

SPECIFICATION

Moving object detecting device

- 5 This invention relates to moving object detecting devices and, more particularly, to improve- 5
ments in Doppler type detecting devices specifically of an object which is continuously moving.
It has been known, as suggested in U.S. Patent No. 2,934,756 of April 26, 1960 to H. P.
Kalmus, to detect a presence of a moving object by radiating continuous energy waves by a
10 wave radiator into a watching space, receiving the waves reflected from the object present 10
within the range of the watching space by a wave receiver, detecting by means of a detector a
beat produced in output signals of the wave receiver due to variations in the distance between
the object and the wave radiator, that is, due to the Doppler effect depending on movements of
the object, and having any detected output of the detector indicated when such output is above
15 a predetermined level. According to this U.S. Patent, however, it is possible that an erroneous 15
indication or reduction of S/N ratio is caused by a clutter noise due to any fluctuations in
conditions existing in the course of the propagation of the energy waves or directionally varying
movements of the object within the watching space.
- There has been suggested in another U.S. Patent No. 3,432,855 of March 11, 1969 to H.P.
Kalmus a different type of moving target indicator of such arrangement as shown in Fig. 1 of
20 the accompanying drawings, wherein any interference of the clutter noise is prevented, utilizing 20
a phenomenon that the object continuously moving in one direction produces a Doppler signal
either above or below the frequency of the radiated wave signal and, on the other hand, the
frequency of the clutter noise is distributed both above and below the frequency of the radiated
wave signal. According to this patent, a generated signal of a radiating wave signal generator
25 10 is radiated through a wave radiator 2', reflected waves are received by a wave receiver 3', a 25
received wave signal is applied to mixers 12 and 14, first Doppler signal E and second Doppler
signal E' the phase of which is delayed by means of a phase shifter 16 by 90° from the first
Doppler signal E are respectively extracted, and a third Doppler signal E'' of a phase delayed by
a phase shifter 19 by 90° from the second Doppler signal E' is obtained. When a moving object
30 30 approaches the wave radiator 2', the frequency of the Doppler signal is higher than the 30
radiating wave frequency radiated by the wave radiator 2', so that the first and third Doppler
signals E and E'' will be in phase with each other and a correlator 52 will produce a positive
voltage signal. On the contrary, when the moving object 30 moves away from the wave radiator
2', the frequency of the Doppler signal is lower than the radiating wave frequency, the Doppler
35 signals E and E'' will be out of phase and the correlator, 52 will produce a negative voltage 35
signal. Thus, when the moving object is present, either one of such positive and negative
signals is present, and the signal will be integrated by an integrator which comprises a
resistance 60 and capacitor 62, an output of the integrator will be amplified by an amplifier 64
and then an indicator 64 will operate. The particular integrator has a function of suppressing the
40 clutter noise when the same is present. While reasons for this suppressing effect are not 40
specified in the U.S. Patent 3,442,855, it is evident that the suppressing effect is that, so long
as the frequency of the clutter noise is distributed above and below the radiating wave
frequency, the correlator 52 will generate positive and negative signals at random and such
positive and negative signals will produce no output of the integrator. It is appreciable that the
45 U.S. patent 3,432,855 realizes a moving object detecting device having a direction sensing 45
ability and suggests a technical idea of thereby suppressing any influence of the clutter noise.
According to this device, however, it is difficult to realize the phase shifter 19. That is, in the
case of such moving object as a human whose moving, speed is variable from a low speed to a
high speed, the frequency of the generated Doppler signal has a width of about an octave and,
50 in order to shift the phase of such Doppler signal including all of this frequency exactly by 90°, 50
the phase shifter 19 is required to be of a very wide band, thus the shifter becomes high in the
cost, the first and third Doppler signals E and E'' will often not be of the same or reverse
phases, and the detecting sensitivity will greatly reduce.
- On the other hand, U.S. Patent No. 3,665,443 of May 23, 1972 to A. A. Galvin suggests to
55 utilize a phenomenon that the spectrum of a moving object is asymmetrical with the frequency 55
of radiated wave signal but the spectrum of a noise is symmetrical with the radiated wave signal
frequency, and a device utilizing these spectrum characteristics different from each other is
shown in the patent. This device is featured, as compared with the above described U.S. patent
3,432,855, in that both first and second signals can be provided in the presence of an
60 interference phenomenon, and is progressive in the presence of a difference in the noise 60
detecting technique. The U.S. patent 3,665,443 is of such a system as shown in Fig. 2A,
wherein a signal oscillated by an oscillator 1 is radiated as ultrasonic waves in air by a radiating
ultrasonic wave transducer 2', reflected waves are received by a received ultrasonic wave
transducer 3', its received signal is extracted and split by a side band splitter 4 into upper side
65 band waves of a frequency larger than that of radiated wave signal and lower side band waves 65

of a frequency smaller than that of the radiated wave signal and of a reverse polarity to the upper side band waves, both side band waves are provided into an adder 7 to be added therein through filter 5a and wave detector 6a or 5b and 6b, added result is integrated by an integrating circuit 8', the time when the energy of either one of these side band waves is larger than that of the other is detected by a limit circuit 9' in respect of an integrated output of the integrating circuit 8', an alarm is indicated by an alarm indicator 11 and, in case both of the side band waves are balanced, no alarm is indicated.

In this U.S. patent 3,665,443, on the other hand, there are still involved such possibilities that, first, an erroneous alarm may be made due to an actually present unbalanced noise such as, for example, such ultrasonic wave noise radiated from a bunch of keys carried by a moving person as shown in Fig. 2B wherein a curve X shows the spectrum of such balanced noise as a bell ring and a curve Y shows the unbalanced noise, and, second, no alarm may be indicated in the case of a so-called kick-back phenomenon. Thus, it is not ignorable that there exists a phenomenon in which a moving object is present but its presence cannot be detected. More specifically, as shown in Fig. 2C, when such moving object 30 as a person is present and moves at a position close to a wall surface lying substantially at right angles with respect to main advancing direction of the radiated ultrasonic waves, a frequency f_d of Doppler signal reflected directly from the moving object and a frequency f_d' of Doppler signal reflected indirectly from the moving object 30 through the wall surface will be present respectively above and below the frequency f_0 of the radiated wave signal and both of these direct and indirect Doppler signals will be simultaneously generated and extracted so that the presence of the object practically cannot be detected. This is an exemplary event where the provision of either the first and second signal depending on the spectrum characteristics at the presence of the object as the U.S. patent 3,665,443 discloses is practically impossible. Further according to this patent, both of the first and second signals are concurrently provided in the presence of a noise, that is, the interference phenomenon so that, in an event when the moving object is present under such conditions as above, both of the first and second Doppler signals will be generated and the moving object will not be able to be detected. The phenomena occurring in the above three examples are all effective in rendering any known defective devices for intruding objects to be defective.

A moving object detecting device according to the present invention comprises an oscillator which produces a reference signal, a transmitter which transmits the reference signal, a receiver which receives the waves reflected from objects to be detected and provides a received-wave signal, and electronic means for establishing the relative phase of reference signal and received-wave signal, for recognizing in which one of at least three predetermined bands of phase angles lies the said relative phase, the predetermined phase bands being contiguous and together covering the complete range (2π) of possible values of the relative phase, and for detecting over a substantial period whether the changes from phase band to phase band occur predominantly in the direction of increasing or decreasing phase angle, indicating in this case the presence of an object moving towards or away from the detector, or whether the direction of change from phase band to phase band appears to be random, indicating that there is no moving object near the detector.

A moving object detector according to the present invention is reliable and is generally unaffected by noise and interference phenomena.

Furthermore, it involves no frequency analysis based on spectrum characteristics of the received wave signals, which can lead to erroneous operation in some known moving object detectors. It can be simple in structure and inexpensive.

Other objects and advantages of the present invention will be made clear upon reading the following descriptions of the invention detailed with reference to a preferred embodiment thereof shown in accompanying drawings, in which:

Figure 1 is a block diagram showing an example of a known circuit for a moving object detecting device;

Figure 2A is a block diagram of another example of a known circuit;

Figures 2B and 2C are explanatory diagrams for the circuit of Fig. 2A;

Figure 3 is a block circuit diagram of a preferred embodiment according to the present invention;

Figure 4 shows a practical circuit arrangement of the embodiment shown in Fig. 3;

Figure 5 is a diagram for explaining Doppler signals in general in relation to the vector and phase angle;

Figure 6A is a diagram similar to Fig. 5 but for explaining the Doppler signals in the case of a moving object;

Figure 6B shows wave forms in respective parts in the device of Fig. 4 in its operation with respect to the moving object;

Figure 7 is a diagram for explaining conditions of the Doppler signals in operation of the device of Fig. 4;

Figure 8 shows wave forms at the respective-parts in the device of Fig. 4 in its operation with respect to a bell ring; and

Figure 9 is a block diagram of an electronic switch used in a quadrant shift direction detecting circuit of the device shown in Fig. 4.

Referring now to Fig. 3 showing an embodiment of the moving object detecting device according to the present invention an oscillator 1 has an oscillating frequency corresponding to the frequency of, for example, ultrasonic waves and its output signal of such frequency is fed as a radiating-wave signal E_4' to a radiating-wave transducer 2 comprising, for example, a pair of electrodes fitted to opposite surfaces of a piezoelectric crystal element so that, in this case, ultrasonic waves will be radiated from the transducer 2 into a space of watching zone. A received-wave transducer 3 of a similar structure to the radiating-wave transducer 2 is installed within the watching zone together with the transducer 2, so as to receive any reflected ultrasonic waves back from an object present in the space and to convert the received reflected-waves into an electric received-wave signal E_{in} . A phase shifter 13 receives the radiating-wave signal E_4' directly from the oscillator 1 and shifts the phase of the radiating-wave signal E_4' to produce a signal E_4 . Mixers 15 and 17 are connected respectively to the phase shifter 13 and oscillator 1 so that the mixer 15 will receive the received-wave signal as E_{in} and mix it with the phase-shifted signal E_4 and the mixer 17 will receive the received-wave signal as E_{in}' and mix it with the radiating-wave signal E_4' , and these mixed and detected signals of E_4 , E_{in} and E_4' , E_{in}' are respectively amplified by amplifiers 18 and 18a and a pair of Doppler signals E and E' are provided. Binary number converters 21 and 22 connected to the amplifiers 18 and 18a convert the respective Doppler signals E and E' to a pair of binary numbers X and Y of digital signals, which store respectively a quadrant information that denotes, when the received wave signal is vector-indicated with the radiating-wave signal E_4 or E_4' used as a reference vector, a specific quadrant in which a received-wave signal vector E_{in} will be present. Level detecting circuits 23 and 24 are also connected to the amplifiers 18 and 18a to detect whether the vector E_{in} is present or not depending on whether signal level of the vector signal is above a predetermined level or not. Resultant outputs of these level detecting circuits 23 and 24 are provided into an OR circuit 25, which generates, upon receiving the output from either one of the level detecting circuits 23 and 24, a signal denoting the presence of the vector E_{in} . A quadrant signal generating circuit 26 is connected to the converters 21 and 22 and to the OR circuit 25 for generating a quadrant signal I, II, III or IV corresponding to the specific quadrant in which the vector E_{in} is present as represented by the binary number digital signals X and Y. A quadrant shift direction detecting circuit 27 receives such quadrant signals I through IV and generates a single signal Z of either positive or negative voltage at a specific moment, depending on whether the last shift of quadrants was in a clockwise or a counter-clockwise direction, and the circuit 27 maintains this positive or negative signal Z until the quadrant is shifted to another quadrant or vanishes. An integrating circuit 8 receives and integrates the output of the quadrant shift direction detecting circuit 27 and its integrated output is detected by a threshold level circuit 9 having a predetermined limit level. The threshold level circuit 9 drives an indicator driving circuit 28 with its detected signal and indicates the presence of a moving object.

While, in the above, the use of the ultrasonic waves has been elucidated as an example, the waves radiated need not be limited to the ultrasonic waves but may be any microwaves

Referring to the present invention more specifically by reference below to a practical example of circuit arrangement of the device as shown in Fig. 4, the radiating-wave signal E_4' is generated by the oscillator 1 which employs a crystal oscillating element XL. The phase shifter 13 comprises a capacitor C_1 , resistance R_1 , and operational amplifier OP_0 . References shall be made briefly here to the pair of Doppler signals provided from the respective amplifiers 18 and 18a by reference to Fig. 5 while these signals have been already detailed, for example, in the U.S. patent 3,432,855. When a vector indication is made as in respective rectangular coordinates of Fig. 5 with the input signal from the oscillator 1 to the mixer 17 denoted as E_4' and the Doppler component of the received-wave signal denoted as E_{in} while denoting the input signal from the phase shifter 13 to the mixer 15 as E_4 , the following relations will exist between the Doppler signals E and E' and the received wave vector E_{in} if the phase angle of the received-wave Doppler component E_{in} with respect to the vector E_4 made as the reference vector is θ as shown:

$$E = |E_{in}| \cos \theta \text{ (as in vertical wave-form diagram of Fig. 5) and}$$

$$E' = |E_{in}| \sin \theta \text{ (as in horizontal wave-form diagram of Fig. 5)}$$

In the U.S. patent 3,432,855, it is considered important that this phase relation between the respective Doppler signals E and E' is different between the case where a single upper side band wave is present and the case where a single lower side band wave is present. That is, the Doppler signal E will advance in phase by 90° (as shown by the broken line) for an object approaching with respect to the Doppler signal E' but will delay in phase by 90° (as shown by the solid line) for an object moving away. However, when the moving object is, for example, a human walking or running, the respective portions of human body will have different speeds so

that the received-wave vector E_{in} will be a resultant vector having all of such advancing and delaying signal information as shown in rectangular coordinates with indications of quadrants I through IV of Fig. 6A and, generally, the wave form of the Doppler signals E and E' will not be of such single sinusoidal wave signal as in Fig. 5 but will be of deformed wave forms such as shown in Fig. 6A.

However, even if the received-wave vector E_{in} is the resultant of a combination of various components, the Doppler signals E and E' will show the relation of the above formulae, that is, a single point P on the rectangular coordinates of Fig. 5 having the tip of the reference vector E_0 as an origin. In other words, the rotary vector of the received-wave vector E_{in} may be of values $E(t_1)$ and $E'(t_1)$ at a time t_1 , which are plotted onto the E—E' rectangular coordinates from the respective E and E' wave form diagrams in Fig. 6A. Thus, the vector of the received-wave signal E_{in} can be correctly reproduced even if the Doppler signals E and E' are combined and the received-wave vector E_{in} contains various frequency components. On the other hand, the thus obtained Doppler signals E and E' contain so many frequencies in most cases that the U.S. patent 3,432,855 employing the 90° phase shift of the entire signal cannot be suitably adopted. Further, a method wherein respective energy levels of the upper and lower side band waves forming the received-wave signal as spectrally separated are strictly extracted or, in other words, the vector shown in Fig. 6A is analyzed and respective component vectors having different angular velocities are separated from one another, requires a complicated circuit and involves at the same time such defects as have been already described. Yet, with a method of judging whether the phase relation of the Doppler signals E and E' is merely an advance or delay of 90°, such deformed wave forms as in Fig. 6A will never be analyzed.

According to the present invention, therefore, above the quadrant in which the vector E_{in} is present and its shifting direction are perceived to be utilizable. In Fig. 6A, the apex E of the vector transfers from I→II→III→(IV→III→)IV→I as shown in the rectangular coordinates of Fig. 6A. It is evident that, except the parenthesized process (IV→III→), all the process shifts counterclockwise. At this time many minor variations are present within a single quadrant but they cause no influence on the quadrant signals, and this clearly shows that the vector itself rotates counterclockwise as a whole. The present invention is, therefore, to detect the vector rotation from the standpoint of the shifting in the quadrants and to detect the moving object responsive to a signal denoting such quadrant shifting.

Now, the Doppler signals E and E' obtained by the mixers 15 and 17 and amplifiers 18 and 18 are converted to the digital signals X and Y by the binary number converters 21 and 22. In these signals X and Y, any level information in the Doppler signals E and E' is erased, and only the information as to whether the vector apex is present above or below or on the right or left of the rectangular coordinates E—E' remains. Further, these signals X and Y are combined with each other, and four quadrant signals I, II, III and IV corresponding to such combination are, generated as in the following Table 1 by the quadrant signal generating circuit 26:

Table 1

X	Y	I	II	III	IV	Remarks
1	1	0	1	1	1	At the time when the vector is above a predetermined level.
0	1	1	0	1	1	
0	0	1	1	0	1	
1	0	1	1	1	0	
1 or 0	1 or 0	1	1	1	1	When the vector is below the level.

The above can be readily obtained by forming the circuit 26 with a suitable decoder. For the convenience of the circuit, the signal 0 shows a quadrant signal and the signal 1 shows that there is no signal in the same quadrant. When the vector is, however, below a predetermined level, irrespective of the values of the signals X and Y, the vector is caused to be returned to the origin and the definition of the "quadrant signal" is not satisfied. Therefore, respective amplitudes of the Doppler signals E and E' are detected by the level detecting circuits 23 and

24. When either one of the Doppler signals is above the predetermined level, the OR circuit 25 here incorporated in the circuit 26 will generate an output and will provide the quadrant signal I, II, III or IV. In practice, the level checking may be made with respect to only one of the Doppler signals E and E' or, strictly, to

$$\sqrt{|E|^2 + |E'|^2},$$

10 i.e. the signal level may be investigated on the criterion that the distance from the origin is within a fixed range.

Thus, the quadrant signals I, II, III and IV in which the apexes of the vector obtained from the Doppler signals are present are obtained from the combination of the binary signals X and Y. Then, these quadrant signals are applied to the quadrant shift direction detecting circuit 27 for
15 investigating the shifting direction of these quadrant signals. The quadrant shift direction detecting circuit 27 is to temporarily store the momentarily shifting quadrant signal and to determine in which direction of the four quadrants the vector shifts by investigating the stored signal when the vector has shifted to a new quadrant and a new quadrant signal is provided. Thus, the circuit 27 comprises two R—S flip-flops FF₁ and FF₂ of the storing circuit section, 8
20 gates G₁ to G₈ and 8 diodes D₁ to D₈ for preventing reverse current flow.

The operation as above of the present invention shall be explained with reference to the case that the signals E and E' as in Fig. 6B are obtained. Wave forms of the signals X and Y obtained by respectively binarily converting the Doppler signals E and E' are shown in (a) and (b) of Fig. 6B on the same axis as of the Doppler signals E and E'. Now, when the binary signals X and Y
25 are 1 and 1, the signal of the quadrant I is provided by the quadrant signal generating circuit 26 as in (c) of Fig. 6B. In the same manner, when the binary signals X and Y are 0 and 1, 0 and 0 and 1 and 0, the signals of the quadrants II, III and IV are respectively provided by the quadrant signal generating circuit 26 as in (d), (e) and (f) of Fig. 6B. The flip-flop FF₁ will be reversed by the quadrant signals I and III and outputs p and q (Fig. 4) of such wave forms as in
30 (g) and (h) in Fig. 6B. As will be clear from the circuit of Fig. 4, during a period from the generation of the quadrant signal I to the generation of the quadrant signal III, p = 1 and q = 0, and, with the quadrant signals II and IV, the flip-flop FF₁ will not operate. On the contrary, after the generation of the quadrant signal III until the generation of the quadrant signal I, p = 0 and q = 1. In the same manner, the flip-flop FF₂ will be operated by the quadrant signals II and IV.
35 During the period after the generation of the quadrant signal II until the generation of the quadrant signal IV, the outputs r and s (Fig. 4) shown in (i) and (j) of Fig. 6B will be r = 1 and s = 0. On the contrary, after the generation of the quadrant signal IV until the generation of the quadrant signal II, r = 0 and s = 1 and, with the quadrant signals I and III, the flip-flop FF₂ will not operate. The above operations are tabulated as in the following Table 2:

Table 2

X	Y	Quadrant Signal	FF ₁ Outputs p & q	FF ₂ Outputs r & s
1	1	I	1 , 0	no variation
0	1	II	no variation	1 , 0
0	0	III	0 , 1	no variation
1	0	IV	no variation	0 , 1

Then, the thus obtained signals p, q, r and s and the respective quadrant signals I, II, III and IV are respectively combined to take AND. That is, the quadrant signal I forms an AND with the
60 signal r at the gate G₁ and an AND with the signal s at the gate G₂. The respective gates G₁ and G₂ are arranged so as to generate outputs under an input condition of both 0 and 0, whereby the gate G₁ generates an output of a positive voltage as in (k) of Fig. 6B, while the gate G₂ generates an output of a negative voltage as in (l) of Fig. 6B. Thus, when the quadrant signal I shows the shift from the quadrant IV, the outputs r and s of the flip-flop FF₂ will be r = 0 and
65 s = 1, and an output will be generated at the gate G₁. When the shift from the quadrant signal

It is shown, the outputs r and s of the flip-flop FF_2 will be $r = 1$ and $s = 1$ and a negative output will be generated at the gate G_2 . That is, when the vector signal shifts counterclockwise, a signal of a positive voltage will be obtained and, when it shifts clockwise, a signal of a negative voltage will be obtained. For the quadrant signal II, the gates G_3 and G_4 will operate, for the quadrant signal III, the gates G_5 and G_6 will operate and, for the quadrant signal IV, the gates G_7 and G_8 will operate so that, by the same operations as described above, the respective outputs will be obtained. Wave forms (m), (n), (o), (p), (q) and (r) of Fig. 6B show respectively the outputs of the gates G_3 , G_4 , G_5 , G_6 , G_7 and G_8 .

Thus, for a vector shifting through the quadrants I $\rightarrow$ II $\rightarrow$ III $\rightarrow$ IV $\rightarrow$ I $\rightarrow$ II $\rightarrow$ III $\rightarrow$ IV $\rightarrow$ I, the outputs of the gates G_1 to G_8 are not known as a preceding state of the first quadrant signal I is not known, but the flip-flop FF_1 will store $p = 1$ and $q = 0$ and, when the next quadrant signal II is generated, an output of a positive voltage will be generated at the gate G_3 and the outputs r and s of the flip-flop FF_2 will be $r = 1$ and $s = 0$. When the next quadrant signal III is generated, an output of a positive voltage will be generated at the gate G_5 and the outputs of the flip-flop FF_1 will be $p = 0$ and $q = 1$. When the further quadrant signal IV is generated, an output of a negative voltage will be generated at the gate G_7 and the outputs r and s of the flip-flop FF_2 will not vary. When the further quadrant signal I is generated, an output of a positive voltage will be generated at the gate G_1 and the outputs of the flip-flop FF_1 will be $p = 0$ and $q = 1$ and will not vary. Then, with the respective quadrant signals IV, I, II, and III, outputs of positive voltage will be generated sequentially at the gates G_7 , G_1 , G_3 and G_5 , the outputs p , q , r and s of the respective flip-flops FF_1 and FF_2 will be as shown in the drawing and an input signal z to the integrating circuit 8 will be as shown by (s) of Fig. 6B. This vector signal is rotating as shown in Fig. 7 as led from the Doppler signals E and E' . In view of this fact, too, it is seen that the shifting direction of the vector is correctly detected. In the above arrangement, the diodes D_1 to D_8 are inserted to prevent any reverse current flow as disposed respectively in such direction, as shown in the drawing to prevent any disorder. The above explained AND circuit of the gates G_1 to G_8 and logical circuit by the diodes D_1 to D_8 may be replaced by any other means having the same function.

The present invention is, therefore, summarizing the above descriptions, to determine the shifting direction in the quadrants of the vector by taking out any appointed one of the outputs p , q , r and s of the flip-flops FF_1 and FF_2 triggered by the respective quadrant signals I, II, III, and IV, by means of the same quadrant signal that triggers the particular output. Now, the outputs p and q of the flip-flop FF_1 and the outputs r and s of the flip-flop FF_2 , are respectively made significant so as to be as follows. The output signal p represents that the vector shifts either from the quadrant I or III to the quadrant II, thus, $p = 1$ means the shift I to II and $p = 0$ means the shift III to II; similarly, the output q represents the shift from the quadrant III or I to the quadrant IV, thus, $q = 1$ means the shift III to IV and $q = 0$ means the shift I to IV; the output r represents the shift from the quadrant II or IV to the quadrant III, thus, $r = 1$ means the shift II to III and $r = 0$ means the shift IV to III, and the output s represents the shift from the quadrant IV or II to the quadrant I, thus, $s = 1$ means the shift IV to I and $s = 0$ means the shift II to I. In this case, it is of course possible to have the respective meanings of the outputs p and q as well as those of the outputs r and s replaced by one another, in which case the outputs of "0" and "1" are only to be reversed. In all events, the output of "1" or "0" is to be generated depending on the counterclockwise shift or the clockwise shift in the respective quadrants of the vector rotating responsive to the movements of the object to be detected.

In the above arrangement, such an electronic switch as shown in Fig. 9 may be used in place of the gates G_1 to G_8 and diodes D_1 to D_8 in the circuit 27 of Fig. 4. This electronic switch SW is provided with four input terminals to which the outputs p , q , r and s of the flip-flops FF_1 and FF_2 are respectively applied, and with an output terminal z to which the single input signal appointed by the quadrant signal applied as a control signal is provided. Relations between the quadrant signals and the output signals are as in the following Table 3. In view of this Table 3, it will be evident that, when the quadrant signal I indicating that the vector is in the quadrant I, for example, is provided, the electronic switch SW selects the input s , which provides an output of "1" when the vector comes as shifted from the quadrant IV, or an output of "0" when the vector comes as shifted from the quadrant II, as has been described in the above. In the same manner, when the quadrant signal II is generated, the electronic switch SW selects the input p , which provides an output of "1" when the signal II comes as shifted from the quadrant I, while an output of "0" is provided when the signal II comes as shifted from the quadrant III. For the quadrant signals III and IV, too, an output of "1" at the time of the counterclockwise rotation and an output of "0" at the time of the clockwise rotation will be provided by the inputs r and q , depending on the process before the quadrant signal is generated, that is, the shifting direction of the vector.

Table 3

Quadrant Signal	Output Z
I	s
II	p
III	r
IV	q

20 When there is no quadrant signal, the shifting direction cannot be defined, so that the electronic switch SW will not select any input signal and, in this case, the input and output are made not to be related to each other. 20

Now, the signal Z obtained by the quadrant shift direction detecting circuit 27 is integrated by the integrating circuit 8, which comprises a resistance R_{11} and capacitor C_{11} . By means of bias resistances R_{b1} and R_{b2} provided at the output end, the output voltage of this circuit 8 at the time of no signal is made $Y_2 V_{cc}$. Even when different moving speeds occur simultaneously as in such an approaching object as a human body, the period when the signal Z is positive showing a counter-clockwise direction by the operations of such respective parts as are described above will be more frequent than the periods when Z is negative and the output of the integrating circuit 8 will be a positive voltage. On the contrary, when the object moves away, the output will be a negative voltage. When it is detected by the threshold level circuit 9 comprising comparators OP_1 and OP_2 that the positive or negative voltage (with respect to $Y_2 V_{cc}$) exceeds a certain threshold level, the threshold level circuit 9 will generate an output, by which a transistor Tr of the indicator driving circuit 28 will be driven to operate a relay Ry so as to indicate the presence of the moving object. Here, noises, for example such random noises as the sounds of a bell ring, will cause the vector rotating direction to be random, because the time of generating such sounds will be random, all the residual sounds will remain for a fixed time and, therefore, the vector will not continuously rotate. The response to the bell sounds is shown in Fig. 8, in which (a) shows the Doppler signal E, (b) shows the Doppler signal E' , (c) shows the binary number X corresponding to the Doppler signal E, (d) shows the binary number Y corresponding to the Doppler signal E' , (e) to (h) show respectively the quadrant signals I, II, III and IV, the parts indicated by hatchings show the presence of the signals, (i) to (p) show respectively the outputs of the gates G_1 to G_8 , the parts marked with a small circle show the presence of the signals, and (q) shows the output of the integrating circuit 8. As will be evident from these wave form diagrams, the circuit operation is performed in the same manner as in the case of the moving object, but the positive and negative voltage signals are generated substantially at an equal probability at random and therefore cancel each other on being integrated over a substantial period. 25 30 35 40 45

According to the present invention, as has been described above, the respective quadrants of the vector of the received-wave signals are made known on the basis of a pair of the Doppler signals and the shifts of the quadrants are traced, whereby the direction and period of the rotation of the vector included in the received-wave signal can be continuously obtained. Accordingly, the present invention is effective in that the presence of the moving object can be reliably detected without requiring any frequency analysis on the spectrum characteristics or any electromechanical correlator, any deterioration of the detecting capacity can be minimised even when an interfering phenomenon is present, the circuit formation is simple, and thus the manufacturing cost can be made lower. 50 55

While in the foregoing descriptions the division of the vector plane into the four quadrants I through IV has been referred to for the purpose of determining the state of the vector rotation, there may be any number of sectors greater than two. In an event when the vector plane is divided, for example, into three, a similar result can be obtained by mixing the received-wave signal with three reference signals respectively different in phase by 120° and obtaining zone signals by means of a combination of respective vector component signals of these reference signals. 60

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CLAIMS

1. A moving object detecting device comprising an oscillator which produces a reference signal, a transmitter which transmits the reference signal, a receiver which receives the waves reflected from objects to be detected and provides a received-wave signal, and electronic means
5 for establishing the relative phase of reference signal and received-wave signal, for recognizing in which one of at least three predetermined bands of phase angles lies the said relative phase, the predetermined phase bands being contiguous and together covering the complete range (2π) of possible values of the relative phase, and for detecting over a substantial period whether the changes from phase band to phase band occur predominantly in the direction of increasing or
10 decreasing phase angle, indicating in this case the presence of an object moving towards or away from the detector, or whether the direction of change from phase band to phase band appears to be random, indicating that there is no moving object near the detector.
2. A moving object detecting device according to claim 1, wherein the electronic means comprises means for mixing the received-wave signal, which may be represented in amplitude
15 and phase as a phase vector, and a plurality of reference signals derived from the original reference signal and differing in phase, to provide a plurality of vector signals representing components of the said phase vector on a plurality of axes corresponding to the reference signals, and means utilising the said plurality of vector signals to detect the direction of change from phase band to phase band.
- 20 3. A moving object detecting device according to claim 2, in which the means utilising the said plurality of vector signals comprises a plurality of binary number converters converting said plurality of vector signals into a plurality of binary numbers, and a phase band signal generating circuit generating a phase band signal depending on the said plurality of binary numbers.
4. A moving object detecting device according to claim 3, in which the means utilising the
25 said plurality of vector signals further comprises a storage means responsive to the phase band signal for temporarily remembering the phase band to which the relative phase of the received-wave signal has been assigned.
5. A moving object detecting device according to claim 4, in which the phase band signal storage means comprises a plurality of flip-flops.
- 30 6. A moving object detecting device according to claim 4 or 5, in which the means utilising the said plurality of vector signals further comprises: a phase band shift direction detecting circuit, responsive to phase band signals from the storage means and from the generating circuit, generating a shift direction signal of one of two different types corresponding to the phase angle shifting to a new phase band in one direction or the other; an integration circuit for
35 time-integrating said shift direction signal; a threshold level circuit detecting output levels of said integrating circuit, and an indicator driving circuit driven by an output of said threshold level circuit, the presence of said moving object being indicated on observing the shift direction to be predominantly in one direction.
7. A moving object detecting device according to claim 6, wherein the phase band shift
40 direction detecting circuit comprises a plurality of AND circuits which process the binary outputs from the flip-flops and the signal generating circuit and provide a single bit output signal representing the direction of change of phase band.
8. A moving object detecting device according to claim 6, wherein the phase band shift
45 direction detecting circuit comprises an electronic switch which receives as inputs the binary outputs from the flip-flops and the signal generating circuit provides a single bit output signal representing the direction of change of phase band.
9. A moving object detecting device according to any preceding claim, wherein the electronic means includes a level detecting circuit with its associated logic circuitry, which tests whether the amplitude of the received-wave signal is above a predetermined level and is then
50 large enough for the signal to be significant.
10. A moving object detecting device according to any preceding claim, wherein the transmitter and receiver are ultrasonic transducers.
11. A moving object detecting device according to any preceding claim, in which there are
55 two reference signals derived from the original reference signal, differing in phase by 90° , the mixing means provides a pair of vector signals in phase with respective reference signals and representing components of the received-wave signal, and in which the means utilising the two vector signals detects the direction of change from phase band to phase band of the received-wave signal.
12. A moving object detecting device substantially as described herein with reference to
60 Figs. 3 to 9 of the accompanying drawings.