and 7 where lines 1 and 2 become parallel. This is pulse 21 of FIG. 10. When the pulse reaches terminal of line 1, most of it is absorbed in the terminating resistor 4. A small amount of energy is coupled into line 2 at the termination and is seen as pulse 22 of FIG. 10. This signal is minimized by the proper choice of terminating resistors 4 and 5 of FIG. 1. The separation between pulses 21 and 22 will be substantially $2L/c$ where L is the length of strip line 1 and c is the velocity of propagation of electromagnetic energy in the transmission line system. As seen in the representative experimental curve of FIG. 10, which is a representation of an actual cathode ray tube presentation, the region between pulses 21 and 22 will have only minor deviations from a substantially zero amplitude or fixed level.

When an object is present on or over or passes over the transmission line system 1, 2 at a local point along its length, a localized change is produced in the field-coupling pattern between lines 1 and 2 such as shown, for instance, in FIGS. 11 and 12. Part of the generator 10 pulse propagating down line 1 is directly coupled to line 2 at the local point because of the presence of the detected object and is propagated along line 2 into output coaxial line 9 and thence into receiver 11a. Such an event is represented by pulse 23 in the typical oscilloscope record shown in FIG. 11 of the response to a vehicle tire. Pulse 23 is characteristically a doublet appearing $2s/c$ seconds after the first pulse 21 where s is the distance between the connector (6, 7) end of the transmission line system and the location of the detected object. If two automobile tires contact conductors 1, 2, two doublet pulses will appear between pulses 21 and 22, separated by $2w/c$ seconds, where w is the distance between the tires. FIG. 12 presents a similar graph representing the response 22a to the presence of a leather sole of a shoe worn by a person.

The receiver 11a may be a threshold detector receiver of the type in which an avalanche or other transistor is used that is time gated by gate generator 11 to exclude spurious input pulses, such as pulses 21 and 23 of FIGS. 11 and 12. The output of such a receiver may be used to control an alarm indicator, counter, or other device such as door opener when employed as utilization device 12. Simple or latching alarms may be employed. FIGS. 8 and 9 illustrate a gating and receiver system particularly useful as the gated or selective receiver 11a.

In FIG. 8, the gate generator 11 and receiver 11a are shown in cooperative relation with a signal generator 10 which includes a system synchronizer 27 and base-band pulse generator 28 whose train of subnanosecond output pulses is coupled via coaxial line 8 to the strip transmission line 1. Synchronizer 27 also provides system synchronizing pulses 10A to the receiver via lead 29. For controlling operation of the receiver, the synchronizer pulse 10A is coupled by line 29 to a variable delay trigger circuit 30 for the purpose of generating on

output line 31 a corresponding pulse 30B. Pulse 30B may be generally similar in characteristics to pulse 10A, though delayed by an arbitrary time interval. Variable delay trigger circuit 30 may be any of several well known adjustable pulse delay circuits, including those, for instance, whose delay characteristic may be varied according to the setting of a tap 32 adjustable along potentiometer 33 relative to lead 34, an appropriate potential being supplied to the opposite end of potentiometer 33 from a voltage source (not shown) connected to terminal 35 and which may also be grounded at its opposite end.

Variable delay trigger circuit 30 serves to determine the initiation of the time gate, while time gate generator 36, whose input is supplied via line 31, determines the duration of the time gate. This duration is determined, as will be further explained in connection with FIG. 9, according to the length of transmission line 37, whose center conductor is adapted to supply certain necessary operating voltages via resistor 38 from terminal 39 to the active circuit elements of time generator 36. The time gate thus formed is the wave 36C.

Wave 36C is supplied by line 40 to low pass filter 41 whose function is to provide a moderate integration to wave 36C, removing any transients or over-shoots from the edges of wave 36C and thus preventing false operation of succeeding circuits. Wave 41D is the modified output of filter 41. Wave 41D is passed through inverter 42 to produce on line 43 the inverted or negative going wave 43E. Wave 43E is generally similar to wave 41D, but is inverted in polarity.

The inverted wave 43E is used to operate the time gated receiver-detector 44 along with current source circuit 45 which forms, as will be explained, the actual gating potential used to control flow of signals through the gated receiver-detector 44 from receiver input coaxial line 9 to output leads 46 (wave 46F). Gated detector 44 is normally desensitized; when a gating signal is present at the output of inverter 42, the gated detector 44 is made sensitive to the presence of millivolt signals appearing on the dispersionless transmission line 9 and propagated into gated detector 44 from transmission line 2. Such sensitivity produces an amplified selected or time gated output wave 46F on leads 46 of the order of 3 volts. Such a signal is adequate to operate conventional display or warning apparatus, such as a warning alarm or presence indicator or control of conventional type.

In FIG. 9, circuit details of the receiver are further illustrated, with elements which also appear in FIG. 8 bearing the same reference numerals as used in FIG. 8, including time gate generator 36, low pass filter 41, inverter 42, current source circuit 45, gated detector 44, and input coaxial line 9.

The output line 31 of variable delay trigger circuit 30 supplies wave 30B via a coupling capacitor 50 and the junction 52 to the base 54a of transistor 54, which transistor may be of the 2N5130 type. Junction 52, and therefore base 54a, is coupled to ground through resistor 51. The collector 54b of transistor 54 is coupled via the inner conductor of coaxial transmission line 37 of length d through resistor 38 to a source (not shown) of positive potential connected between terminal 39 and ground. The length d of open-circuited delay line 37 is adjusted according to the desired duration of the sampling or time gate wave 43E. The emitter 54c of transistor 54 provides an output connection via lead 40 to low

pass filter 41. In a representative circuit resistor 38 has the value of 47 K ohms, while the voltage on terminal 39 may be from +200 to +300 volts. Other avalanche transistor delay-line pulse generators of known type may be employed as the time gate generator 36.

The emitter 54c of transistor 54 is coupled to junction 55 to provide an input to low pass filter 41, which filter 41 is of generally conventional nature and whose components include in series relation junction 55, resistor 57, junction 58, resistor 60, junction 61, resistor 63, resistor 64, junction 65, resistor 66, and a ground connection. Junction 55 is coupled to ground via resistor 56 and the respective junctions 58 and 61 are coupled to ground through low pass filter capacitors 59 and 62. Junction 65 serves as an output terminal for the filter.

Junction 65 is coupled through the small coupling capacitor 67 to junction 68 of the inverter circuit 42 and thence to the base 69a of transistor 69, which may be of the 2N4258 kind. The emitter 69b of transistor 69 is coupled through a series circuit including junctions 79 and 74, resistor 70, and junction 73, to a source (not shown) of positive potential applied at terminal 71 and connected to ground at its opposite end. Junctions 73 and 79 are respectively coupled to ground via capacitors 72 and 80, while junction 74 is connected through potentiometer 75 and resistor 78 to ground. Capacitors 72 and 80 serve as radio frequency by-pass and decoupling elements in the conventional manner. The tap 76 of potentiometer 75 is connected through resistor 77 to junction 68. The collector 69c of transistor 69 is connected as an output of the inverter 42 through diode 85. The resistance network associated with potentiometer 75 serves to adjust the potential across resistor 87 which determines the steady state hold off bias on the detector.

Diode 85 is connected by line 43 to junction 86 through resistor 87 to ground and via line 88 to the emitter 44c of time gated detector transistor 44, which may be of the 2N5130 type. The collector 44b of transistor 44 is connected through junction 91 to the gate electrode 93a of field effect transistor 93, which latter may be of the 2N4274 type. The drain electrode 93b of transistor 93 is connected to a source (not shown) of positive potential applied at terminal 98 which may be of the order of +75 to +100 volts with respect to its grounded terminal. The source electrode 93c of transistor 93 is coupled via resistor 92 to junction 91 and via coupling condenser 95 to the output 46 consisting of output leads 97 and 97a connected across load resistor 96.

Base-band or subnanosecond signals received from the sensor strip line 2 to be gated are applied by coaxial line 9 to the base 44a of detector transistor 44. Such base-band signals may be found across the matching load resistor 90 attached across a conventional non-dispersive TEM mode transmission line 9 such as a coaxial or continuous two-wire line comprising constant impedance or uniformly spaced parallel conductors or other TEM mode transmission line.

Operation of the time gated circuit will be understood from the foregoing. It is seen that time gate generator 36 relies for its operation upon characteristics inherent in the 2N5130 avalanche transistor 54 and in the open circuited delay line 37 of length d . In response to the positive triggering signal 31B, transistor 54 breaks into conduction and a voltage step wave is prop-

agated into delay line 37. When this step wave reaches the open end of line 37, it is inverted there upon reflection and returns to collector 54b, whereupon the current flow in transistor 54 is brought to zero and the transistor reverts to its non-conducting condition. Thus, the voltage wave 36C across filter resistor 56 is a sharply rising and terminating positive pulse of duration $2d/c$ seconds, a duration dictated by delay line 37 (c is the velocity of propagation of the step wave in delay line 37).

In the quiescent state of the circuit of FIG. 9, transistor 69 in inverter circuit 42 is normally fully conducting, causing a current of about 30 milliamperes to flow through the emitter resistor 87 associated with detector transistor 44 (resistor 87 may have a resistance value of about 100 ohms). The voltage consequently appearing across resistor 87 will be about +3 volts and assures that detector transistor 44 is in its non-conducting state. The field effect transistor 93 acts as a constant current source, assuring that a constant current is fed via the collector 44b and emitter or c of detector transistor 44 in its quiescent or non-conducting state so that its bias state is precisely controlled. Resistor 92 in the collector circuit of detector transistor 44 has a positive thermal coefficient and serves to afford temperature compensation for the thermal characteristic of the conduction threshold of detector transistor 44.

When wave 30B triggers time gate generator 36, the positive output wave 36C produced by time gate generator 36, is as previously explained, fed through low pass filter 41 to inverter 42. In traversing filter 41, wave 36C is acted upon so that the positive wave 41D results, having rounded rise and fall portions. Accordingly, any high level transient near the start or the end of wave 36C is removed, a desirable result since such spurious transients might otherwise undesirably trigger detector transistor 44 into conduction.

The positive wave 41D, when coupled by capacitor 67 to inverter circuit 42 and thus to the base 69a of transistor 69, causes current conduction through transistor 69 to stop, forcing the voltage across resistor 87 rapidly to fall to zero. This event places detector transistor 44 in its fully sensitive state with respect to any signal to be sampled that is propagated within transmission line 2 and thereby arrives on line 9 at the base 44a of transistor 44. Any signal sampled by detector transistor 44 appears as a negative amplified and time extended wave 46F on the collector 44b of detector transistor 44 and is supplied by coupling condenser 95 across load resistor 96, for example. It may be then supplied to the aforementioned utilization apparatus via terminals 97 and 97a in the customary manner, since wave 46F is amplified and time extended with respect to the received short base-band pulses. Upon termination of the gating pulse 41D, the circuit returns to its above described quiescent state, awaiting receipt of the next succeeding triggering wave 30B.

It will be noted that transmission of short duration pulses from their source, such as from base-band pulse generator 10 of FIG. 1, is through a transmission line system or other medium that preferably operates substantially solely in the TEM mode, and that propagation modes that permit dispersion of pulses such as subnanosecond or base-band pulses are not used. Thus, the full energy of base-band pulses originating in transmission line 2 is effectively directed to processing within the time gated detector 44. It will be apparent that vari-

able delay trigger circuit 30 and time gate generator 36 may readily be adjusted so that receiver 11a is, in effect, sensitive only to pulses above a predetermined threshold coupled to transmission line 2 when an object passes over line 1, 2 in the restricted region encompassed by distance D in FIG. 1. Thus, the spurious pulses 21 and 22 of FIGS. 11 and 12 are not passed by receiver 11a and are not coupled to the alarm or other utilization device 12.

It will also be seen that other time gating arrangements may be employed; for example, the distance D in FIG. 1 may be divided into a plurality of non-overlapping range or time bins by employing a multiple time selector device, such as that disclosed in G. F. Ross U.S. Pat. application Ser. No. 134,990 for a "Base Band Pulse Object Sensor System," filed Apr. 16, 1971 and assigned to the Sperry Rand Corporation. For example, the receiver 11a may readily be time-gated according to the number of lanes of a highway, the two strip transmission lines 1 and 2 extending across the highway or aircraft taxi roadway so that all lanes are covered. Multiple range gates may then be used to separate the signals due to returns coming from individual traffic lanes. It will be appreciated that two or more traffic lanes may be monitored by using parallel multiple channel sensors or by the use of one range gate which is cyclically scanned over the lanes sufficiently rapidly that no vehicles are missed.

As previously noted, the novel sensor system provides presence detection of objects having greater than relatively low predetermined weights. The threshold sensitive characteristic of the receiver 11a may also be employed, as in FIGS. 13 and 14, to detect an object such as a package according to its weight with respect to other threshold values. In FIG. 13, the configuration employed in FIG. 3 comprising dielectric substrate 24, conducting ground plane 26, and strip conductors 1 and 2 is again seen. These elements are placed in a recess below the surface 15 of a floor or other planar element. Over the combination is placed a layer 103 of compressible material, such as sponge rubber or other flexible material. Across the layer 103 is located an array of substantially regularly spaced contacting metal bars 101a to 101f. A metal or other plate or platform 102 is placed on top of the metal bars or contactors 101a to 101f for distributing any load placed on plate 102 generally to each of contactor bars 101a to 101f. Bars 101a to 101f and plate 102, on which an object whose weight is to be sensed are dimensioned so as to provide clearance between them and the walls 104 and 104a of the recess in floor 15 so that plate 102 may move downward without contacting walls 104, 104a, for instance.

When an object such as a package or a person is placed or steps on plate 102, the weight of the package compresses the flexible layer 103 beneath each bar 101a to 101f. The consequently decreased separation between the bottom surface of bars 101a to 101f and the strip transmission line conductors 1 and 2 again causes the above-discussed type of increased localized coupling between lines 1 and 2. This occurs at each of bars 101a to 101f, particularly if the object is substantially centered on plate 102. To a substantial degree, detection is independent of the exact location and composition of the object on plate 102. The minimal weight to be detected can, for instance, be adjusted by control-

ling the thickness or density of the flexible layer 103 or the distance separating the bars 101a to 101f.

In practice, the metal or other plate 102 of FIGS. 13 and 14 may be replaced as in FIG. 15 by a rubber mat 110 backed by a conducting metal foil or flexible plate 111. The mat 110 and foil 111 may be placed directly on a foam rubber mat 103 placed, in turn, directly on top of the strip conductors 1 and 2 of the transmission line system.

The invention is not limited to use in a substantially horizontal plane. For example, the strip transmission line conductors 1 and 2 of FIG. 16 are oriented vertically, being placed on the inside of a vertical wall 123 of an inclined sluice or flume formed of walls 123 and 125 and floor 124. The surface of vertical wall 123 underlying strip lines 1 and 2 may be made of low loss dielectric material. The presence of a material such as a dielectric or non-conducting fluid or sand or a solid aggregate will be sensed by the apparatus as its presence will again distort the electromagnetic-field-pattern between conductors 1 and 2.

It is seen that the novel object presence detector employs a wide band or wide open detector device, a detector which will respond to any signal level in excess of the bias level which might be dictated by the characteristics of a particular transistor detector 44. The amplitude of the received base-band pulse at the detector 44 may be, for example, about 200 millivolts in a typical operating circumstance, a value several orders of magnitude greater than the amplitude of the signals present in an urban environment due to conventional radiation sources, such as interfering signals normally being at a microvolt level. Accordingly, although the presence detecting receiver of the invention essentially accepts all signals over a very wide pass band, it is substantially immune to interference from conventional radiation sources, including electrical noise signals such as internal combustion engine ignition noise; being time gated, the receiver is sensitive only for 1 nanosecond, for example, for each generator pulse.

The transmission line system 1 of FIG. 1 may, for instance, employ a regular train of extremely short duration, relatively low amplitude base-band pulses. In one typical situation, these impulse-like signals have time durations of substantially 200 picoseconds and a pulse repetition frequency of the order of 10 kilohertz. However, the upper bound on the average power coupled through space may be considerably less than 1 microwatt. The spectrum of the propagating base-band signal is spread over an extremely wide band, typically 100 megahertz to 10 gigahertz. Accordingly, the power that may be radiated in any typical narrow communication band is far below the thermal noise threshold of a typical conventional communication receiver operating in that band. The base-band pulse energy is therefore incapable of interfering with the operation of standard radio communication equipment, while being remarkably adapted for use with the object presence detection apparatus of the present invention.

While the invention has been described in its preferred embodiments, it is to be understood that the words which have been used are words of description rather than of limitation and that changes within the purview of the appended claims may be made without departing from the true scope and spirit of the invention in its broader aspects.

We claim:

1. In combination:

passageway surface means having a principal direction of passage,

dielectric substrate means having surface means substantially coplanar with said passageway surface means,

signal generator means for supplying pulse signals, transmission line energy coupling means excited by said pulse signals comprising first and second transmission line conductor means of finite length spaced apart in substantially parallel relation on said substrate surface means and lying substantially transverse of said principal direction,

said coupling means having a predetermined coupling characteristic alterable according to the proximity of an object overlying at least a portion of said coupling means,

receiver means for receiving presence detection signals propagating on said second conductor means, utilization means, and

gating means for passing said received presence detection signals to said utilization means while rejecting spurious signals arising adjacent the ends of said conductors of finite length.

2. Variable transmission line energy coupling object presence detector means having a predetermined energy coupling characteristic comprising:

dielectric substrate means having surface means adapted to be placed in substantially coplanar relation with passageway surface means,

first and second substantially parallel planar transmission line conductor means at said dielectric surface means,

said substrate means and said conductor means being so constructed and arranged as to respond to said object when overlying at least a portion of said coupling means by a change in the degree of energy coupling between said conductor means, and

means responsive to said change.

3. Apparatus as described in claim 2 wherein said dielectric substrate means is adapted to be placed on said passageway surface means.

4. Apparatus as described in claim 2 wherein said dielectric substrate means is placed within a recess in said passageway surface means.

5. Variable transmission line energy-coupling object-weight-detection means having a predetermined energy coupling characteristic comprising:

dielectric substrate means having surface means,

first and second substantially parallel planar transmission line conductor means at said dielectric surface means,

flexible dielectric sheet means overlying said conductor means,

platform means overlying said dielectric sheet means, said platform means having contact means for contacting said flexible sheet means,

pulse generator means for exciting said first conductor means,

receiver means responsive to signals coupled to said second conductor means in the presence of said object, and

utilization means responsive to said receiver means.

6. Variable transmission line energy coupling object presence detector means having a predetermined energy coupling characteristic comprising:

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dielectric substrate means having surface means adapted to be placed in substantially coplanar relation with passageway surface means, first and second substantially parallel planar transmission line conductor means at said dielectric surface means.

said substrate means and said conductor means being so constructed and arranged as to respond to said object when overlying at least a portion of said coupling means by a change in the degree of energy coupling between said conductor means, means responsive to said change,

flexible layer means underlying said conductor means within said dielectric means, and dielectric sheet means overlying said conductor means,

said flexible layer means being adapted to be reversibly compressed for permitting reversible variation of the amount of dielectric material of said dielectric substrate lying between said conductor means.

7. Variable transmission line energy coupling object presence detector means having a predetermined energy coupling characteristic comprising:

dielectric substrate means having surface means adapted to be placed in substantially coplanar relation with passageway surface means,

first and second substantially parallel planar transmission line conductor means at said dielectric surface means,

said substrate means surface means including a recessed portion between said conductor means, flexible dielectric sheet means overlying said conductor means, said flexible sheet means being adapted to be reversibly flexed into said recessed portion of said surface means,

said substrate means and said conductor means being so constructed and arranged as to respond to said object when overlying at least a portion of said coupling means by a change in the degree of energy coupling between said conductor means, and means responsive to said change.

8. Presence detector means for detecting the presence of an object comprising:

first and second transmission lines having a common directionally coupling region for coupling high frequency signals from said first to said second transmission line in the presence of said object, said first transmission line having input port means and first absorber means at opposite ends of said

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directionally coupling region,

said second transmission line having output port means and second absorber means at opposite ends of said directionally coupling region,

signal generator means for supplying high frequency signals at said input port means,

receiver means for receiving presence detection signals at said output port means,

utilization means, and

gating means responsive to said signal generator means for passing said received presence detection signals to said utilization means while rejecting spurious signals caused by any impedance mismatch at said input port means, said output port means, or said first or second absorber means.

9. Apparatus as described in claim 8 further including:

dielectric substrate means having a substantially planar surface,

said first and second transmission lines being affixed to said planar surface.

10. Apparatus as described in claim 9 wherein said planar surface of said dielectric substrate means lies substantially in the plane of passageway surface means for forming a substantially coplanar extension of said passageway surface means.

11. Apparatus as described in claim 8 wherein said signal generator means comprises pulse generator means.

12. Apparatus as described in claim 11 wherein said pulse generator means is adapted to generate a train of base-band subnanosecond electromagnetic pulses.

13. Apparatus as described in claim 11 wherein said receiver means is adapted to respond to pulse signals.

14. Apparatus as described in claim 13 wherein said receiver means is adapted to respond to the receipt of base-band subnanosecond electromagnetic pulses.

15. Apparatus as described in claim 10 wherein said gating means is operated in synchronism with said pulse generator means.

16. Apparatus as described in claim 8 wherein said utilization means comprises alarm means.

17. Apparatus as described in claim 8 wherein said utilization means includes visual display means.

18. Apparatus as described in claim 8 wherein said utilization means includes control means adapted to control controllable means.

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