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(54) Title: INTRUSION DETECTION SYSTEM

(57) Abstract

   In an intrusion detection system comprising an open transmission line (10), for example a "leaky cable", and a receiver unit (12S, 12T, 14S, 14T, 16) for processing a radio frequency signal received by the line to detect perturbations caused by an intruder (28), problems of nonlinear sensitivity due to line attenuation are resolved by combining perturbation signals (R_S, R_T) from both ends of the open transmission line. A processor unit (18) computes logarithmic values of the perturbation signals from the opposite ends of the line and combines them to detect presence of an intruder. The sum of the logarithmic values may be used to determine presence of the intruder and the difference between them may be used to determine the location of the intruder relative to the end of the line. The processor may also use phase information from the two perturbation signals to facilitate detection in the presence of multipath effects. Reference signals (LO, IF_T, RF) and power may be transmitted between receiver units (12S, 14S, 12T, 14T, 16) by way of the open transmission line (10) itself. The system may employ several transmissions having different frequencies, in which case the processor (18) will sum perturbation signals for all transmission frequencies for each end of the line, combine the two sums, and compare the result with a predetermined threshold (T).

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INTRUSION DETECTION SYSTEM

DESCRIPTION

TECHNICAL FIELD:

5   The invention relates to intrusion detection systems and
in particular to intrusion detection systems which comprise
an open or "leaky" transmission line, for example a leaky
cable, for receiving a radio frequency signal and receiver
means attached to the open transmission line for processing
10 the received radio frequency signal to detect perturbations
caused by an intruder in proximity to the open transmission
line.

BACKGROUND ART:

15   It is desirable for such an intrusion detection system
to have uniform sensitivity along the length of the open
transmission line. All transmission lines, including open
transmission lines, attenuate signals as they propagate along
their length. This attenuation is due to resistive losses in
20 the conductors, to losses in surrounding dielectric materials,
or to radiation. Usually attenuation is dominated by resistive
losses. With a line receiver connected to one end of the
line, and the detector sensitivity set to detect a large
intruder, for example a human, at the far end of the line, the
25 alarm could be triggered by a small animal, for example a
rodent, adjacent the near end of the line. In systems
employing a leaky coaxial cable as the line, this problem has
been addressed by increasing the aperture size with distance
along the cable (cable grading). Such graded cables are very
30 expensive, which is a disadvantage for large area protection,
and must be supplied and stocked in standard lengths, which
leads to additional expense.
       US patent number 4,224,607 (Poirier) issued September 23,
1980, discloses an intrusion detection system comprising a
35 length of leaky transmission line encompassing the region to
be protected, a receiving antenna within the region, an R.F.
transmitter and a remotely located receiver and detector.
Effects of attenuation along the line are reduced by switching

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the transmitter periodically to opposite ends of the leaky
cable. Nevertheless, this is only a partial solution. The
sensitivity is still greater at the ends of the cable than at
the middle of the cable so the system would not necessarily
5 provide detection anywhere along the cable while not being
susceptible to false alarms from the more sensitive start end
of the cable.   Where a longer line is needed to protect a
greater area, especially if an inexpensive cable with a
relatively high attenuation is used, the variation in
10 sensitivity would be even greater.

DISCLOSURE OF INVENTION:
        The present invention seeks to eliminate, or at least
mitigate, the disadvantages of the known intrusion detection
15 systems and to provide an improved leaky cable intrusion
detection system.
        To this end, according to one aspect of the present
invention, an intruder detection system comprises an open
transmission line; receiver means connected to both ends of
20 the transmission line; means for providing at the receiver
means a reference local oscillator signal (LO) and a reference
intermediate frequency signal (IF$_{REF}$); and processor means for
processing signals output from the receiver means. The
receiver means is responsive to the reference local oscillator
25 signal and the reference intermediate frequency signal to
extract from a first radio frequency signal received at one
end of the line a first baseband signal comprising a first
perturbation signal produced by an intruder in proximity to
the line and to extract from a second radio frequency signal
30 received at the other end of the line a second baseband signal
comprising a second perturbation signal. The processor
determines the presence of the intruder in dependence upon
both the first and second perturbation signals.
        The system may, advantageously, be capable of receiving,
35 selectively, a plurality of transmissions at different
frequencies, perhaps different commercial stations. The
processor means may conveniently select the different
frequencies by varying the reference local oscillator signal

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frequency. The processor means may also be capable of adjusting receiver gain to compensate for different signal strengths of the different transmissions. The particular frequencies selected, and the corresponding gain factors, may be determined during a preliminary calibration of the installed system.

It is also desirable for the system to be capable of determining the position of the intruder along the cable. In preferred embodiments of the invention, the processor means also derives the distance to the intruder from the start end of the line in dependence upon the first perturbation signal and the corresponding perturbation signal, preferably in proportion to the difference between logarithmic values derived from them.

The receiver means may comprise first receiver means and second receiver means connected to opposite ends, respectively, of the transmission line, both tuned to the frequency of the radio frequency signal and coupled for synchronous detection of the signal. Preferably, the first and second receiver means both use the reference local oscillator signal to detect the radio frequency signal at each end of the line and produce respective intermediate frequency signals.

Advantageously, communication of signals and power between the first and second receiver means may take place via the line itself.

In preferred embodiments of the invention, the means for providing the reference local oscillator signal and the reference intermediate frequency signal comprises a third receiver which receives the transmitted radio frequency signal directly from a remote transmitter, for example a commercial radio or television station or a navigation signal transmitter, and derives the reference signals from the direct radio frequency signal. Where two receiver means are involved, the reference intermediate frequency signal will synchronize them to the transmitted radio frequency signal and to each other.

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In preferred embodiments of the invention, the first and second receiver means each comprise a line receiver and a demodulator.   Each line receiver is connected to the transmission line and uses the reference local oscillator signal to derive its intermediate frequency signal from the line signal.   The demodulator will then use the reference intermediate signal to demodulate the intermediate frequency signal from the associated line receiver to provide the perturbation signals representing the perturbation created by the intruder.   The perturbation signals from the first and second receiver means are processed by the processing means, as previously mentioned, to detect the presence of an intruder or/and the location of the intruder along the open transmission line.

Preferably each demodulator provides in-phase and quadrature signal components of the perturbation signal at its end of the line and the processor combines the magnitude and phase information of each of the perturbation signals to detect the presence of an intruder.   One means of combining the signals from the two ends of the line is to add the logarithmic values of the sum of the squares of the in-phase and quadrature component signals.   In this case, the system indicates the presence of the intruder when the sum of the two logarithms exceeds a predefined threshold.   The processor may also use the difference between the two magnitude logarithms to determine the distance of the intruder from the start of the line.

In situations where the signal to noise ratio is high, the use of logarithmic values is a very practical way to combine the signals from both ends of the line.   In situations involving poor signal to noise conditions, however, performance can be enhanced by using linear summation of magnitudes of the signals from the two ends of the line and comparing the sum with a variable threshold.   More particularly, in one preferred embodiment of the invention, the perturbation signals from opposite ends of the line are added and compared with a threshold which varies according to the distance along the line, especially according to the ratio

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between the perturbation signal magnitudes at various discrete positions along it. Thus, in a middle region of the line, the ratio might be 2:1, increasing in steps to, say, 4:1 at the ends.

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BRIEF DESCRIPTION OF DRAWINGS:

The foregoing and other objects, features, aspects and advantages of the present invention will become more apparent from the following detailed description of preferred
10 embodiments of the invention, which are described by way of example only and with reference to the accompanying drawings, in which:

Figure 1 is a general schematic representation of an intruder detection system comprising an open transmission line
15 and receiver means for detecting intruder-induced perturbations of a radio frequency signal on the line;

Figure 2 illustrates a demodulator of the system shown in Figure 1;

Figure 3 illustrates various signals in the system;
20 Figure 4 illustrates functions of a processor means of the system of Figure 1;

Figures 5A and 5B are vector diagrams illustrating corresponding signals at opposite ends of the open transmission line;
25 Figures 6A and 6B are simplified schematic diagrams of alternative reference receivers for the system of Figure 1;

Figure 7 illustrates multipath discrimination between the signal due to an intruder adjacent the line and signals from large objects further from the line;
30 Figure 8 is a schematic diagram of an embodiment of the invention in which power and reference signals transmitted between line receivers at opposite ends of the line travel via the open transmission line itself;

Figure 9 depicts variation of thresholds with distance
35 along the line for an alternative embodiment of the invention;

Figures 10, 11 and 12 illustrate modifications of the system;

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Figure 13 illustrates variation of detection threshold according to distance from the end of the line; and

Figure 14 illustrates another modification of the system.

5 BEST MODE(S) FOR CARRYING OUT THE INVENTION:

Referring to Figure 1, an intruder detection system comprises an open or "leaky" transmission line 10, conveniently an apertured coaxial cable of the kind usually called a "leaky cable". The line 10 is connected to receiver

10 means comprising two line receivers 12S and 12T coupled to coherent demodulators 14S and 14T, respectively, and a reference receiver 16. The receiver means are controlled by, and supply signals to, a microcontroller or digital signal processor 18. The reference receiver 16 has an antenna 20 for

15 direct reception of a radio frequency signal transmitted by a remote transmitter 22 of a commercial radio or television station. The reference receiver 16 derives from the received radio frequency signal a reference local oscillator signal LO, which it supplies on line 24 to both of the line receivers 12S

20 and 12T, and a reference intermediate frequency signal IF_{REF} which it supplies on line 26 to the demodulators 14S and 14T.

The line receivers 12S and 12T are connected to the start and the termination, respectively, of the open transmission line 10 and will receive the radio frequency signal from

25 transmitter 22 via the line 10.

Where the setting is substantially ideal, with a homogenous medium surrounding the open transmission line 10 and a uniformly constructed line (no discontinuities in the field of the surface wave), the open transmission line 10,

30 properly terminated, receives only a very weak signal from the radio transmitter 22. When the intruder 28 moves in proximity to the open transmission line 10, a discontinuity is created in the characteristic impedance of the line 10 and the radio frequency signal striking the intruder 28 is introduced into

35 the line 10, where it propagates both to the start and termination ends of the line 10. Hence the line receivers 12S and 12T receive perturbed radio frequency signals RF_S and RF_T, respectively, which each comprise a component due to the

perturbation signal coupled by the intruder 28 into the open
transmission line 10. In the case of a system operating in
the FM band, the modulation caused by a human intruder moving
between 0.02 and 8 meters per second is between,
5 approximately, 0.005 Hz. and 6 Hz.

Assuming that the reference antenna 20 is suitably
located, the reference intermediate frequency signal IF_{REF} is
not disturbed by the intruder 28, whereas the intermediate
frequency signals IF_S and IF_T produced by the line receivers
10 12S and 12T are modulated by the intruder 28.

The line receivers 12S and 12T, by sharing the same local
oscillator signal LO, are tuned precisely to the same station
as reference receiver 16, so their intermediate frequency
signals IF_S and IF_T contain the same broadcast frequency
15 modulation but at the IF frequency. Because these
intermediate frequency signals are coherent, the demodulation
process effectively eliminates the broadcast modulation
leaving only the modulation induced via the line 10. In
particular, when the intermediate frequency signal IF_{REF} from
20 the reference receiver 16 is mixed with the intermediate
frequency signals IF_S and IF_T from the line receivers 12S and
12T in demodulators 14S and 14T, corresponding baseband
signals M_S and M_T comprising amplitude and phase modulation due
to the intruder 28, are detected.

25   Demodulator 14S is shown in detail in Figure 2;
demodulator 14T being identical. An amplifier 29, the gain
of which is variable under the control of the processor 18,
amplifies the intermediate frequency signal IF_S from the line
receiver 12S and supplies it to a mixer 30. The mixer 30
30 mixes the reference intermediate frequency signal IF_{REF} with
the intermediate frequency signal IF_S from the line receiver
12S to extract the baseband signal M_S. Since the output of
mixer 30 includes all the usual mixing products, it is
supplied to a low pass filter 32 which eliminates all of the
35 upper cross products above about 3.75 Hz. leaving only the in-
phase baseband component I_S of baseband signal M_S. The
reference intermediate frequency signal IF_{REF} is delayed by 90
degrees in a quadrature hybrid circuit 34 before being

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supplied to a second mixer 36 which mixes it with the intermediate frequency signal IF_S. The output of mixer 36 is filtered by a second low pass filter 38 to remove frequencies above about 3.75 Hz., resulting in the quadrature baseband

5   component Q_S of baseband signal M_S.

Referring again to Figure 1, demodulator 14S supplies the in-phase and quadrature components I_S and Q_S of the start-end baseband signal M_S to the digital signal processor 18. Similarly, the demodulator 14T, having used the reference

10   intermediate frequency signal IF_{REF} and the intermediate frequency signal IF_T from line receiver 12T to produce corresponding in-phase and quadrature components I_T and Q_T for the termination baseband signal M_T, supplies the components I_T and Q_T to the digital signal processor 18.

15   The digital signal processor 18 uses the in-phase and quadrature signals I_S, Q_S, I_T and Q_T from both demodulators 14S and 14T to compute a logarithmic value, as will be described in more detail later, and compares this logarithmic value with a reference or threshold, illustrated in Figure 3 by the

20   dashed line T. If this combined logarithmic value exceeds the threshold T, the processor 18 generates an alarm indicating that an intruder 28 is within the detection zone somewhere along the open transmission line 10.

In an ideal case, the open transmission line 10 does not

25   pick up any of the radio transmissions unless an intruder 28 is in proximity to the line. In practice, however, stationary objects and line imperfections scatter the transmissions and introduce "fixed clutter" signals into the open transmission line 10 along its length. Also, slow environmental changes

30   occur below the passband and higher frequency responses above the passband may be caused by flying birds, etc. Consequently, the processor 18 processes the baseband signals M_S and M_T in such a way that signals introduced into the line 10 at frequencies outside the range 0.005 Hz. to 6 Hz.,

35   mentioned above, will be excluded. Processing of the baseband signals by processor 18 is illustrated in Figure 4. For the purpose of describing the processing, it is convenient to represent the base band outputs M_S and M_T of the demodulators

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14S and 14T, respectively, vectorially as illustrated in Figures 5A and 5B, with the clutter represented by vectors C_S and C_T and the perturbation components due to the intruder by vectors R_S and R_T. Thus, the in-phase and quadrature
5 components I_S and Q_S from demodulator 14S include clutter components I_{CS} and I_{CT} and intruder perturbation signal components I_{RS} and Q_{RS}, combining to give a magnitude of M_S. Similarly, the in-phase and quadrature response components I_T and Q_T of demodulator 14T include clutter components I_{CT} and
10 Q_{CT} and intruder perturbation signal components I_{RT} and Q_{RT} combining to give a magnitude of M_T.

As shown in Figure 4, initially the processor 18 digitizes and filters the in-phase and quadrature components. Normal precautions need to be taken to digitize at a
15 sufficient rate to eliminate aliasing and with a sufficient number of bits to provide adequate dynamic range to accommodate the expected range of modulation.

The quadrature signal component Q_S from low pass filter 38 in demodulator 14S (Figure 2) is digitized by analogue-to-
20 digital converter 40S and filtered by a band pass filter 42S, with a lower cutoff of about 0.005 Hz. and an upper cutoff of about 6 Hz, to derive the incremental intruder response vector component Q_{RS}. In a similar way, the in-phase signal component I_S from low pass filter 32 (Figure 2) is digitized
25 by analogue-to-digital converter 44S and filtered by band pass filter 46S to derive the incremental intruder response vector component I_{RS}. The in-phase and quadrature signal components I_T and Q_T from the demodulator 14T are processed in like manner by analogue-to-digital converters 40T and 44T and band
30 pass filters 42T and 46T to give corresponding incremental intruder response or perturbation signal components I_{RT} and Q_{RT}, respectively.

The lower cutoff frequency of each of the band pass filters 42S, 42T, 46S, 46T is in the order of 0.005 Hz to pass
35 the perturbation signal due to an intruder moving faster than 0.002 m/sec. while removing the environmental drift and fixed clutter information. The upper cutoff frequency of each of the bandpass filters 42S, 42T, 46S and 46T, is in the order

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of 6 Hz. to pass the perturbation signal due to the intruder
28 moving slower than about 8 meters/second while removing all
higher frequency noise.

As indicated by function box 56, the processor 18
computes the value R_S' as the logarithm of the sum of the
squares of the corresponding incremental responses I_{RS} and Q_{RS},
and, as indicated by function box 58, the response R_T' from
incremental responses I_{RT} and Q_{RT}. The processor 18 computes
the sum R and the difference L of the logarithmic responses
R_S' and R_T' as indicated by box 60. The sum R is then compared
to threshold T, as shown in decision box 62, to determine
whether or not an intruder is present and, if so, generate an
alarm signal.

Once an intruder is determined to be present, the
difference L between the logarithmic responses is determined
to indicate where the intruder is located along the length of
the open transmission line 10 relative to the start of the
line 10. The difference L between the logarithmic values R_S'
and R_T' of the perturbation signals is linear and, as shown in
Figure 3, decreases rapidly as the intruder moves along the
length of the open transmission line 10. The magnitude of
this difference L between the logarithmic values is directly
proportional to the intruder's distance x from the start end
of the open transmission line 10. Hence, the digital signal
processor 18 is able to determine the intruder's location
along the open transmission line 10.

Thus, the system takes account of the attenuation of
signals propagating along the length of the open transmission
line 10 to locate the intruder 28. Attenuation causes signals
propagating along transmission lines to decay exponentially
with distance. Hence, a logarithmic function of the
exponential attenuation with distance along the length of the
line becomes linear.

In Figure 3, the ideal magnitude of the logarithmic
perturbation signal for the start of the line due to an
intruder 28 walking along the length of the open transmission
line 10 is represented by the sloping line R_S'. The slope of
this line R_S' is determined by the attenuation of the open

transmission line 10. Likewise the magnitude of the logarithmic perturbation signal for the termination end of the line is shown as sloping line R_T'. It will be noted that, because line receivers 12S and 12T are at opposite ends of the
5 open transmission line 10, the slopes of lines R_S' and R_T' are equal and opposite. Adding the logarithmic values R_S' and R_T' yields a constant magnitude along the length of the open transmission line 10, as depicted by line R in Figure 3. Thus, it will be seen that the combined logarithmic response
10 from line receivers 12S and 12T is independent of the intruder's location along the length of the open transmission line 10.

The actual level of the threshold T, and hence the sensitivity of the system, will be determined by the processor
15 18 following an initial set-up phase. As shown in Figure 1, the processor 18 controls the tuning of the reference receiver 16 by means of the control signal Select f, and the associated gain settings for the demodulators 14S and 14T by means of the gain control signal ADJ. GAIN. During the initial system set-
20 up phase, the processor 18 controls the reference receiver 16 to scan the entire FM band so as to select the most desirable station frequency for use by the system. Where, as will be described later, the system uses a plurality of transmissions at different frequencies, the processor 18 will generate a
25 table of available stations and appropriate gain settings for the demodulators 14S and 14T to maintain the signal components I_S, Q_S and I_T, Q_T at a constant amplitude. The processor 18 is then able to select N frequencies for use by the detection system where N is the number of stations for which the system
30 is designed. Once this initial set-up phase is completed the system is ready to be calibrated.

During the calibration procedure, the processor 18 determines the appropriate level for threshold T to provide the desired detection capability. With the system in
35 calibration mode, a human, or a simulated human, crosses the line 10 at its centre. The processor 18 records the peak signal perturbation during this crossing as seen from each end of the line 10. (Where N transmission frequencies are used,

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it does so for the combination of the N frequencies). The
processor 18 uses this peak response together with a
sensitivity setting controlled by the user to select an
appropriate threshold setting T. This calibration procedure
5 takes into account the length of line 10, its attenuation and
the nature of its installation; i.e suspended in air, laid on
the ground or buried in the ground.

Since the human, or simulated human, approaches the line
at its centre, the intruder-induced perturbation signals at
10 opposite ends of the line 10 should have the same amplitude.
If not, the processor 18 adjusts the gain of the demodulators
14S and 14T by means of the variable amplifier 29 (Figure 2)
until they do.

Another way of describing the detection phenomena is to
15 consider that the intruder 28 scatters the plane waves
produced by the FM radio transmitter 22. The scattered signal
propagates away from the intruder 28 in all directions causing
a portion of the signal to be coupled into the open
transmission line 10 where it propagates to the start and
20 termination ends. As the intruder 28 approaches the open
transmission line 10, an increasing amount of the scattered
energy is coupled into the line causing a phase and/or
amplitude modulation of the signal received on the open
transmission line 10. This causes the combined logarithmic
25 values of magnitude R_S' plus R_T' to increase as the intruder
28 approaches the line 10. At a particular radial distance,
the combined response R exceeds the threshold T and the alarm
is sounded. Assuming that the radial decay associated with
the particular line 10 is uniform along the length of the
30 line, the appropriate selection of a threshold value T
determines the width of the detection zone which surrounds the
open transmission line. In practice, one might set the
threshold T to detect an intruder 28 within one meter of the
line. Because the combined response is independent of
35 location along the length of the open transmission line 10,
the detection zone is uniform along the length of the line 10,
thereby eliminating the need for cable grading. It should be
noted that, since the difference (R_S' - R_T') between the

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logarithmic values is equivalent to the ratio between the perturbation signal magnitudes (R_S/R_T), the determination of location does not depend upon the magnitude of the perturbation.   In other words, the determination of location
5   is not a function of the radial distance to the intruder from the line.

The performance of the intrusion detection system in terms of Probability of Detection (Pd) and False Alarm Rate (FAR) is largely determined by the Signal to Noise Ratio (SNR)
10   of the system and the processing bandwidth.   Because the open transmission line 10 is much less efficient than the reference antenna 20 in receiving the radio transmission, the RF signal received by the reference receiver 16 is much stronger than the signal received by the line receivers 12S, 12T (20 to 30
15   dB stronger).   Hence the line receivers 12S and 12T have considerably more gain than the reference receiver 16 which means that the line receivers 12S and 12T are the primary source of noise, typically thermal noise at the receiver "front end".

20   The system SNR can be improved by minimizing the bandwidth of the line receivers 12S and 12T.   Whereas conventional commercial FM radio receivers utilize 180 KHz of occupied bandwidth in order to accommodate the monaural and stereo transmissions, a much narrower bandwidth will
25   accommodate the 0.005 to 6 Hz. modulation caused by the intruder 28.   In order to reduce the line receiver bandwidth while receiving all of the RF energy in the transmitted signal, it is proposed according to the invention to use the reference receiver 16 to track the station modulation.   If the
30   reference receiver 16 tracks the station modulation perfectly, the reference local oscillator signal LO contains the modulation signal and the intermediate frequency signal is virtually free of the modulation.   Since the LO signal produced by the tracking reference receiver 16 tunes the line
35   receivers 12S and 12T, their intermediate frequency signals IF_S and IF_T are essentially limited to the modulation or perturbation produced by the intruder 28.

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Figures 6A and 6B illustrate embodiments of reference receiver which will track the station modulation. In the reference receiver 16A shown in Figure 6A, the RF signal received on antenna 20 is passed through a broad bandpass

5   filter 64A to eliminate signals from outside the FM band (88 to 108 MHz). The band-limited output of the filter 64A is amplified in a low noise amplifier 66A and passed to a mixer 68A which mixes it with the reference local oscillator signal LO produced by a Voltage Controlled Oscillator (VCO) 70A. The

10 frequency of the VCO 70A is controlled by the SELECT f signal from processor 18. The SELECT f signal is actually a dc voltage that selects the desired station, much as in normal digitally controlled radios. In addition the VCO 70A responds to the output of a Phase Locked Loop (PLL) filter 72A which

15 receives its input from a phase comparator 74A. The reference intermediate frequency signal IF_{REF} is extracted from the output of mixer 68A by filter 75A and compared by phase comparator 74A with a 10.7 MHz reference signal from an oscillator 76A. This PLL circuit tracks the modulation

20 thereby effectively removing the modulation from the intermediate frequency and imposing the modulation on the reference local oscillator signal LO which is sent to the line receivers 12S and 12T.

An alternative approach to the use of a PLL is employed

25 in the reference receiver 16B in Figure 6B. In this case, the RF signal received by antenna 20 is filtered by a tunable station pre-selection filter 64B. The output of filter 64B is passed through a pre-amplifier 66B to a mixer 68B where it is down-converted by a reference 10.7 MHz signal generated by

30 reference oscillator 76B. The output of mixer 68B is filtered in a tunable bandpass filter 78B to produce the desired tracking reference local oscillator signal LO which is used to tune the line receivers 12S and 12T. The tuning of the pre-selection filter 64B and the bandpass filter 78B is

35 controlled by the Select f signal from processor 18.

Reducing the bandwidth from 180 KHz. to 12 Hz. would potentially improve the SNR by 83.5 dB. In practice, factors such as the noise figure of the receivers, aliasing during

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sampling, and approximations made in the digital signal processing limit the improvement which can actually be realized.

Combining the perturbation signals from the ends of the
5   line 10 by taking the sum of their logarithms and comparing this sum to the fixed threshold T is equivalent to comparing the product of the two perturbation signals to a fixed threshold. This method of combining the two perturbation signals is easy to implement because it results in a single
10 threshold regardless of where the intrusion occurs along the length of the cable. It does, however, reduce the detection Signal to Noise Ratio (SNR) to that of the smallest signal.

In order to enhance SNR, the processor 18 may be programmed instead to use the arithmetic sum of the two
15 perturbation signals, i.e. $R = R_S + R_T$.

In practice, one does not often have a clear line-of-sight path from the transmitting station antenna 22 to all sections of the open transmission line 10. In many applications the electromagnetic fields produced by the radio
20 station at the open transmission line 10 include significant multipath components. For example, a large building can reflect the broadcast plane waves over the open transmission line 10. It is envisaged, therefore, that embodiments of the invention might employ a plurality of different radio
25 frequency signals as references so as to employ frequency and spatial diversity to minimize the effects of multipath components. In virtually all metropolitan areas, there are a number of FM stations within the 88 to 108 MHz band which can be used in the present intrusion detection system. In
30 many cases the transmit antennas are collocated for most of the stations. With collocated transmitters, the time-multiplexing between two or more stations makes it very unlikely that a null can occur at the same location due to frequency diversity. In the case of stations that are not
35 collocated, it is also very unlikely that a null can exist at both frequencies due to both frequency and spatial diversity.

When multiple frequencies are used, it is desirable to take the sum of the perturbation signals corresponding to each

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end of the line prior to taking the logarithms. In equation form:

$$R_T = \sum_{i=1}^{N} R_{Ti} \quad \text{and} \quad R_S = \sum_{i=1}^{N} R_{Si}$$

where N is the number of frequencies and the subscript i is
5   used to denote the perturbation signal at frequencies i. This
    approach averages out any peaks or nulls caused by multipath
    effects thus improving the overall signal to noise ratio.

        Rather than duplicating the reference receiver 16, line
    receivers 12S and 12T and demodulators 14S and 14T (Figure 1)
10 for each of the plurality of frequencies, it is possible to
    time-multiplex the receiver means to measure the response at
    each of the plurality of frequencies. To achieve this
    multiplexing, the processor 18 simply uses the SELECT f
    control signal to cause the reference receiver 16 to switch
15 between the different frequencies alternately. The selected
    frequencies may be taken from the table of frequencies
    generated by the processor 18 during the calibration process
    described earlier. Since the local oscillator signal LO for
    the line receivers 12S and 12T comes from the reference
20 receiver 16, they automatically track the station switching.
    The digital signal processor 18 keeps the perturbation signals
    for each of the different frequencies separate until the final
    stage where the combined logarithmic responses are added
    together to get the geometric mean. Combining perturbation
25 signals for a plurality of frequencies in this way effectively
    "smooths out" peaks and nulls in the perturbation signals.

        While the addition of the logarithms of the response
    magnitudes provides a good way of combining the signal
    information, it is not optimal in terms of the resulting
30 Signal to Noise Ratio (SNR). From a SNR perspective, it may
    be desirable to add the response magnitudes prior to taking
    the logarithm. This would produce the logarithm of the
    arithmetic means as opposed to the logarithm of the geometric
    means. In general the SNR of a geometric means is
35 approximately that of the input signal with the lowest SNR.

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Hence, even though one of the input signals has an excellent SNR it will be degraded to the SNR of the input signal with a poor SNR. On the other hand if the noise on the input signals has a normal distribution with equal variances, an
5   arithmetic mean can significantly improve the SNR.

In short lengths of line, say 50 meters or less, the line attenuation may be sufficiently small that the difference between the magnitudes of the perturbation signals seen at opposite ends of the line may be less than the variations in
10 magnitude caused by noise. While this would inhibit the location ability of the system according to the present invention, since it is not usually necessary to know the location of an intruder on such a short length of sensor line, there is still considerable SNR benefit to be gained by
15 adding the magnitudes of the perturbation signals from both ends of the line.

The multipath effects described above are basically static in nature as they come from stationary objects and it is assumed that the open transmission line 10 also remains
20 stationary. Figure 7, which corresponds to Figure 4, illustrates an embodiment of the invention which deals with a more complex form of multipath distortion, i.e. transient multipath distortion, which is caused by reflections from moving objects such as vehicles on nearby roads. As shown in
25 Figure 7, a moving vehicle 81 reflects a plane wave over the open transmission line 10. If the open transmission line 10 were perfectly uniform with no irregularities within its near field, the reflection from the moving vehicle 81 would not couple into the open transmission line 10 and would not cause
30 a false alarm. In practice, however, the open transmission line 10 does have many small scattering objects randomly distributed along its length which couple energy into the open transmission line 10. Hence the moving vehicle 81 can cause false alarms by reflecting radio signals onto the fixed but
35 distributed small objects within the field of the open transmission line 10.

In the embodiment illustrated in Figure 7, the processor 18B uses the intruder phase response information to reduce the

number of false alarms due to transient multipath effects from moving distant vehicles. Assuming that the open transmission line 10 operates in a quasi-TEM or surface wave mode, the constant phase fronts close to the open transmission line 10

5 are virtually orthogonal to the line 10. Hence the phase ϕ_{RS} of the intruder perturbation signal R_S via the receiver 12S is the product of the transmission line phase factor, β, and the distance x_S from the start of the line 10 to the intruder 28. Likewise, the phase ϕ_{RT} of the perturbation signal R_T received

10 by line receiver 12T is the product of the transmission line phase factor, β, and the distance x_T. i.e.

$$\phi_{RS} = \beta \, x_S \qquad \text{and} \qquad \phi_{RT} = \beta \, x_T$$

Once the intrusion detection system is installed, the length of the open transmission line 10 is fixed so the sum

15 of these two phase factors is a constant, i.e.

$$\phi = \phi_{RS} + \phi_{RT} = \beta \, X$$

where X is the length of the open transmission line 10. The constant ϕ is independent of the intruder location along the open transmission line 10. The signal injected by the distant

20 moving vehicle 81 into the open transmission line 10 enters at random locations along the line and the phase angle ϕ will be time-varying as the vehicle 81 moves. Hence, the processor 18B computes ϕ_{RS}, the phase of the incremental response vector at the start; ϕ_{RT}, the phase at the termination end; and sums

25 them to give the phase angle ϕ, as indicated by function boxes 80, 82 and 84, respectively. In step 86, the processor 18B compares ϕ with threshold values ϕ_1 and ϕ_2 to discriminate between perturbations due to intruders near the open transmission line 10 and perturbations due to large moving

30 vehicles at a distance from the line 10.

It will be appreciated that the embodiment of the invention shown in Figure 1 requires three interconnecting cables; open transmission line 10, line 24 for the reference local oscillator signal, and line 26 for the reference

35 intermediate frequency signal, as well as some means of connecting the demodulators 14S and 14T to the processor unit 18, and a power distribution network. This number of interconnecting cables could make the sensor procurement and

installation costs prohibitive. Figure 8 illustrates an embodiment of the invention in which a control module 90 at the start end of the open transmission line 10 and an end-of-line or termination unit 92 at the other end are
5 interconnected only by the open transmission line 10, the various signals being carried by the line 10 itself.

Thus, the control module 90 comprises a reference receiver 16, line receiver 12S, demodulators 14S and 14T, and a processor unit 18, all similar to those described with
10 reference to Figure 1. In addition, the control module 90 comprises a power supply 94 and a multiplexer unit 96. The end-of-line or termination unit 92 comprises line receiver 12T and a multiplexer unit 98. D.c. power from the power supply unit 94 and the local oscillator signal LO from the reference
15 receiver 16 in the control module 90 are transmitted by way of the multiplexer units 96 and 98 to the line receiver 12T in the end-of-line unit 92. The intermediate frequency signal IF_T from the line receiver 12T is returned to the demodulator 14T by way of the multiplexers 98 and 96. In addition, the
20 open transmission line 10 carries the RF signal coupled into it along its length in both directions to the line receivers 12S and 12T, respectively, by way of multiplexers 98 and 96.

The control module 90 may be designed to operate in an indoor environment and the end-of-line unit 92 designed to
25 operate in either an indoor or an outdoor environment. Multiplexing the signals on the open transmission line 10 avoids the cost of additional cable and installation to incorporate the termination line receiver.

In order to further simplify the hardware illustrated in
30 Figure 8, it is possible to time multiplex the demodulators 14S and 14T. When this is done, care must be taken to ensure that the multiplexing ratio is sufficiently fast that the intruder 28 has not moved an appreciable distance between samples. The processor 18 will control the multiplexing and
35 allow for it in detecting and combining the perturbation signals from opposite ends of the line.

It should be noted that the use of the end-of-line receiver provides an automatic form of self test for the open

20

transmission line 10. This can easily be used to replace the normal tamper detection circuitry required in security sensors to detect when the cable is damaged.

As illustrated in Figure 10, in order to make the best

5 possible utilization of the processing hardware, the central control module 90 can be time-multiplexed between two open transmission lines 10A and 10B terminated by termination units 92A and 92B, respectively. This allows one to have two lengths of open transmission line 10A and 10B for one

10 reference antenna 20, one reference receiver 16, one line receiver 12S, one pair of demodulators 14S and 14T and one processor unit 18.

Figure 11 illustrates another of the many ways that systems with a common, time multiplexed control module 90 can

15 be adapted to address specific applications. Figure 11 illustrates a closed loop system in which the end-of-line receivers 92 are eliminated by connecting the line 10 between the A and B ports of the control module 90. Appropriate changes in the processing software of processor 18 enable

20 ports A and B to replace start S and termination T in the more general application. It should be noted that, in this embodiment of the invention, one does not need to communicate the signals over the open transmission line 10 since the control module 90 has access to both ends of the line 10.

25 Figure 12 illustrates the two open transmission lines 10A and 10B installed parallel to each other. This approach enlarges the detection zone and allows one to combine the detection results to lower the false alarm rate or to provide the direction of crossing.

30 Various modifications of the described embodiments of the invention are comprehended by the present invention. Thus, in order to maintain a uniform detection zone size with a constant probability of detection along the length of the line 10, the processor 18 may compare the average magnitude R to

35 a threshold which is a function of the location of the intrusion along the length of the line 10. Where multiple frequencies are involved, the average magnitude R will be obtained by summing the start perturbation signals for all

frequencies, summing the termination perturbation signals for all frequencies and taking the average. Since the signals propagating inside the line 10 attenuate exponentially with distance along it, the processor 18 will determine the
5 threshold using the function

$$T(l) = T_0 \; Cosh \; (\alpha l)$$

where T_0 is the threshold at the centre of the line 10, l is the distance from the centre of the line in meters, and α is the attenuation of the cable in Nepers per meter. Figure 9
10 illustrates the function $T(l)$ to provide uniform detection for a line with 18dB of attenuation per meter.

Thus, the processor 18 will combine the start and termination perturbations signals and then determine the approximate location of the intruder so as to compare the
15 magnitude R to the appropriate threshold. Since the signals attenuate exponentially from each end of the line 10, the ratio between the two perturbation signals is used to estimate the location of the intrusion along the length of the line using the expression:

20
$$\frac{R_S}{R_T}(l) = e^{-2\alpha l}$$

It is envisaged that the programming of processor 18 might be further modified to make a stepwise approximation to the ideal threshold curve shown in Figure 9 as a function of
25 simple binary ratios of R_S/R_T so as to avoid performing the division, the logarithm and the cosh function. As shown in Figure 9, for the line quarter-sections adjacent the centre of the line 10, the threshold is T_0, the level set by the user during calibration, as mentioned previously. For the quarter
30 sections adjacent the ends of the line, 10, the threshold is T_1 where $T_1 = 1.5T_0$. The operation of processor 18 to process the signals using a variable threshold is illustrated in Figure 13.

The reference receiver antenna 20 should be located so
35 as to obtain the strongest signal from the station transmitter free of time-varying multipath signals such as those which could be caused by nearby vehicular traffic.

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Although it will not be a problem in most cases, there may be applications where it is not possible to restrict movement of the reference antenna 20 or restrict movement of people or objects near to it. Because the system has a line
5 receiver at each end of the line 10, and both phase and magnitude information of the baseband signals M_S and M_T is available from both ends, additional processing can be used to reduce false alarms due to motion of the reference antenna and/or people or objects close to it. Because such motion
10 will cause an identical change in the phases of the baseband signal vectors M_S and M_T, but not affect their amplitudes, the processing could be arranged so that no alarm was declared if the phase changes of both baseband signals were the same and their magnitudes were unchanged.

15   Such additional processing is shown in Figure 14, in which components corresponding to those in Figure 7 have the same reference numeral. The processor means is identified by reference numeral 18C, the suffix "C" indicating that it differs from those of Figure 4 and Figure 7 in that it
20 provides the additional processing.

In the processor means 18C of Figure 14, the components Q_{RS}, I_{RS} and Q_{RT}, I_{RT} are extracted by A/D converters 40, filtered using bandpass filters and processed as described before with reference to Figure 7. For convenience of
25 illustration, such bandpass filtering and other processing are designated as "OTHER PROC'G" in Figure 14, only the additional processing being illustrated in detail.

Referring to Figure 14, following digitization by the A/D converters 40S, 44S, 40T and 44T, the baseband signal
30 components Q_S, I_S and Q_T, I_T are processed as shown by function boxes 100 and 102 to determine the phase values ϕ_S and ϕ_T, respectively, of the baseband signal vectors M_S and M_T. The magnitudes of the baseband vectors M_S and M_T also are computed from their components Q_S, I_S and Q_T, I_T, respectively, as
35 indicated by function box 104 . A truck 81 is shown moving so close to the reference antenna 20 that it interferes with the signal from transmitter 22. The motion of the truck 81 causes an identical change in the respective phases ϕ_S and ϕ_T

of baseband signals M_S and M_T (Figures 5A and 5B) but does not affect the amplitudes of baseband signals M_S and M_T because the reference receiver 16 "hard" limits to a fixed amplitude. As indicated by function box 106, the phase value changes $\Delta\phi_S$ and

5   $\Delta\phi_T$ are subtracted to give the differential phase change $\Delta\phi_M$ between the baseband vectors. If there is a differential phase change, as detected by a positive result from comparison step 108, the possibility of the change being due to motion of, or at, the reference antenna 20 is determined by

10 comparison step 110 which detects changes in amplitude of both M_S and M_T. If both amplitudes have not changed, the changes are attributed to motion at or of the reference antenna.

If comparison steps 108 and 110 both give negative outputs, i.e. the differential phase changed and one or both

15 of the magnitudes M_S and M_T changed, a "possible target" is indicated, as determined by function box 112.

It should be appreciated that the processing to find R (Figure 4) and ϕ (Figure 7) still contributes to the POSSIBLE TARGET decision. The outputs of decision steps 108 and 110

20 are used, as indicated by combination function box 112, to qualify the results of the other processing which, as previously mentioned,is designated as OTHER PROC'G.

Other approaches are also envisaged to deal with motion at, or of, the reference antenna. Thus, it would be possible

25 to measure response as change in magnitude of the vector extending between the tips of the baseband signal vectors M_S and M_T. The length of this vector will not change if M_S and M_T both rotate in the same way with no change in amplitude, but will change if an intruder causes a non-correlated change

30 in either amplitude or phase of M_S and M_T. This method requires accurate calculations, especially when clutter is large relative to intruder response, and can involve singularity problems if the target is much larger than clutter.

35   A third approach is to "normalize" the response by rotating the vector plane by the phase response of one end (preferably the one with the larger clutter as this will give more accurate measurement of phase angle), or some function

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of the phase response of both ends, such as the average. This would eliminate response due to mutual phase shift, while still responding to amplitude response or non-correlated phase response, as would be generated by an intruder.

5   In areas where there is no FM radio station, the intrusion detection system according to the invention can be operated by providing a local CW transmission in the FM band. Naturally this will require radio regulatory approval.

       Because of the popularity of FM radio, many types of low
10 cost antennas are readily available as the reference antenna 20. Likewise the electronic circuitry required in the reference receiver 16 and the line receivers 12S, 12T may employ inexpensive sophisticated integrated circuits development for the entertainment industry.

15   The open transmission line 10 can be virtually any type of transmission line that supports an external electromagnetic field. Perhaps the simplest such transmission line is a wire suspended above ground to form an Image Line. Other suitable open transmission lines are Two Wire Lines, Strip Line and
20 Surface Wave Lines. The key properties of such an open transmission line as it relates to the present invention are that it guides an electromagnetic field along its length at a known velocity of propagation with minimal radiation and with a field that decays with radial distance. The radial
25 decay rate determines the size of the detection zone.

       Embodiments of the invention yield various advantages over known systems. For example, embodiments using only one cable involve reduced costs. The intruder detection system may be passive which simplifies production and obviates the
30 need for FCC approval or approval of other regulatory bodies. Embodiments which use a commercial FM radio signal may use parts which are relatively cheap because they are available for FM radio receivers. The use of multiple reference signal frequencies enhances signal to noise ratio and reduces
35 multipath effects while increasing reliability.

       In the preferred embodiment the radio station is a commercial FM radio station operating in the 88 to 108 MHz band of frequencies. Electromagnetic fields at these

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frequencies are ideal for detecting human intruders while
rejecting small animals and birds because an adult human is
between one quarter and one half wavelength tall causing it
to have considerably larger radar cross section than a small
5   animal which may only be one tenth of a wavelength tall.
Commercial FM radio stations are also ideal because there are
usually many such stations in urban areas where crime is
prevalent and security is required and because they typically
transmit twenty four hours a day.
10

INDUSTRIAL APPLICABILITY

An advantage of embodiments of the present invention,
which deploy a receiver at each end of the open transmission
line, is that they provide substantially uniform sensitivity
15   without the expense and inconvenience of cable grading.
Embodiments of the invention which employ transmissions from
two or more stations, also give enhanced performance through
the use of frequency diversity which, together with the
spatial diversity arising from the use of receivers at each
20   end of the line, significantly improves the sensor performance
in terms of uniformity of detection along the line length as
well as providing a higher probability of detection and lower
false alarms ratio than conventional single frequency, single
ended leaky cable sensors.
25   Although embodiments of the invention have been described
and illustrated in detail, it is to be clearly understood that
the same is by way of illustration and example only and is not
to be taken by way of limitation, the spirit and scope of the
present invention being limited only by the appended claims.
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CLAIMS:

1.   An intruder detection system characterized by:
        an open transmission line (10); receiver means (12S,12T,
14S,14T) connected to both ends of the transmission line;
5 means (16) for providing at the receiver means a reference
local oscillator signal (LO) and a reference intermediate
frequency signal (IF_{REF}); and processor means (18) for
processing signals output from the receiver means; the
receiver means being responsive to the reference local
10 oscillator signal and the reference intermediate frequency
signal to extract from a first radio frequency signal (RF_S)
received at one end (S) of the line a first baseband signal
(M_S) comprising a perturbation signal (R_S) and to extract from
a second radio frequency signal (RF_T) received at the other
15 end (T) of the line a second baseband signal (M_T) comprising
a second perturbation signal(R_T), the first and second
perturbation signals being produced contemporaneously by an
intruder in proximity to the line, the processor being
operable to determine the presence of the intruder in
20 dependence upon both the first perturbation signal and the
second perturbation signal.

2.   An intruder detection system as claimed in claim 1,
characterized in that the processor means (18) is operable to
25 combine said first perturbation (R_S) signal and said second
perturbation signal (R_T) and to compare the combined value (R)
with a threshold (T) to determine presence of the intruder.

3.   An intruder detection system as claimed in claim 1,
30 characterized in that said first baseband signal (M_S) and said
second baseband signal (M_T) comprise first and second
components (C_S, C_T), respectively, outside a predetermined
frequency range in addition to the first and second
perturbation signals (R_S,R_T) and the processor is operable to
35 remove the first and second clutter components (C_S,C_T) before
combining the first and second perturbation signals (R_S, R_T).

4.   An intruder detection system as claimed in claim 3, <u>characterized in that</u> the predetermined frequency range is from about 0.005 Hertz to about 6 Hertz.

5 5.   An intruder detection system as claimed in claim 1, <u>characterized in that</u> the processor means (18) is operable to sum logarithmic values (R_S', R_T') of said first perturbation signal and said second perturbation signal to derive the combined value (R).

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6.   An intruder detection system as claimed in claim 1, <u>characterized in that</u> the processor means (18) is operable to compute the difference (L) between a logarithmic value (R_S') of the first perturbation signal and a logarithmic value (R_T')

15 of the second perturbation signal, and to determine the location of the intruder by comparing the difference with a reference dependent upon the length of the line.

7.   An intruder detection system as claimed in claim 1,

20 <u>characterized in that</u> the receiver means comprises a first line receiver (12S) connected to said one end of the line (10) and a second line receiver (12T) connected to said other end of the line (10), the first line receiver being responsive to the reference local oscillator signal (LO) to derive from the

25 radio frequency signal (RF_S) a first intermediate frequency signal (IF_S) comprising intruder-induced perturbations, the second line receiver (12T) being responsive to the reference local oscillator (LO) to derive from the second radio frequency signal (RF_T) a second intermediate frequency signal

30 (IF_T) comprising corresponding intruder-induced perturbations, a first demodulator (14S) responsive to the first intermediate frequency signal (IF_S) and the reference intermediate frequency signal (IF_{REF}) to derive said first baseband signal (M_S), and a second demodulator (14T) responsive to the second

35 intermediate frequency signal (IF_T) and the reference intermediate frequency signal (IF_{REF}) to derive said second baseband signal (M_T).

8.   An intruder detection system as claimed in claim 7,
characterized in that the first demodulator means (14S) and
second demodulator means (14T) supply the first baseband
signal (M_S) and second baseband signal (M_T), respectively, in
the form of in-phase and quadrature components (I_S, Q_S; I_T,
Q_T), and the processor means (18) is operable to combine the
sum of the squares of the in-phase and quadrature components
of each of the first baseband signal and second baseband
signal.

9.   An intruder detection system as claimed in claim 8,
characterized in that the processor means (18) is further
operable to remove clutter components outside a predetermined
frequency range.

10.   An intruder detection system as claimed in claim 9,
characterized in that the frequency range is from about 0.005
Hertz.

11.   An intruder detection system as claimed in claim 1,
characterized in that the receiver means comprises a first
line receiver (12S) and a second line receiver (12T) connected
to said one end and said other end, respectively, of the
transmission line (10), and the means (16) for providing a
reference local oscillator signal, the first line receiver
(12S), and the processor means (18) are located at, and
coupled to, said one end of the line (10), the second line
receiver (12T) is located at said other end of the line (10),
the reference local oscillator signal (LO) is supplied to the
second line receiver by way of the line (10) and the
intermediate frequency signal (IF_T) from the second line
receiver (12T) is returned by way of the line (10) for
processing.

12.   An intruder detection system as claimed in claim 1,
characterized in that the receiver means comprises a first
line receiver (12S) responsive to the reference local
oscillator signal (LO) to derive from the first radio

frequency signal received a first perturbed intermediate
frequency signal (IF_S), a first demodulator means (14S)
responsive to the reference intermediate frequency signal
(IF_{REF}) to derive from the first perturbed intermediate
5 frequency signal (IF_S) a first baseband signal (M_S), a second
line receiver (12T) responsive to the reference local
oscillator signal (LO) to derive from the second radio
frequency signal a second perturbed intermediate frequency
signal (IF_T), second demodulator means (14T) responsive to the
10 reference intermediate frequency signal (IF_{REF}) to derive from
the second perturbed intermediate frequency signal a second
baseband signal (M_T), first multiplexer means (96) coupling
the first line receiver (12S), the means (16) for supplying
the reference local oscillator signal (LO) and reference
15 intermediate frequency signal (IF_{REF}), the first demodulator
means (14S) and the second demodulator means (14T) to the
first end of the line (10), and second multiplexer means (98)
coupling the second line receiver (12T) to the other end of
the line, the arrangement being such that the reference local
20 oscillator signal (LO) and reference intermediate frequency
(IF_{REF}) are coupled to the second line receiver (12T) by way
of the first and second multiplexer means (96,98) and the line
(10), and the second perturbed intermediate frequency signal
($1F_T$) is returned from the second line receiver (12T) to the
25 second demodulator means (14T) by way of the first and second
multiplexer means (96,98) and the line (10).

13.   An intruder detection system as claimed in claim 1,
characterized in that the processor means (18) is further
30 operable to determine the respective phase angles (ϕ_{RS}, ϕ_{RT}) of
the first perturbation signal and second perturbation signal
and to determine an intruder to be present when the sum (ϕ)
of the phase angles is within a predetermined range ($\phi_1 - \phi_2$).

35 14.   A system as claimed in claim 1, characterized in
that the means (16) for providing comprises a reference
receiver for receiving the radio frequency signal without
perturbation by the intruder and generating therefrom the

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reference local oscillator signal (LO) and the reference
intermediate frequency signal (IF$_{REF}$).

15.   A system as claimed in claim 1, <u>characterized in</u>
5 <u>that</u> the receiver means (12S,12T,14S,14T) is tunable to
receive, selectively, a plurality (N) of transmissions at
different frequencies (f) and the processor means (18) is
operable to combine a corresponding plurality of first
perturbation signals at the different frequencies for said one
10 end of the line and a corresponding plurality of second
perturbation signals for said other end of the line.

16.   A system as claimed in claim 15, <u>characterized in</u>
<u>that</u> the processor means (18) is operable to select a
15 particular transmission frequency and adjust gain of said
receiver means (12S,12T,14S,14T) to a corresponding value
thereby to compensate for different signal strengths of the
different transmissions.

20 17.   A system as claimed in claim 15, <u>characterized in</u>
<u>that</u> the processor means (18) is operable to derive the
combined value by summing the plurality of first perturbation
signals, summing the plurality of second perturbation signals,
computing the logarithmic value of each sum so produced, and
25 summing the logarithmic values to give said combined value.

18.   A system as claimed in claim 15, <u>characterized in</u>
<u>that</u> the processor means (18) is operable to sum the plurality
of first perturbation signals, sum the plurality of second
30 perturbation signals, add the first sum and the second sum,
and compute the logarithm of the result as said combined
value.

19.   A system as claimed in claim 2, <u>characterized in</u>
35 <u>that</u> the processor means (18) is operable to combine the
perturbation signals to vary the threshold in dependence upon
the length of the line.

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20.   A system as claimed in claim 19, <u>characterized in</u> <u>that</u> the processor means (18) is operable to vary the threshold in accordance with the expression:

$$T(l) = T_0 \text{ Cosh } (\alpha l)$$

5   where T_0 is the threshold at the centre of the line, l is the distance from the centre of the line (10) in meters and α is the attenuation of the line in nepers per meter.

21.   A system as claimed in claim 2, <u>characterized in</u>
10 <u>that</u> the processor means (18) is operable to determine from the first and second perturbation signals the location of the intruder relative to the ends of the line and to compare the combined value with one of a predetermined plurality of threshold levels, a minimum of said levels corresponding to
15 the centre of the line and maxima of said levels corresponding to respective end portions of the line.

22.   A system as claimed in claim 2, <u>characterized in</u> <u>that</u> the receiver means (16) is tunable to receive,
20 selectively, a plurality (N) of transmissions at different frequencies (f) and the processor means (18) is operable to sum a corresponding plurality of first perturbation signals at the different frequencies for said one end of the line, sum a corresponding plurality of corresponding perturbation
25 signals at the different frequencies for said other end of the line, and combine the first sum and second sum to give said combined value, and <u>further characterized in that</u> the processor means (18) is operable to compare said combined value with one of a plurality of threshold levels, a minimum
30 of said levels corresponding to the centre of the line and maxima of said levels corresponding to respective end portions of the line, the processor means selecting the particular level in dependence upon the ratio between the first signal and second signal.
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23.   A system as claimed in claim 14, <u>characterized in</u> <u>that</u> the processor means (18C) is further operable to compensate for variations in the baseband signals caused by

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either or both of motion of an object near to an antenna of
the reference receiver and motion of the antenna itself.


24.   A system as claimed in claim 23, <u>characterized in</u>
5 <u>that</u> the processor means (18C) is operable to compensate the
variations by computing (106) differences ($\Delta\phi_M$) between
changes in phase ($\Delta\phi_S, \Delta\phi_T$) of the first baseband signal (M_S)
and second baseband signal (M_T), and computing (104)
differences in amplitude of both the first baseband signal and
10 second baseband signal (M_T), and inhibiting the determination
of the presence of an intruder when a variation in the
baseband signals is not accompanied by a difference ($\Delta\phi_M$)
between the changes in phase and a change in amplitude of at
least one of the baseband signals (M_S, M_T).
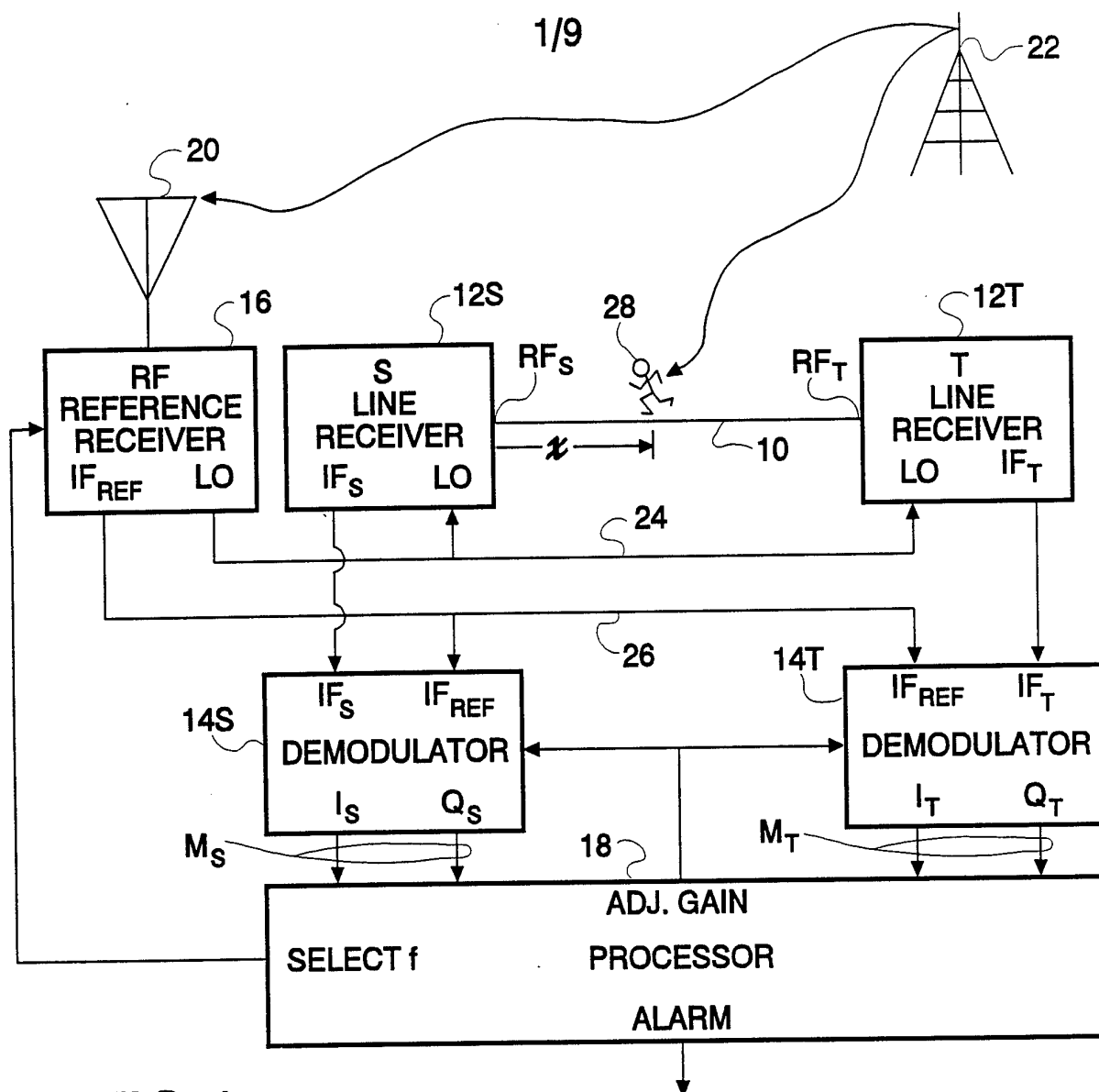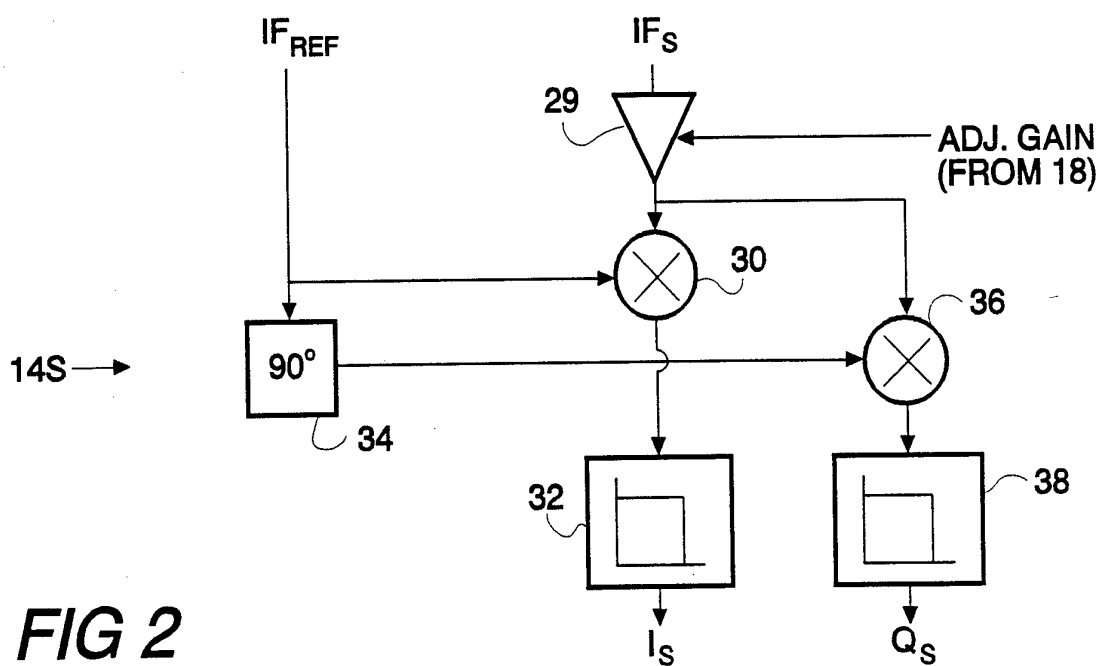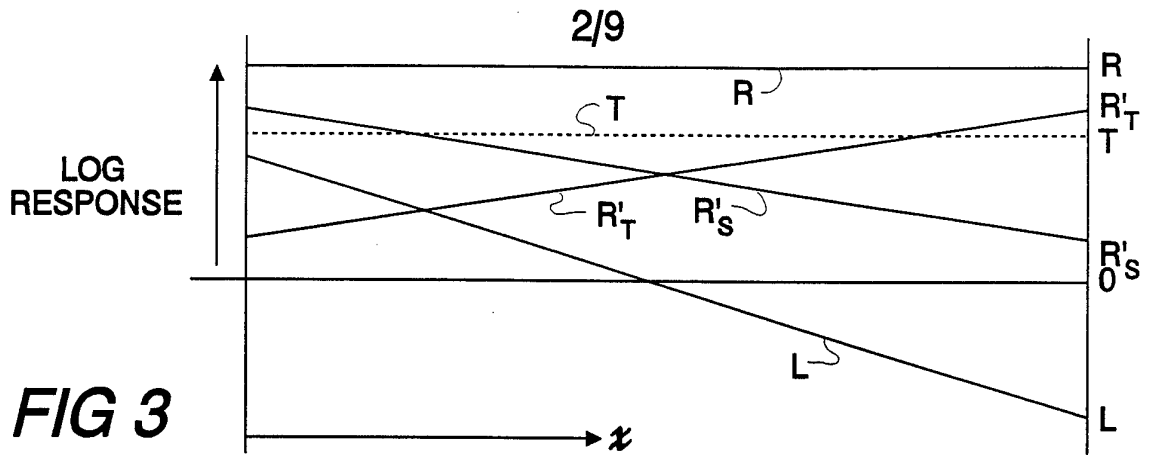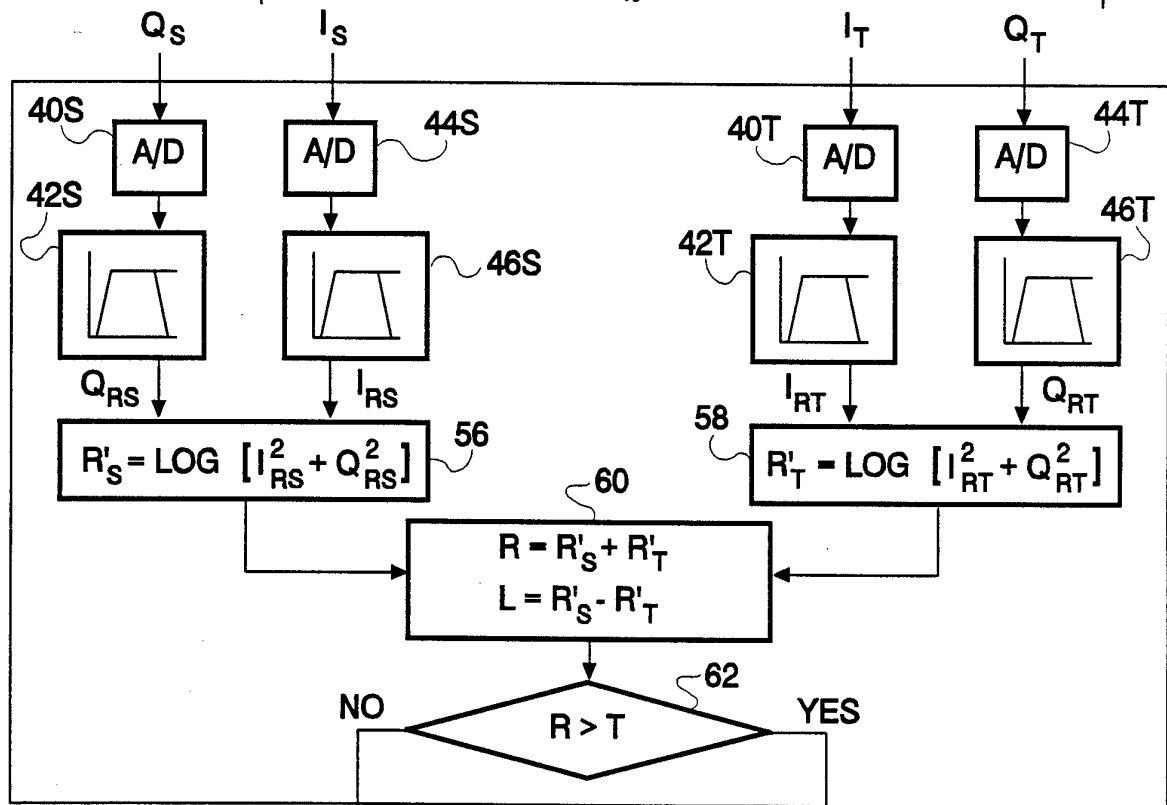
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FIG 1

FIG 2

FIG 3

FIG 4
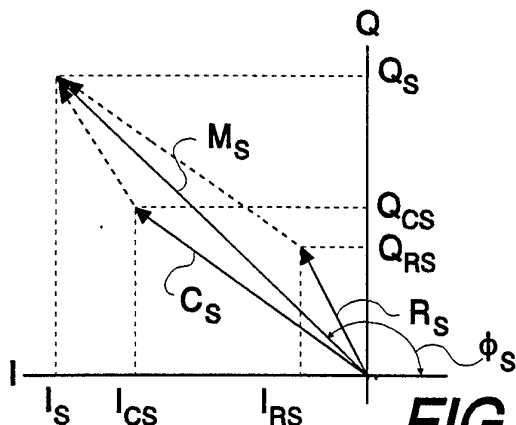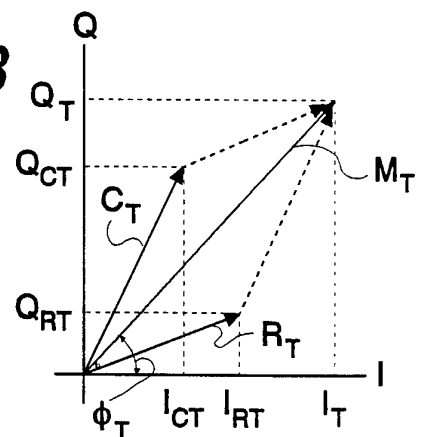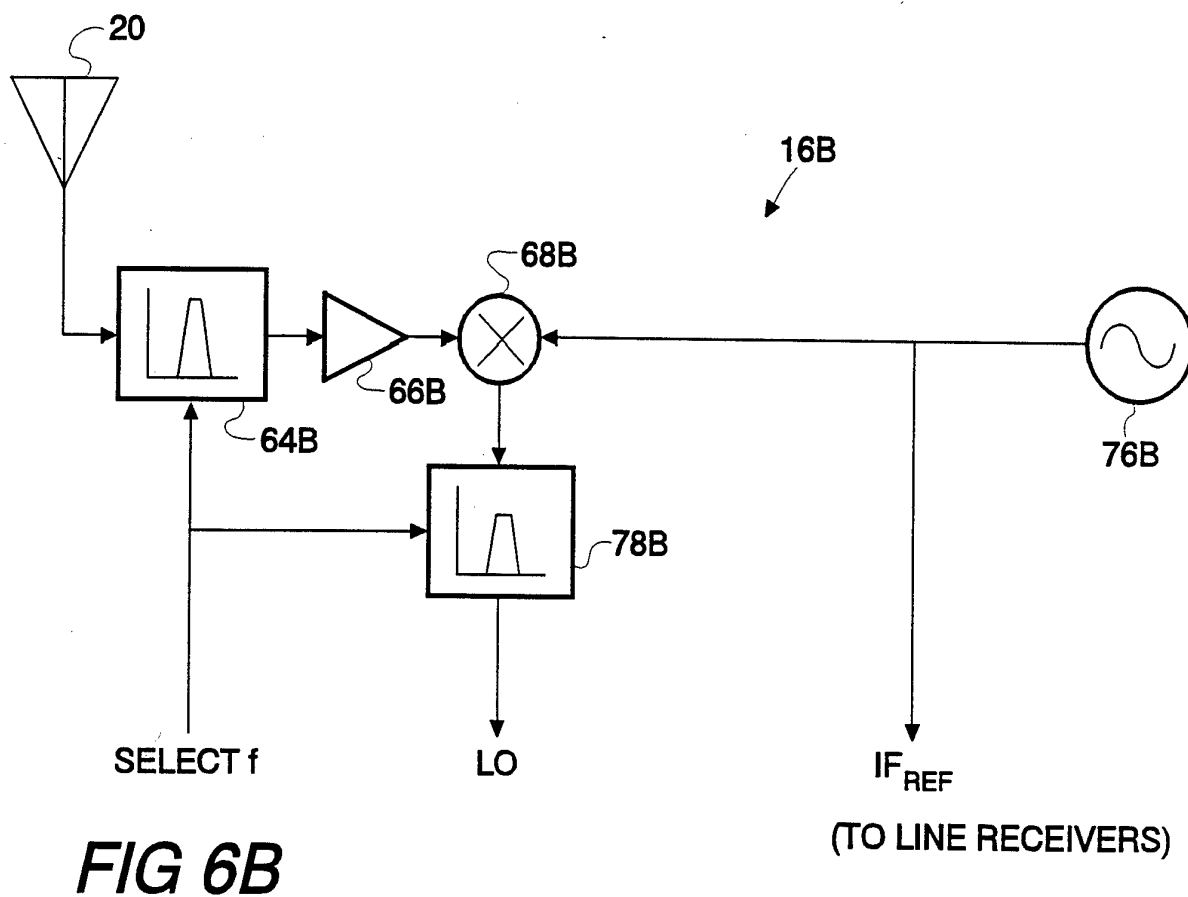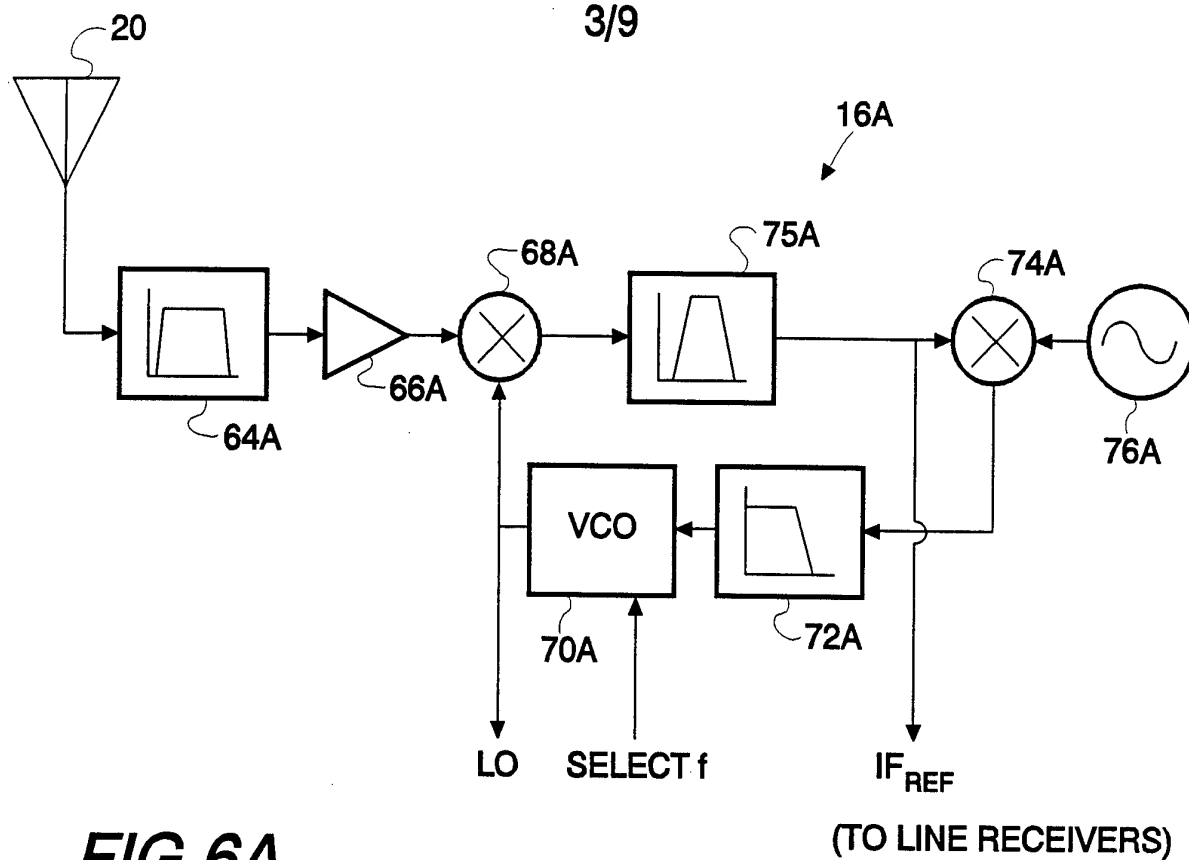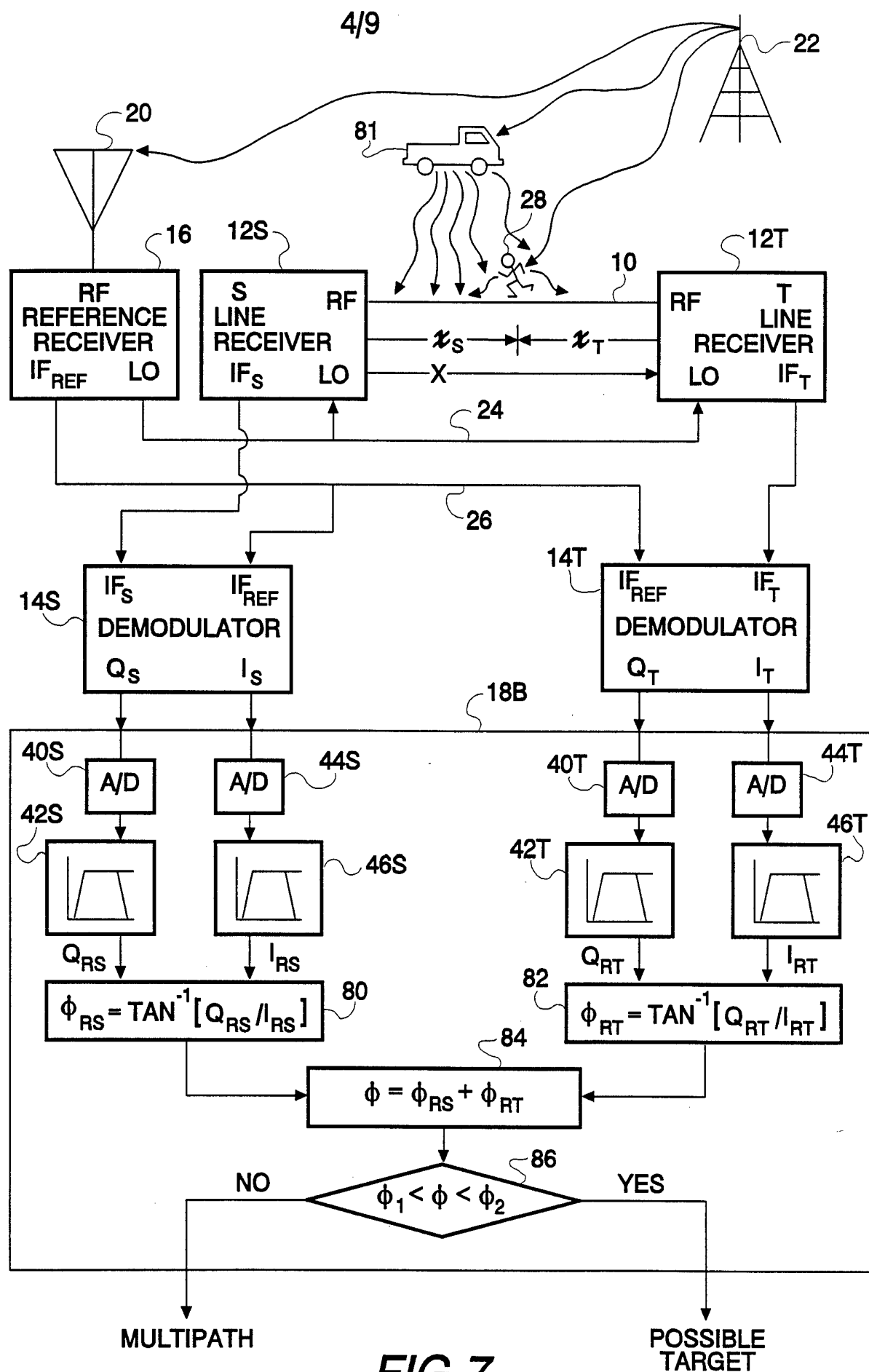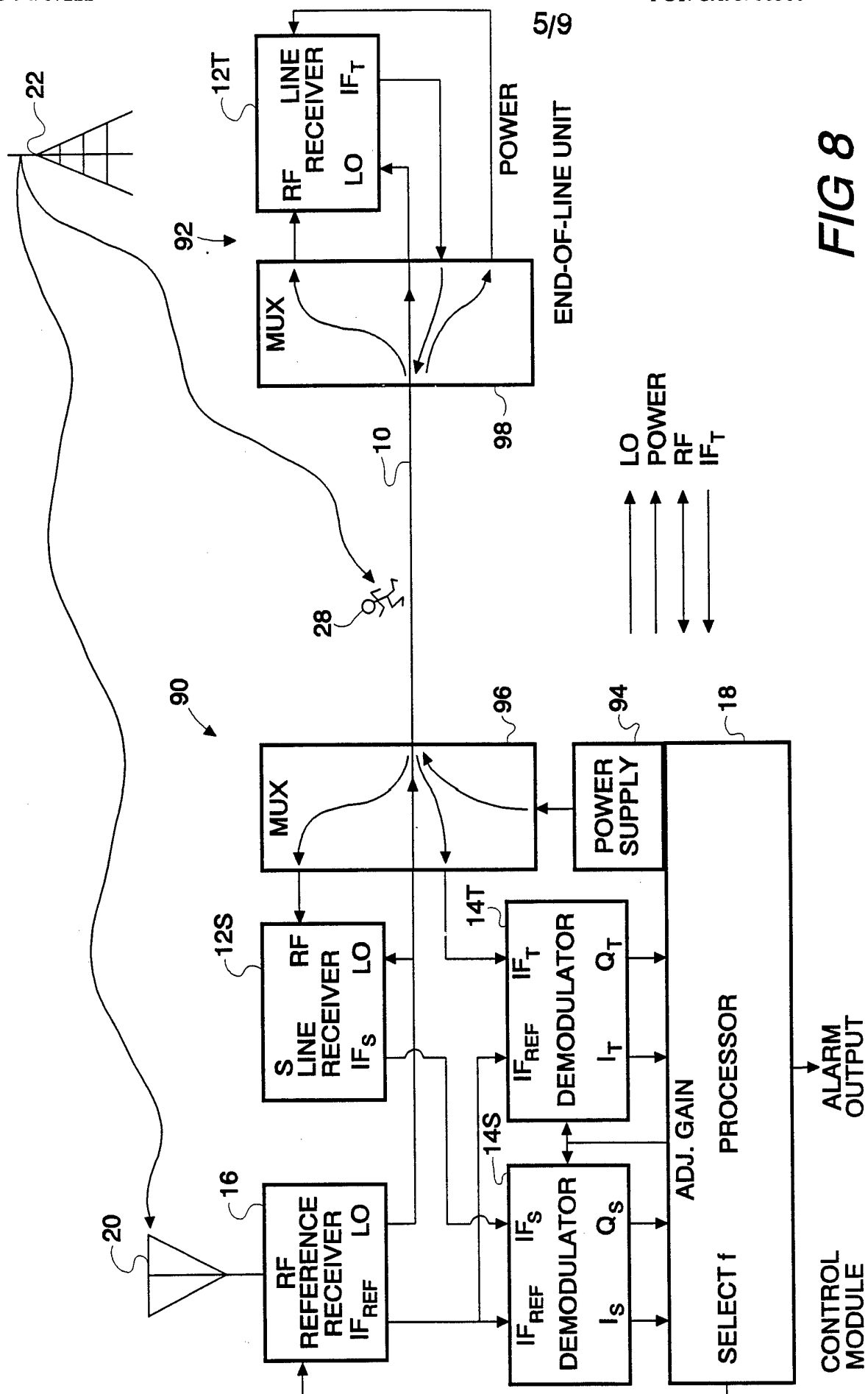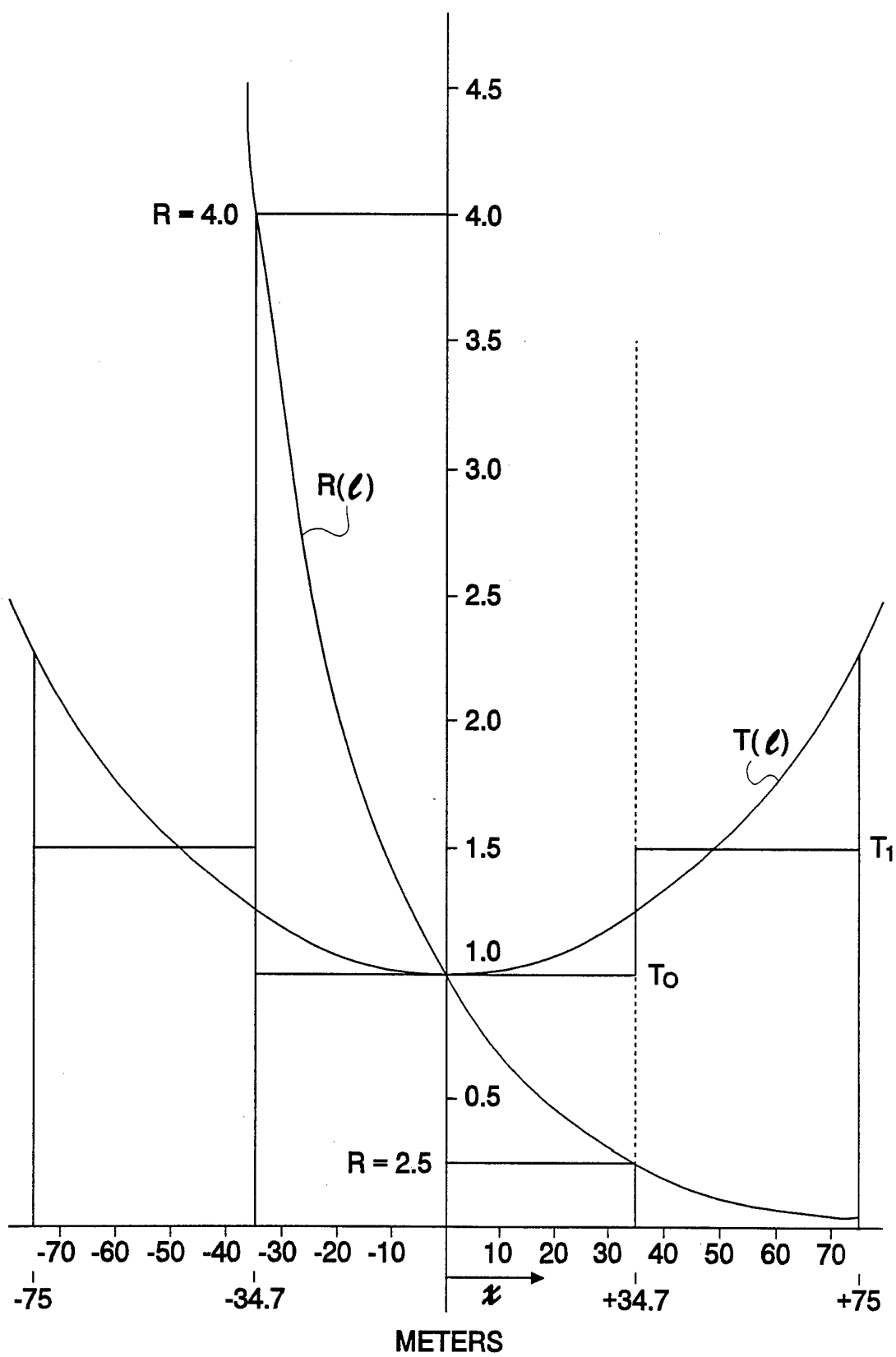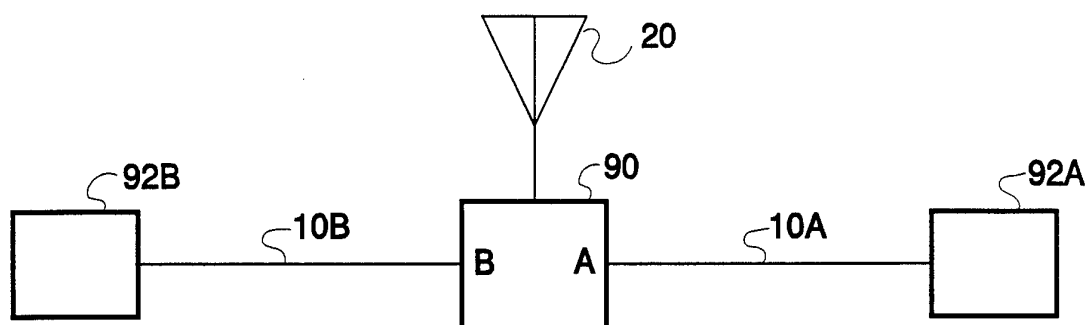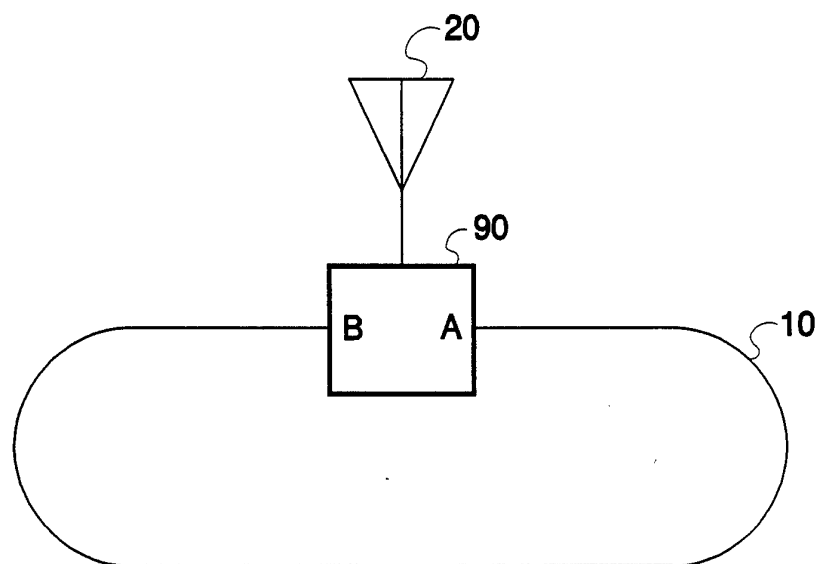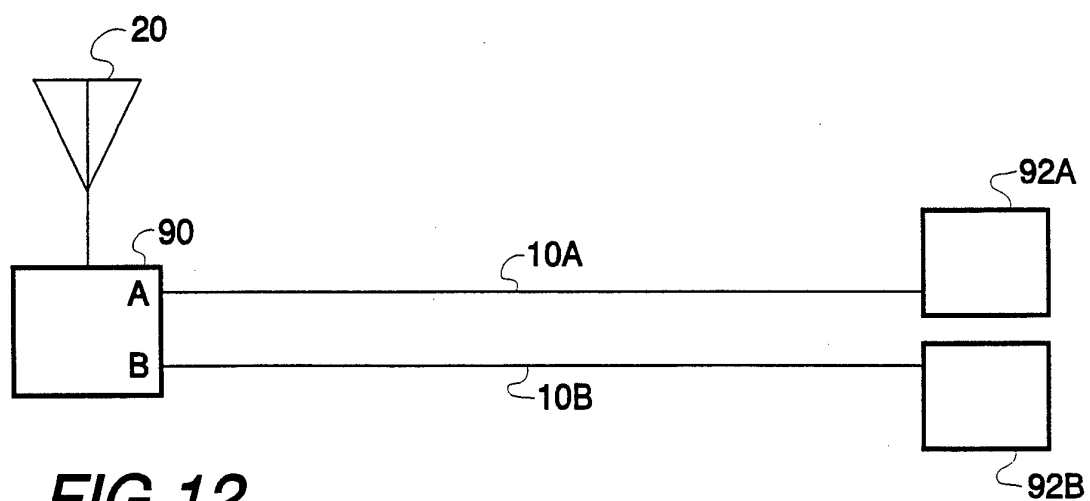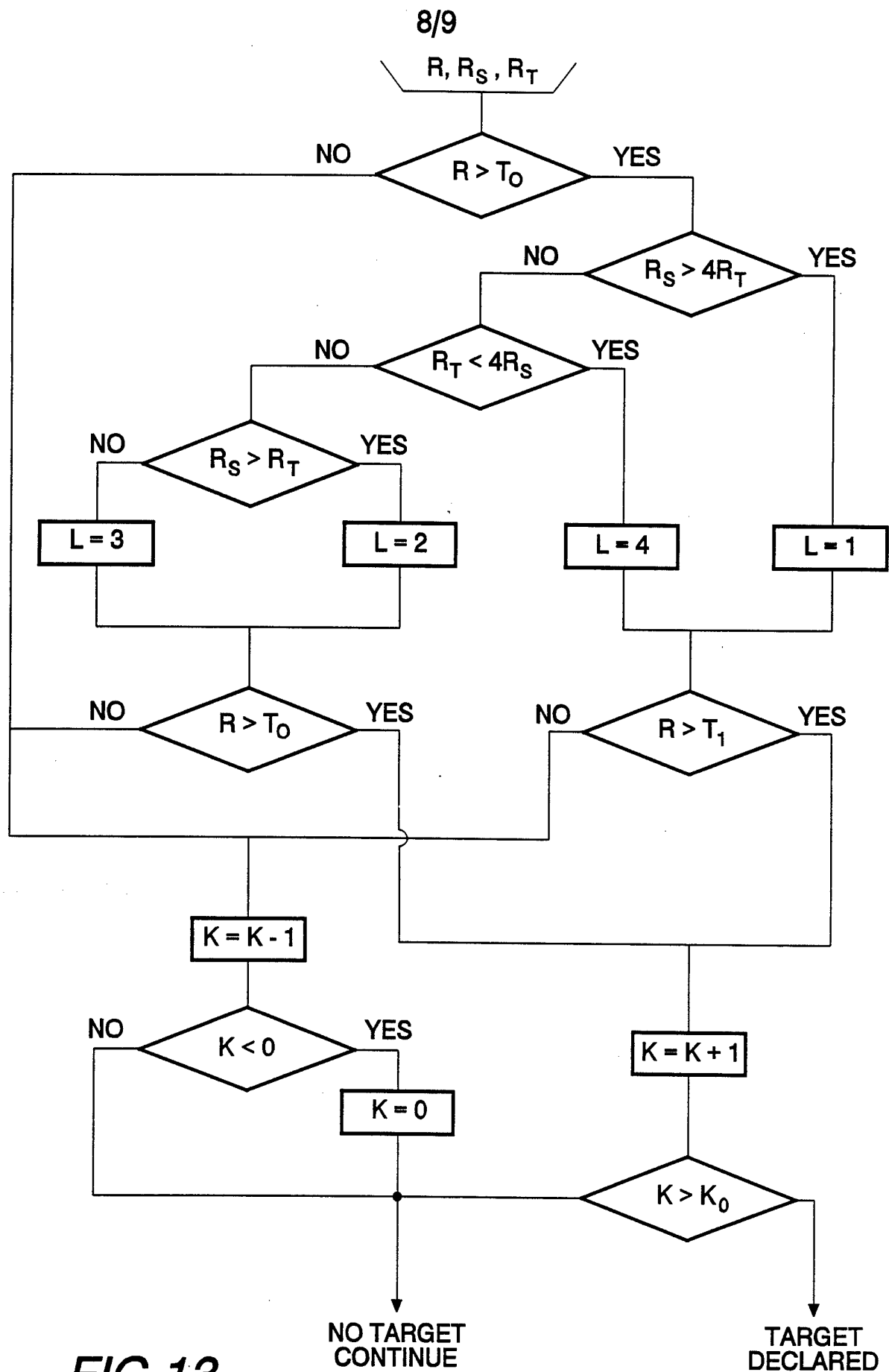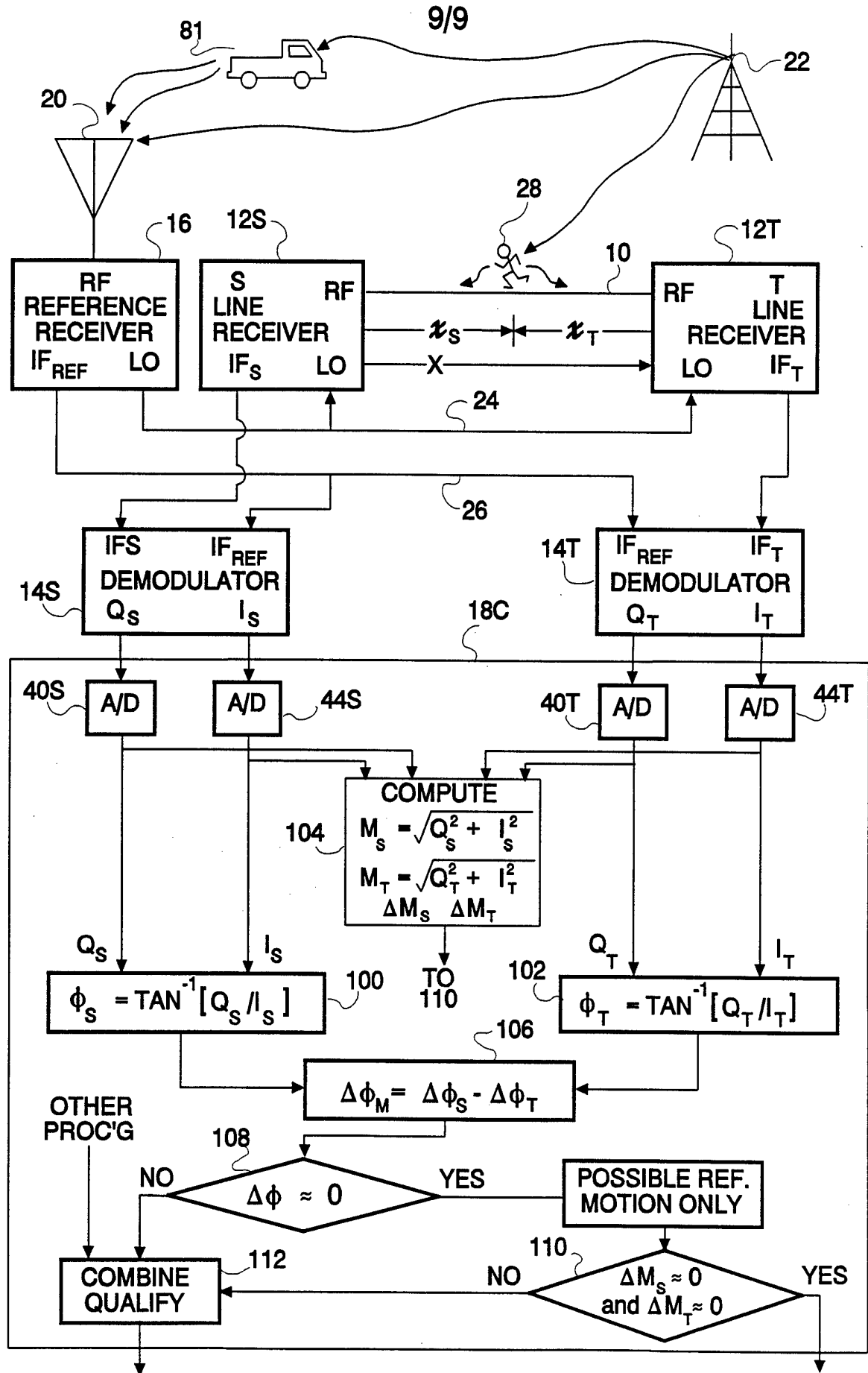
$$R'_S = LOG \ [I^2_{RS} + Q^2_{RS}]$$

$$R'_T = LOG \ [I^2_{RT} + Q^2_{RT}]$$

$$R = R'_S + R'_T$$
$$L = R'_S - R'_T$$

R > T

FIG 5B

FIG 5A

FIG 6A

FIG 6B

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FIG 7

FIG 8

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FIG 9

FIG 10

FIG 11

FIG 12

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FIG 13

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$$\phi_S = TAN^{-1}[Q_S/I_S]$$

$$\phi_T = TAN^{-1}[Q_T/I_T]$$

$$\Delta\phi_M = \Delta\phi_S - \Delta\phi_T$$

COMPUTE
$$M_S = \sqrt{Q_S^2 + I_S^2}$$
$$M_T = \sqrt{Q_T^2 + I_T^2}$$
$$\Delta M_S \quad \Delta M_T$$

$\Delta\phi \approx 0$

$\Delta M_S \approx 0$ and $\Delta M_T \approx 0$

POSSIBLE REF. MOTION ONLY

COMBINE QUALIFY

REF. MOTION ONLY

FIG. 14

INTERNATIONAL SEARCH REPORT

| A. CLASSIFICATION OF SUBJECT MATTER |
| IPC 5   G08B13/24 |

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 5   G08B   H01Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO,A,91 13415 (INSTANTEL INC.) 5 September 1991 see page 11, line 37 - page 13, line 37; figure 1	1
Y	US,A,4 419 659 (R. HARMAN) 6 December 1983 see column 4, line 64 - line 68; figure 1B	1

☐ Further documents are listed in the continuation of box C.   ☒ Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 December 1993	2 0. 01. 94

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Sgura, S

INTERNATIONAL SEARCH REPORT

Information on patent family members

Intern. al Application No

PCT/CA 93/00366

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
WO-A-9113415	05-09-91	EP-A-	0516661	09-12-92
US-A-4419659	06-12-83	CA-A-	1169939	26-06-84