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(54) MOVING OBJECT DETECTION SYSTEM

(71) We, OMRON TATEISI ELECTRONICS CO., a corporation of Japan of No 10, Tsuchido-cho, Hanazono, Ukyo-ku, Kyoto, Japan, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:-

5 The present invention relates to an ultrasonic, moving-object detection system and to a method for detecting the presence of moving objects by the utilization of ultra-sonic waves or energy with the employment, for example, of a micro-processor, and apparatus for effecting said method in which the detecting period is automatically set.

10 In general, in order to detect the presence of moving objects such as vehicles or the like, for example in a traffic survey, ultrasonic waves are directed toward a surface of the road and the presence of vehicles is detected on the basis of the time difference in arrival of reflected waves from the road surface and from the vehicles, that is the difference in echo times from the road surface and from the vehicles. More specifically, Figs. 1(a) to 2(d) are explanatory of a known arrangement for moving object detection using an ultrasonic detector. A detecting unit UL selectively transmitting and receiving ultrasonic energy is provided at a height H_a from a road surface R for transmitting the energy towards the road surface. In the absence of a vehicle V as shown in Fig 1(a), the ultrasonic detector unit UL receives, or detects the reflection of waves from the road surface R, and if the echo time, that is the elapsed time between the time of transmission and that of reception of the reflected waves is designated as τ_a , such time τ_a is represented by the following equation (1).

$$\tau_a = \frac{2H_a}{C} \quad \dots\dots (1)$$

25 wherein C is the velocity of sound which is equal to $331+0.6T$ (m/s) and T is the ambient temperature ($^{\circ}\text{C}$). Meanwhile, in the presence of a vehicle V as shown in Fig. 1(b), the detector unit UL receives waves reflected from such a vehicle. If the height of the vehicle V is denoted by H_c , the height from the vehicle to the detector unit UL is H_b ($H_b=H_a-H_c$), and if the echo time in the presence of the vehicle is designated as τ_b , τ_b is represented by the following equation (2).

$$\tau_b = \frac{2H_b}{C} = \frac{2(H_a-H_c)}{C} \quad \dots\dots (2)$$

35 Therefore, the presence of vehicles may be detected by detecting whether the echo time is equal to the time τ_a or τ_b ($\tau_a > \tau_b$). As is seen from Figs. 2(a) to 2(d) showing typical time charts for vehicle detection using ultrasonic energy, the time τ_0 for one period between successive transmissions is arranged to be larger than the echo time τ_a , while the echo time τ_b is smaller than the echo time τ_a . For accurate detection of the wave reflected from the particular vehicle, however, it is necessary properly to define a gate period τ_v during which the vehicle can be detected. Such vehicle detection gate period τ_v starts later than a time τ_l which is the sum of the time of the transmission of energy and of the reverberation developed by the detector unit UL due to resonance immediately after said transmission and is selected to end slightly earlier (by a time τ_h for preventing wrong detection, for

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example, of a raised road surface due to accumulation of snow, as the presence of a vehicle than the time point for the detection of the waves reflected from the road surface R. In the conventional arrangement as described above, however, proper adjustments are required in the installation of the detector unit UL, since the vehicle detection gate period τ_v differs depending on the installed position of such detector unit UL although the time periods τ_l and τ_h are of a fixed nature, and such adjustments are conventionally carried out by skilled technicians at the installation site with the use of an oscilloscope and the like by means of complicated procedures. As is seen from the foregoing description, in known detecting apparatus utilizing ultrasonic energy, it has been extremely difficult properly to set the vehicle detection gate period τ_v , and even when it is properly adjusted, such period τ_v must be corrected frequently due to changes in the propagation velocity of the ultrasonic waves due to variations of sound velocity through fluctuations of external factors such as ambient temperature.

In other words, in the detection of the presence of vehicles by utilizing ultrasonic energy, it is commonly arranged that, in order to eliminate the effects of reverberation due to the transmission of ultrasonic energy and the influence of the reflected ultrasonic energy from a surface of a road, a wave-reception gate or detection gate of the transmitter-receiver is opened after an elapse of a predetermined period of time subsequent to transmission of ultrasonic energy and is closed after an elapse of another predetermined period of time, so that when the reflected energy is received while the detection gate is open, the particular reflected energy is regarded as that coming from a vehicle.

It should be noted, however, that the velocity of propagation of ultrasonic waves varies depending on ambient temperatures and the like as mentioned earlier. Therefore, if the open period of such a detection gate is fixed on the basis of the propagation velocity of ultrasonic energy at a given standard ambient temperature as in the known arrangement, there is a possibility on the one hand that ultrasonic energy reflected from the surface of a road may be received before the detection gate has been closed, for example, due to increase of the propagation velocity of the ultrasonic energy due to variations of ambient temperature, while on the other hand, if the propagation velocity is reduced, the ultrasonic energy reflected from a vehicle may reach the transmitter-receiver after the detection gate has been closed.

Therefore, the accurate detection of traffic would be more feasible if it were possible to detect the echo time τ_a of energy reflected from the road surface in response to the variation in propagation velocity of ultrasonic energy and to discriminate any reflected energy arriving in a time shorter than said echo time τ_a by a preset time span as energy from the traffic. For the above purpose, however, it is necessary to keep a constant check on the echo times τ_a .

In view of the foregoing problem, it is intended in the present invention to provide a method for automatically setting a standard echo time which is such that even if there is any change in the echo time of the energy reflected from the road surface to the transmitter-receiver, such echo times are automatically detected and set by means of a micro-processor, each echo time is compared with the standard set time and, when any particular echo time is smaller than said set time by more than a preset value, it is regarded as energy reflected back from the traffic.

The term "standard echo time" is used herein to mean the time after transmission of ultrasonic energy from an ultrasonic transmitter-receiver till the arrival of the corresponding reflected energy at the transmitter-receiver. The distance between the transmitter-receiver and the road surface is constant and, hence, the flight time of reflected energy from the road surface to the transmitter-receiver should be constant if the propagation velocity of ultrasonic energy were constant. However, a variation in echo time due to variations in the propagation velocity of ultrasonic energy may be regarded as a change in distance between the road surface and the transmitter-receiver. It may also happen that the reflection surface is different from the actual road surface. If a variation in propagation velocity of ultrasonic energy be thus assumed to be a change in the relative distance between road surface and transmitter-receiver and the road surface be regarded as a standard plane, any reflected energy arriving within a time span shorter than the echo time of reflected energy from said standard plane by more than a preset time value may be discriminated as reflected energy from the traffic.

Accordingly, an object of the present invention is to provide a method and a system for detecting the presence of moving objects such as vehicles and the like, through the utilization of a micro-processor, and capable of emitting detection signals by positively identifying ultrasonic energy reflected from vehicles irrespective of fluctuations in the propagation velocity of ultrasonic energy due to variations of ambient temperatures, etc.

Another object of the present invention is to provide a method and system for detecting the presence of moving objects such as vehicles and the like as described above, in which a

standard echo time is automatically set for correct identification of the ultrasonic energy reflected from the vehicles to be detected.

A further object of the present invention is to provide a method and system for detecting the presence of moving objects such as vehicles and the like as described above in which, in effecting the above control with the use of a micro-processor, no separate programming is required for preventing the set program from running again, for example, when ultrasonic energy reflected from a road surface is received after reception of the reflected energy from vehicles, with substantial elimination of or reduction in the disadvantages inherent in the conventional methods and systems of the kind.

A further object of the present invention is to provide an apparatus for detecting the presence of moving objects such as vehicles and the like as described above which is comparatively simple in construction and stable in operations, and can be manufactured at low cost.

According to the invention there is provided a detection system for detecting the presence of moving objects and the like moving over a surface comprising means for transmitting ultrasonic energy towards the surface and for receiving reflected energy from the direction of the surface, a standard location provided in a memory unit for storing therein an echo time corresponding to the time from transmission of ultrasonic energy to the time of reception of reflected energy corresponding thereto from said surface, means for computing the difference a between an immediately preceding echo time stored in said standard location and a current echo time corresponding to the time of transmission of ultrasonic energy to the time of reception of reflected energy corresponding thereto, means for storing in said standard location said current echo time when the difference a is smaller than a predetermined time α , and means for generating a moving object detection signal when said difference a is larger than a preset time β which is larger than said time α .

By means of a system according to the present invention, it has been made possible not only correctly to identify the reflected ultrasonic energy from particular vehicles, but also to effect such identification irrespective of fluctuations in the propagation velocity of ultrasonic energy due to variations of ambient temperatures or the like, with a substantial reduction or elimination of the disadvantages inherent in conventional traffic detection systems.

The invention will now be described by way of example with reference to the accompanying drawings, in which:-

Figs. 1(a) and 1(b) are schematic diagrams already referred to and explanatory of a conventional arrangement for moving object detection.

Figs. 2(a) to 2(d) are time charts explanatory of the moving object detection arrangement of Figs. 1(a) and 1(b) using ultrasonic energy.

Figs. 3(a) to 4 are graphs explanatory of the principle of the present invention,

Fig. 5 is an electrical block diagram showing one preferred embodiment of the arrangement of the moving object detection system according to the present invention,

Fig. 6 is a map showing contents in each area of a RAM (random access memory) employed in the arrangement of Fig. 5,

Figs. 7 to 8(h) are flow charts explanatory of the sequence of operations of the arrangement of Fig. 5,

Fig. 9 is a block diagram similar to Fig. 5, but showing a modification thereof,

Fig. 10 is a map showing contents in areas of a RAM (random access memory) employed in the modification of Fig. 9, and

Figs. 11 to 12(h) are flow charts explanatory of the sequence of operations of the modified embodiment of Fig. 9.

Referring now to the drawings, there are shown in Figs. 3(a) and 3(b) graphs explanatory of the principle of the method of detecting the presence of moving objects according to the present invention, in which horizontal axes represent time, and Fig. 3(b) particularly shows in detail the sequence from time-point t_2' to t_5' in Fig. 3(a).

In Figs. 3(a) and 3(b), P_1 and P_2 represent the ultrasonic pulses transmitted at a period of T_1 with a pulse width of T_1 . To allow for the reverberation, the detection gate is opened at a time-point T_1' which is delayed by a duration of T_2 from the time-point t_0' when the pulse was transmitted. The time-point at which the ultrasonic energy transmitted at time-point t_0' is received by a transmitter-receiver is designated as t_4' . The time from time-point t_0' to time-point t_4' is variable within the range of $\pm\alpha$ due to variations in ambient temperatures, etc. The value α may be predetermined. The critical detection limit value for the difference in time between the energy reflected from a vehicle and the energy reflected from the road surface is designated as β . β is the value determinative of the vehicle detection limit and, for example, is the time required for ultrasonic energy to make a return trip over a distance of 34 cm. By setting the value β in this manner, the reflected energy can be judged as one coming from a vehicle when it is received before the time-point t_2' which is earlier than

time-point t_4' by the magnitude of the time β . Thus, the values of α and β are preset and the time which elapses between the transmission of ultrasonic energy and the reception of the corresponding reflected energy is judged by means of a micro-processor, which is loaded from a memory area in which the road surface echo time has been stored to compute a difference a from the current echo time. If this difference a is not larger than the value α , that is to say, the time up to the reception of reflected energy is within the range of t_3' to t_5' as counted from the time-point of t_0' this reflected energy can be judged as coming from the road surface. Therefore, the data representing the echo time for the particular transmission of ultrasonic energy is stored in the above memory area. Thus, if the echo time is the time period t_0' to t_4'' , the time data are stored in said memory area. This time is stored in the memory area on the assumption that the road surface echo time has changed to a time period from time-point t_0' to time-point t_4'' for example due to a variation in ambient temperature, etc. Thus, the echo time from the subsequent transmission of ultrasonic energy is compared with this time from time-point t_0' to time-point t_4'' and the difference a is computed.

If the difference a is larger than the value β , it means that the reflected ultrasonic energy has been received before the time-point t_2' and the particular reflected energy is judged to have come from the vehicle so that a vehicle detection signal output is generated.

Now, the procedure for setting the time-point t_4' as shown in Figs. 3(a) and 3(b) will be described with reference to Fig. 4.

Fig. 4 shows the relative position of an ultrasonic transmitter-receiver UL and vehicles V and V', wherein chronological time is represented as elapsing in the sequence of $t_1, t_2 \dots$ and t_{14} . Up to the time-points t_1 through t_3 or the time-points t_9 through t_{12} , the reflected energy is assumed to have come from the vehicles, while it is assumed that, in other time-points the energy has been reflected from the road surface.

The time data from the time-point t_0' to the time-point t_4' are first stored in a memory. The data are assumed to represent the echo time of energy reflected from an imaginary road surface. This imaginary road surface must be preset initially, thus, the time from the time-points t_0' to t_4' must be preset. Therefore, the period of time from the time-point when the traffic detection apparatus is energized to the time-point at which a total of, say, 15 vehicles have just passed the detection apparatus is now designated as the "initial state". In this initial state, the time from the time-point t_0' to time-point t_4' as shown in Fig 3 is stored in the memory. First, in this initial state, a first ultrasonic energy pulse is transmitted and the corresponding reflected energy is received. The echo time between said transmission and said reception is stored in the memory. In Fig. 4, the horizontal axis represents time, with t_1 through t_{13} signifying various time-points and, at the same time, representing the times up to reception of the reflected energy at the respective time-points. Thus, for example, t_1 not only represents time-point t_1 but also represents the length of time before the reception of reflected energy takes place.

It will be seen from Fig. 4 that the echo time from the road surface is longer than the echo time of energy reflected from the vehicle and that there is always energy reflected from the road surface between vehicles V and V'. Irrespective of the type of vehicle, and of the part of the vehicle from which the energy has been reflected, the echo time of energy reflected from the road surface is longer than the echo time from the vehicle. The echo time from the road surface is longer than the echo time from the vehicle by the time β and the change in time of the reflected energy from the road surface is smaller than the value α . Based on the above premises, the time after the energization of the traffic detection apparatus till the reception of reflected energy at the time-point t_1 is stored in the memory and, thereafter, the difference a is computed at t_2 and subsequent time-points. If $|a|$ is smaller than the value α , the data stored in the memory are updated to the particular current echo time data. In this initial state, however, even if a is larger than the value α , the data stored in the memory are updated to the current echo time when $|a|$ is smaller than the value β . By repeating this function until a total of fifteen vehicles, for example, have been detected, the standard echo time; that is to say, the actual echo time of ultrasonic energy from the road surface, is set. During the above series of functions, the data in the memory are not updated if the difference a is larger than the value β . Thus, if the current echo time is shorter than the time data stored in the memory area by a magnitude of β , the data in the memory are not updated.

Based on the principle as described in the foregoing, according to the present invention, the memory is provided with a predetermined location for storing the echo time data, and the echo time after the transmission of a given ultrasonic energy till the reception of the corresponding reflected energy is detected and processed by the micro-processor. Then, the micro-processor is loaded from the above predetermined location of the memory to compute the difference a from the current echo time of ultrasonic energy. If the above difference a is less than the preset time α , the current echo time is stored in the

predetermined memory location. If the difference a is smaller than the value β (also preset) which is larger than the time α , the current data representing the current echo time is stored in the above predetermined memory location only in the initial state. When the difference a is larger than the time β , a vehicle detection signal output is generated.

5 In another aspect of the present invention in addition to having a predetermined location 5 where the road surface echo time is stored, the memory includes a first reception counter location in which the echo time of ultrasonic energy is stored and the second reception counter location in which the previous echo time is stored. In this arrangement, the echo time is processed by the micro-processor and stored in said first reception counter location. 10 The difference a between the data in said first reception counter location and the data in said second reception counter location is computed and if the difference $|a|$ is smaller than the preset time α , the data of said first reception counter location are stored in both the second reception counter location and said predetermined location. When the difference $|a|$ is larger than the time α and smaller than the preset time β the value in said first reception 15 counter location is stored in said second reception counter location only in the initial condition. When the difference a is larger than the time β , the data of said predetermined location are stored in said second reception counter location and a vehicle detection output signal is generated.

Referring particularly to Figs 5 through 8(h), there is shown in Fig. 5 an electrical block 20 diagram illustrating one example of an apparatus for carrying out the present invention. Before the description of the apparatus proceeds, it should be noted that, in this embodiment, arrangement is so made that the detection gate is opened by determining the time period for receiving the reflected energy by means of a micro-processor to be described later. The detection gate is adapted to be closed under the control of the 25 micro-processor which determines the echo time of a given ultrasonic energy transmission. The micro-processor is subsequently loaded from a memory location storing the echo time from a road surface to compute the difference a from the current echo time. If the above difference a is smaller than a preset time α , the current data representing the current flight time is stored in the above memory location. When the difference a is larger than the preset 30 time β a vehicle detection output is developed.

Referring back to Figs. 3(a) and 3(b), specifically, if the difference a between the echo time stored in the memory location and the current echo time is within the preset value α , the data of the memory location are updated, i.e., the echo time of the current reflected energy is stored, and therefore, the echo time stored is equivalent to the echo time from the 35 road surface. It should be noted here that it may be so arranged that at a first transmission of the ultrasonic energy no vehicles are present to reflect the energy, so that the echo time at the time of the first transmission is first stored in the memory location. After storing the data in the memory location as described above, if for a subsequent transmission the difference a is larger than the value β , this is regarded as reflected energy from a vehicle and 40 a vehicle detection signal is generated. Since the latest road surface echo time is always stored, and reflected energy received within an echo time period less than such time by the time β is regarded as reflected energy from the vehicle, it is possible positively to detect the reflected energy from the particular vehicle even if the propagation velocity of the ultrasonic energy fluctuates. Furthermore, if the ultrasonic wave transmitter-receiver is 45 provided with a detection gate circuit so that the detection gate is opened after the time T_2 subsequent to the transmission of the ultrasonic energy and is closed, for example, upon reception of reflected energy from the vehicle, the subsequent arrival of reflected energy from the road surface is not acted upon by the transmitter-receiver, since the detection gate has been closed as described above. Therefore, in the above case, it is unnecessary to 50 provide a separate program for preventing the existing program from continuing in response to reflected energy from the road surface.

In the circuit arrangement of Fig. 5 according to the present invention, a pulse oscillator 1, a wave transmission gate 2, an amplifier 3, a limiter 4 and an ultrasonic wave transmitter and receiver, or transducer, 5 are coupled to one another as shown for applying pulses 55 developed at the oscillator 1 to the transducer 5. To a junction between the limiter 4 and the transducer 5, there is connected a wave reception limiter 6 which is in turn sequentially coupled to a wave reception amplifier 7, a waveform shaping circuit 8, a detection gate 9 (wave reception gate) and then to a counter 10, and thus the reflected energy received by the transducer 5 is applied as an input to the counter 10. A clock pulse generator 11, an 60 AND circuit 12 and a flip-flop circuit 13 are further coupled to the counter 10 in such a manner that the output of the generator 11 and the set output of the flip-flop 13 are inputs to the AND circuit 12, and the output of the AND circuit 12 is coupled to the counter 10, while the output of the counter 10 upon reaching a predetermined count value is coupled to the flip-flop 13 as a reset input. The apparatus is provided with a micro-processor 15 65 (surrounded by a chain line in Fig. 5) which includes a ROM 16 (read-only memory)

containing a program, an operation circuit 17 coupled to the ROM 16 and to the counter 10 through a line 23, an output circuit 18 which has an output line 26 for providing the vehicle detection signal and outputs coupled to the wave transmission gate 2 through a line 24 and to the detection gate 9 through another line 25. An X register 19 is coupled to the ROM 16, a Y register 20 is coupled to the operation circuit 17 and an A register 21 is also coupled to the operation circuit 17. Further coupled to the apparatus is a RAM 22 (random access memory) which may either be included in the micro-processor 15 or be provided externally of the micro-processor 15. It should be noted here that in the foregoing embodiment, the following items are employed for the micro-processor 15, or the ROM 16, operation circuit 17, output circuit 18, X, Y and A registers 19, 20 and 21, and RAM 22.

Micro-processor 15: Four-bit, one-chip micro-computer TMS 1000 of Texas Instruments Inc., U.S.A.

The micro-processor 15 can be made up from the following components:

ROM 16: ROM 1702A of Intel

Operation circuit 17: Alameda Logic Unit MC 14581 of Motorola Inc.

Output circuit: ROM 1702T of Intel

X, Y and A registers 19, 20 and 21: RAM MC 14537 of Motorola Inc.

RAM 22: RAM MC 14537 of Motorola Inc.

Referring also to Fig. 6 which shows a map of the memory contents for each location of the RAM 22, the respective areas which are each constituted by four bits are designated by the X register 19 and Y register 20, with areas (X=1, Y=14), (X=2, Y=14) and (X=3, Y=14), for example, having road level counters (low order), (intermediate order) and (high order). For this purpose, the road level counters are each constituted by twelve bits, with each four bits thereof being adapted to be of the low order, intermediate order or high order. Meanwhile, a 1m.sec.counter, 2m.sec.counter and a 32m.sec. counter in the areas (X=1, 2, 3, Y=1) constitute system counters so that the 1m.sec.counter counts time at 1m.sec.units, the 2m.sec.counts at 2m.sec.units and the 32m.sec.counts at 32m.sec.units. In the description hereinbelow, the area of the RAM 22 designated, for example by X=m and Y=n is denoted as M (m,n).

Referring also to the flow charts of Figs. 7 to 8(h), the function of the detection system of Fig. 5 will be explained. In Fig. 7, codes (101) through (122) given alongside blocks represent the respective step numbers, and hereinbelow these steps will be referred to briefly as (101) through (122).

In the first place, upon turning ON the power supply to the apparatus of Fig. 5, the operation circuit 17 functions in accordance with the program set in ROM 16. First at the step (101) the system counter (referred to as SC hereinbelow) of RAM 22 is set, and the wave transmission signal is outputted at the step (102). For the above function, the operation circuit 17 enters numeric value 2 into the A register 21 (labelled as ACR in Fig. 8(a)) for subsequent emission of the TDO instruction. Upon emission of the TDO instruction, the output circuit 18 is inputted with the content 2 of the A register 21 to render the signal on the line 24 "High", by which the gate 2 is opened, with the output of the oscillator 1 being applied to the ultrasonic transducer 5 for transmitting the ultrasonic energy. At the step (103), enquiry is made to determine if the count of the system counter SC has reached the transmission wave width T_1 shown in Fig. 3. This is accomplished by entering numeric value 1 into the X register 19 (on the basis of an instruction by an instruction decoder (not shown) attached to the ROM 16), and also into the Y register 20, while the data of the 1m.sec.counter of the location (Fig. 6) of M (1, 1) (which is the area of X=1, and Y=1 as described earlier) for the RAM 22 are entered into the A register 21, with subsequent entry of numeric value 3 into the Y register 20 for subtracting the data entered into the A register 21 from the data in the location M(1,3) (i.e., 32m.sec.counter of Fig. 6) which contain data of the wave transmission width T_1 . Subsequently, the value entered in the A register 21 is subtracted from T_1 , with the result being again entered in the A register 21. At this stage, enquiry is made to see if the result of the subtraction is zero or not to repeat the above function until zero is reached, and at "No borrow", i.e., when the result of the subtraction has reached zero, the operation is moved to step (104). In the above case, the wave transmission width time T_1 is regarded to have passed, and thus, wave transmission signal OFF is outputted. For the above function, numeric value 0 is entered into the A register (ACR) 21 as shown in Fig. 8 (C) for giving the instruction TDO, by which the output circuit 18 is inputted with the content (numeric value 0) of the A register 21 so as to render all the signals on the output lines to be "Low". Accordingly, the signal on the line 24 is rendered "Low" (all other lines are "Low"), and the gate 2 is closed so that wave transmission by the transducer 5 is inhibited.

Subsequently, at the step (105), enquiry is made to see if the system counter SC has reached the time T_2 of Fig. 3. When the time T_2 has been reached, the output for gate signal ON is developed at the step of (106). For the above function, numeric value 4 is entered

into the A register 21 (ACR) as shown in Fig. 8(d) for giving the instruction TDO, by which the output circuit 18 is inputted with the content (numeric value 0) of the A register 21 to render the output on line 25 "High". Accordingly, the detection gate 9 is opened, and in the presence of the wave reception output of the transducer 5, such output is applied to the counter 10 through the limiter 6, amplifier 7, waveform shaping circuit 8 and detection gate 9. Although clock pulses from the generator 11 are applied to the counter 10 through the AND gate 12, the counter 10 does not count so long as the wave reception output from the transducer 5 is not present. It should be noted that the flip-flop 13 remains set until the count of the counter 10 reaches a predetermined value so as to keep the AND gate 12 open, but when the count of the counter 10 reaches a certain value, the flip-flop 13 is reset to close the AND gate 12.

Therefore, at the step (107), enquiry is made to see if the reception of waves is detected. For the above purpose, the numeric value 1 is entered into the Y register 20 for applying R_1 set output, with the line 23 being designated by the above function. Subsequently, an instruction KNEZ is applied, by which instruction, the count of the counter 10 is entered into the operation circuit 17 by way of the line 23. If the count value is zero, it is almost certain that no wave reception output has been supplied from the transducer 5 to the counter 10. The counter 10 starts counting at the time point whereat the wave reception output is developed, but since the operation circuit 17 of the micro-processor 15 is arranged to read off the signal of the line 23 at every predetermined time period, such operation circuit does not always read off the output of the line 23 at the time point at which the wave reception output is developed. Therefore, if the output of the line 23 is read off after the wave reception output is developed, the count of the counter 10 is, of a certain value different from zero. If the count value K of the counter 10 is of a certain value different from zero, K input INPUT = 0 and the operation circuit 17 determines the data of the wave reception counter I. In the above case, due to the fact that the system counter SC continues to count from the time point of the wave transmission it is possible to find the time up to the time point (referred to as t10) at which the micro-processor 15 determines that the count of the counter 10 has reached a certain value different from zero, and the time between the actual development of the wave reception output and the time point t10 is counted by the counter 10, the time from the transmission of the ultrasonic waves to the initial reception of the reflected wave is obtained by subtracting the count value of the counter 10 from the count value of the system counter SC. The time thus obtained is regarded as data of the wave reception counter I, which are stored in the locations M (1, 4), M (2, 4) and M (3, 4) of the RAM 22. Such locations are those entered as the wave reception detection counter in the graph of Fig. 6. Subsequently, in step (109), wave reception down detection is effected. By wave reception down is meant the detection of the absence of wave reception or that no wave is received. Since the counter 10 is arranged to lose its output when the wave output reception of the transmitter-receiver 5 disappears, "down" or absence of wave reception is detected by the output of the line 23 being reduced to zero. It is to be noted, however, that in the steps (107) and (109), if the results are respectively "NO" the operation is shifted at once to the step (111) to see if the count of the system counter SC is longer than the time T_3 (Fig. 3), and if $SC \geq T_3$, gate signal OFF is developed at the step (112). (T_3 shows time later than the time point t5 by a certain value). Such function as described above is exactly the same as that in Fig. 8(c) as shown in Fig. 8(f), by which function, the signal of the line 25 of the output circuit 18 is rendered "Low" to close the detection gate 9. In the above case, it is to be noted that the signal of the line 24 is "Low", with the gate 21 being already closed. Upon detection of the wave reception down at the step (109), the gate signal OFF is developed at the step (110), which function is the same as in the step (112). Upon detection of the wave reception at the step (107) and of the wave reception down at the step (109), the difference α between the wave reception counters I and II in RAM 22 is worked out at the step (113) after the detection gate 9 is closed at the step (110). In other words, the data in the counter I are subtracted from the data in the counter II. The wave reception counter II is provided each at the locations M (1, 13), M (2, 13) and M (3, 13) of Fig. 8, and the data in these areas will be mentioned later. After determining the difference α , such difference α is set in the wave reception counter II at the step (113-2) (in this case previous data up to that time for this area are cancelled, and a positive or negative sign for the difference α is set in the area M (0, 13) at the step (113-3). On the basis of the difference α worked out at the step (113), enquiry is made to see if $|\alpha| \geq \alpha$ at the step (114). The value α is as shown in Fig. 3 and is set in the area M (1, 6) of Fig. 6. The above function for determining $|\alpha| \geq \alpha$ is shown in Fig. 8(g). First, numerical value 3 is entered into the X register 19, and numerical value 13 into the Y register 20 to designate the location M (3, 13) for reading out the data thereof. Since it is clear that such data are those in the high order of the wave reception counter II (having the data of α) and that if such data are zero, α is larger than α , the response is immediately YES at the step (114).

Meanwhile, if the data of M (3,13) are not zero, numerical values 1 and 6 are entered into the X register 19 and Y register 20 respectively, while the location M (1,6) of the RAM 22 is designated to enter the data α thereof into the A register 21, with subsequent entry of numeric value 13 into the Y register 20 (The X register 19 remains at numerical value 1) and designation of the location M (1,13) to read out the data thereof for comparison of the data α of the A register 21 with the data of the location M (1,13) so as to see if $a \leq |\alpha|$. In the above case, the difference $|a|$, after having been worked out at the step (113), is entered in the locations M (1,13), M (2, 13) and M (3, 13). If the difference $|a|$ is smaller than the value α , the data of the wave reception counter I are set in the road level counter (M (1, 14), M (2, 14) and M (3, 14)) at the step (119), and at the step (120), the data in the wave reception counter I are set in the wave reception counter II. On the contrary, if the value $|a|$ is larger than the value α , enquiry is made at the step (115) to see if the data in the wave reception counter I are larger than those of the wave reception counter II, and this can be found by judging whether the sign of the value a entered in the location M (0,13) is positive or negative. In the case where the data in the wave reception counter I, i.e., the time up to the current reflected wave reception is smaller than the time up to the reflected wave reception entered in the wave reception counter II, comparison is made between the values α and β at the step (116), which comparison is effected by the program of Fig. 8(h). More specifically, numerical values 2 and 6 are respectively entered into the X register 19 and Y register 20 to designate the location M (2,6) of the RAM 22 for reading out the data (the value β) of this area which are entered into the A register 21. Subsequently, numerical value 13 is entered into the Y register 20 so as to read out the value for the location M (2,13) for comparison of the value β of the A register 21 with the value of the location M (2,13). If the value a is larger than the value β , a detection signal (pulse) ON is outputted at the step (117). Such detection signal is arranged to be ON by rendering the signal of the output line 26 for the output circuit 18 to be "High". In cases where the responses are YES at the step (115) and NO at the step (116) and the detection pulse is set to be ON at the step (117), data in the road level counter are set in the wave reception counter II at the step (118). After completion of any one of the steps (112), (118), and (120), the program is moved to the step (121) to see if the system counter SC has reached the period T_4 of the wave transmission pulse, and when the period T_4 has been reached, detection pulse OFF is outputted at the step (122). This is effected by rendering the signal of the output line 26 to be "Low". Subsequently, the sequence is returned to the step (101).

As is clear from the foregoing description, in the arrangement of Figs. 5 to 8(f), since the detection gate is opened (at the time T_2 in Fig. 3) and closed by the micro-processor, any subsequent reflected energy received after the first reception of reflected energy from a particular vehicle or road surface, subsequent to one ultrasonic transmission is not effective. Thus the inconvenience inherent in conventional arrangements that after a program to be run by the reception of a reflected wave from a given transmission is caused to run, for example, by the reception of reflected waves from a vehicle, such program is again caused to run by the reception of subsequent waves due to the same transmission but reflected from a road surface, is advantageously eliminated.

Furthermore, in the arrangement as described above in which, the time from the current ultrasonic wave transmission to the reception of the reflected wave is compared with the data of the wave reception counter II, if the difference $|a|$ therebetween is smaller than the present time α , the reflected waves are regarded as those from the road surface to update the data in the wave reception counter II. If the difference $|a|$ is larger than the value α , and if the value a is positive and larger than the value β upon comparison of the values a and β , this is regarded as reflected energy from the vehicle to provide a detection signal output. Thus, the arrangement is effective for accurate vehicle detection irrespective of variations in the ultrasonic wave propagation velocity, since the wave reception counter II is always set with the latest actual time required for the reception of reflected energy from the road surface so that a vehicle detection signal is outputted only when the time required for the current wave reception is shorter, by more than the set value β , than the time set in the wave reception counter II.

Referring now to Figs. 9 through 12(h), there is shown in Fig. 9 a modification of the circuit arrangement of the detection system of Fig. 5. The modified detection system of Fig. 9 is arranged to function in a manner based on a method of automatically setting a standard plane in a moving object detection system which comprises the steps of providing in a memory a predetermined location in which the echo time for reflection of an ultrasonic wave from a road surface is stored, determining an echo time after transmission of ultrasonic energy by means of the micro-processor, loading the micro-processor with data from said predetermined memory location to compute a difference a from an echo time after a current transmission of ultrasonic energy, storing said current time in said predetermined memory location when said difference a is less than a preset time α , storing

data representing said current time till reception of reflected energy in said predetermined memory location when said difference α is less than β which is a preset time larger than said time α and only in an initial state, and outputting a vehicle detection signal when said difference α is larger than said time β .

In the circuit diagram of Fig. 9 illustrating the modified arrangement as described above, since the circuit construction is generally the same as that in Fig. 5, detailed description thereof is abbreviated for brevity except for the contents of the RAM 22' which are to be described in detail hereinbelow.

From the map of Fig. 10 and flow charts of Figs. 11 to 12(h), it will be noticed that in the modified arrangement of Fig. 9, steps (221), (222), (223), (225), (226), (216'), (219) and (201) (shown in detail in Figs. 12(a), 12(b), 12(c), 12(d), 12(e), 12(f), 12(g) and 12(h) respectively are further added to the steps of Fig. 7 for the embodiment of Fig. 5, while other steps of Fig. 11 for the modification are generally similar to those in Fig. 7.

In the modified arrangement of Fig. 9, the RAM 22' is provided with locations representing the functions of the system counter, detection gate rise- or fall-time setting, α and β setting, reception-wave width setting, reception counters I and II, road-level counter, initial-state flag, vehicle detection flag, vehicle counter, vehicle number setting and code flag, respectively. These locations are respectively designated by the addresses set in the X-register 19 and Y register 20.

The operation of the modified arrangement of Fig. 9 will be explained hereinbelow with reference to the graph and flow charts shown in Figs. 11 to 12(h). In Fig. 11, the codes (201) through (228) given alongside blocks represent the respective step numbers and, hereinafter, these steps will be referred to briefly as (201) through (228).

In the first place, the power supply to the apparatus of Fig. 9 is switched on to start the operation. From this moment on, the operation circuit 17 functions in accordance with the program set in the ROM 16. First, at the step (201), the initial state flag in the initial flag area of the RAM 22 becomes ON (Fig. 12(h)). Then, at the step (202), the system counter of the RAM 22 is reset, whereupon the system counter starts counting. At the step (203), an output is generated which turns a wave transmission signal on, whereby the signal on the line 24 of the output circuit 18 becomes "High", thus opening the gate 2 so that the output of the oscillator 1 is fed to the transmitter-receiver transducer 5. Thereupon, this transducer 5 transmits the ultrasonic energy. At the step (204), enquiry is made to determine if the system counter (SC in Fig. 11) has reached the transmission wave width T_1 shown in Fig. 3. This is accomplished by reading out the data in the transmission wave width location of RAM 22 into the A-register 21 and comparing it with the count of the system counter AC. When the count of the system counter AC has reached the transmission wave width T_1 , a transmission signal OFF signal is generated at the step (205), whereupon the output of the output circuit 18 becomes "Low" and the output of the line 24 which was "High" becomes "Low". As the output of the line 24 becomes "Low", the gate 2 is closed so that the output of the oscillator 1 is no longer applied to the transducer 5. At the step (206), enquiry is made to determine if the count of system counter SC has reached the time period T_2 of Fig. 3. When the time T_2 (the value of the detection gate fall-location of RAM 22) is reached, an output is generated which turns the gate signal ON. By the above procedure, the output circuit 18 converts the signal on the line 25 to "High", thereby opening the gate 9. Until the gate 9 is opened, even if the transducer 5 receives the reflected energy, its reception output is not applied to the counter 10. At the step (208), enquiry is made to see if the wave reception has been detected. This is determined by whether the count at the counter 10 is zero or a figure other than zero. The flip-flop 13 is set till the count of the counter 10 reaches a preset figure and the AND gate 12 remains open due to its set output. Although the clock pulse from the generator 11 is applied to the counter 10 through the AND gate 12, the counter 10 does not count until the wave reception output from the transducer 5 is applied. Since the operation circuit 17 reads the signal on the line 23 at times intervals, it does not necessarily read out the signal on the line 23 at the moment when the wave-reception output of the transducer 5 is applied to the counter 10 but, normally, it reads out the signal on the line 23 with a slight delay from the time-point when the reception from the transducer 5 is applied to the counter 10. When, after the application of the reception output to the counter 10, the operation circuit 17 reads out the signal on the line 23, the count of the counter 10 is a certain figure other than zero. Thus, if the count of the counter 10 is such a certain figure other than zero, it is assumed that a reflected wave has been detected and, hence, the data is entered in the wave-reception counter I at the step (210). The time after the transmission of the ultrasonic energy till the recognition of a reception detection has already been counted by the system counter SC but, as mentioned above, the time of the step (210) is slightly delayed from the time when the wave-reception output was actually generated and the time corresponding to this delay has been counted by the counter 10. Therefore, by deducting the measured time value of the counter 10 from the

measured time value of the system counter SC, the time till the actual reception of the reflected wave takes place can be obtained. This is used as the data for the reception counter I and is stored in the reception counter I area of the RAM 22. At the step (211), enquiry is made to determine if wave-reception has ended, and if so the reception output of the transducer 5 is inhibited, whereby the count of the counter 10 is cancelled.

From the fact that the count of the counter 10 has once reached a certain value and, then, reached zero, it is determined that wave-reception has ended. At the step (212), the gate signal OFF output is generated, so that the output circuit 18 makes the signals on all the output lines "Low". In this situation, the signal on the line 24 which was "High" is made "Low", whereby the gate 9 is closed. If enquiries at the steps (208) and (211) each elicits a response of NO, enquiry is made at the step (209) if the count of the system counter SC has reached the time T_3 . The time T_3 is previously set at a time somewhat longer than the maximum echo time as shown in Fig. 3 for reception of the reflected waves from the road surface. If a reflected wave is not detected before the time T_3 or if there is no indication of a shut-down in the wave-reception, it indicates that some abnormality has taken place. Therefore, a gate signal OFF output is generated at the step (213').

Following the step (212), the difference a between the wave-reception counters I and II is computed at the step (213). At the time-point t_1 as shown in Fig. 4, where no data is present in the reception counter II area, the difference a is equal to the data of wave-reception counter I which has been entered at the step (210).

At the step (214), enquiry is made to see that $|a| \geq \alpha$, although the difference $|a|$ is naturally larger than the value α . At the step (215), enquiry is made to determine if the reception counter I > reception counter II, although the response is naturally YES because the data in the reception counter II are zero. Therefore, a further enquiry is made to determine if the initial-state flag is ON at the step (219); (Fig. 12(g)), and because it is ON, the data in the wave-reception counter I are set in the wave reception counter II. At this moment, data enter the wave-reception counter for the first time. Then, enquiry is made at the step (225) to see if $n \geq N$ (Fig. 12(d)). The symbol N represents the number which has been stored in the vehicle-number setting location of the RAM 22' (initial predetermined sets of vehicles). Thus, when the initial state is the time until a total of fifteen vehicles have been detected, for example, the number fifteen has been stored in that location. The symbol n represents the number of vehicles actually detected, and this information is stored in the vehicle counter location of the RAM 22' every time a vehicle is detected. Now that n is zero, the step (225) (Fig. 12(d)) is NO and the sequence proceeds to the step (227), where

an enquiry is made to determine if the count data of system counter SC have reached the time T_4 . Assuming that there is a vehicle detection pulse at the time T_4 an output is produced at the step (228) to generate an OFF pulse and, reset the operation to the step (202), so that the system counter SC is reset to commence counting anew and a transmission signal ON output is produced at the step (203). In this manner, an ultrasonic sound wave is transmitted at a period of T_4 . As the reflected wave derived from this transmission is received at the time-point t_2 , the data of reception counter I are executed at the step (210) and the difference a is computed at the step (213). If this difference a is substantially equal to zero, the relation $a \geq \alpha$ does not hold true at the step (214) and, therefore, the vehicle flag is reset at the step (216') (Fig. 12(f)). In this instance, since the vehicle flag has not been set as yet, it remains as it is. At the step (217), the data of the reception counter I are set in the road-level counter, and at the step (218), the data of the reception counter I are set in the reception counter II. At the step (225) (Fig. 12(d)), enquiry is made to determine if $n \geq N$. Since the response is No, the sequence goes back to the steps (202) through (227) and (228).

Then, at the time-point t_3 , the data of reception counter I are executed at the step (210), difference a is computed at the step (213) and enquiry is made as to whether $|a| \geq \alpha$ at the step (214). If the relation of $|a| \geq \alpha$ does not hold true, the sequence goes back to the steps (202) through (216), (217), (226), (227) and (228), and in the course of this sequence, the data of the reception counter I are set in the reception counter II and road-level counter. If the relation $|a| \geq \alpha$ does not hold true, enquiry is made at the step (215) to see if the reception counter I > reception counter II. Since the response to this inquiry is No, the sequence returns to the step (202) via the steps (219), (218), (225), (226), (227) and (228) and, in the course of this sequence, the data of the reception counter I are set in the reception counter II. In this manner, at the time-point t_3 , irrespective of whether the response to the enquiry $|a| \geq \alpha$ is YES or NO, the current data of the reception counter I are set in the reception counter II. Then, at the time-point t_4 , the difference a is computed at the step (213) by a similar procedure, enquiry $|a| \geq \alpha$ being made at the step (214). The reflected waves at the time-point t_4 are waves coming from the road surface and those at the time-point t_3 are waves from a vehicle. Thus, the response to the enquiry $|a| \geq \alpha$ is YES. Therefore, enquiry is made at the step (215) to determine if the reception counter I > reception counter II. Since the response to this inquiry is always YES, the data of the

reception counter I are set in the reception counter II at the step (218) via the step (219) and the sequence returns to the step (20) via the steps (224) or (228). At the time-point t5, the current data of the reception counter I are entered at the step (210) and a is computed at the step (213). Because, both at the time-point t4 and at the time-point t5, the reflected energy is from the road surface, the result of enquiry $|a| \geq \alpha$ at the step (214) is NO. Therefore, through the step (216') (because the vehicle flag has not been set as yet, there is no function here), the data of the reception counter I are set in the road-level counter II at the step (218). Therefore, at the time-point t5, the data of the road-level counter are at parity with the data of the reception counter II, the particular data being the data of the reception counter I at the time-point t5, that is echo time of a wave reflected back from the road surface at time-point t5. The waves reflected back from the road surface being available during the time series from t5 to t8, enquiry $|a| \geq \alpha$ is made at the step (214) to check the value a obtained by computation at the step (213) at each of these time-points. Since the results are invariably NO, the data of the reception counter I executed at the respective time-points are set in the reception counter II and road-level counter at the steps (217) and (218). Thus, during the time series from t5 to t8, the echo time of ultrasonic energy reflection from the road surface is executed by the reception counter I at each time-point and the result is set in both the road-level counter and reception counter II. In this manner, the actual echo times of sound waves reflected from the road surface are sequentially set in the road-level counter and reception counter II at these time-points and, if a variation takes place in the echo time from the road surface, the data in the road-level counter and reception counter II are updated each time such a change occurs. During the above operation the data of the road-level counter are at parity with the data of the reception counter II. Assuming that there is a reflection from a vehicle at the time-point t9, now the data of the reception counter I are entered at the step (210), the apparatus is loaded with the data of the reception counter II to compare and compute the difference a at the step (213) and enquiry is made at the step (214) to determine if $|a| \geq \alpha$. Therefore, enquiry is made at the step (215) to see if the reception counter I > reception counter II. Actually, because the value a as computed has been set in the reception counter II and the positive or negative sign of a has been set in the code flag area of the RAM 22 as shown in Fig. 5, the above determination at the step (215) is made with reference to said positive or negative sign in the above area. In this instance, because the data of the reception counter I are smaller than the data of the reception counter II, the enquiry $a \geq \beta$ is made at the step (216). At this time-point, the relation is $a \geq \beta$ because the reflected energy is from a vehicle. Therefore, a detection pulse ON signal is generated at the step (220) and the output on the line 26 of output circuit 18 goes "High" to cause a detection signal to be generated. Enquiry is made at the step (221) to see if the vehicle flag is ON and, if the response is NO, the vehicle counter (n) is advanced by plus one at the step (222) to make $n=1$ (Vehicle counter (n) addition Fig. 12(b)). The vehicle flag is set ON at the step (223) (Fig. 12(c) and the road-level counter is set in the reception counter II. Thus, when the reflected energy from the vehicle has been received, the data of the road-level counter and reception counter II are not updated by the current data of the reception counter I. However, since the data of reception counter II has been converted to a , the data of the road-level counter is entered in the reception counter II, whereby the data reverts to the data prior to the time-point where the reflected energy from the vehicle was obtained, i.e. to the data at the time-point t8. The function at the time-point t10 is similar to that described for t9, up to the step (220). However, because the vehicle flag is already ON at the time-point t'10 the sequence advances from the step (221) (Fig. 12(c)), bypassing the step (222) (Fig. 12(b)), with the result that the vehicle counter will not count the same vehicle twice. At the step (224), the data of road-level counter (the data at the time-point t8) are set in the reception counter II. Thus, throughout the period in which the reflected energy from the vehicle is available, the data of the road-level counter and of the reception counter II are not updated but both remain the same as the echo time of reflected energy from the road surface at the time-point t8. The vehicle flag is reset in the step (216') (Fig. 12(f)) at the time-point t14 in the same manner as described with reference to the time-point t5.

As the above operation is repeated until the detected number of vehicles n has reached a set number N (e.g. fifteen), the response at the step (225) (Fig. 12(d)) is YES and, hence, the sequence goes to the step (226) (Fig. 12(e)) where the initial-state flag is reset.

Because, up to the time of the resetting of the initial-state flag, the echo time of the reflected energy from the road surface has been repeatedly updated and set as correct values in the road-level counter and wave-reception counter II, the response at the step (214) is in the relation of $a \geq \alpha$ thereafter, and if the response at the step (215) is reception counter I > reception counter II, enquiry is made at the step (216) to determine if $|a| \geq \beta$. If the response to this enquiry is YES, a vehicle detection signal is generated. If the response is NO, the sequence advances directly to the step (224) because the initial-state flag is not

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ON at the step (219), thus setting the data of the road-level counter in the reception counter II. Thus, after the initial state has ended, neither the road-level counter nor the reception counter II is updated insofar as $|a| \leq \alpha$ and $|a| > \beta$. Updating occurs only in the case of a $> \alpha$.

Thus, in the initial state of the system, the data of the reception counter II are updated when the difference $|a|$ is smaller than the value α and, even if it is larger than the value α , but smaller than the value β , the data of the reception counter II being thus used as the standard data for the determination that energy is reflected from a vehicle. However, after the initial state, since the standard road level providing the basis for standard data has already been set, the standard data are updated only when the value $|a|$ is smaller than α .

Moreover, there are provided a reception counter I, a road-level counter and another reception counter II in such a manner that, in an initial state, the data of the road-level counter and the reception counter II are both updated when the difference $|a|$ is smaller than the value α but only the data of the reception counter II are updated at first when the value $|a|$ is larger than the value α and has a positive sign and a value smaller than the value β and, subsequently, at the next reception of the reflected energy, the data of road-level counter and reception counter II are both updated if the value $|a|$ is smaller than the value α . Let it be assumed that the difference a is smaller than the value β just once, e.g. as the time-point t_2 , due to noise, for instance. In this arrangement, insofar as this erratic operation is due to noise, the value a will be larger than the value α at the time-point t_3 . According to this invention, therefore, the road-level counter is not updated in the above case, thus precluding the possibility that erroneous standard data are entered.

It should be understood that, except at certain transient points, the road-level counter and reception counter are identical in the contents of data. In the second aspect of this invention, the road level counter is the standard plane.

It should be noted here that although the present invention is mainly described with reference to a moving object detection system of vehicles in the foregoing embodiments, the concept of the present invention is not limited in its application to such vehicles alone, but may readily be applicable to detection of various other moving objects or articles within the scope.

Although the present invention has been fully described by way of example with reference to the accompanying drawings, it is to be noted that various changes and modifications are apparent to those skilled in the art.

WHAT WE CLAIM IS:

1. A detection system for detecting the presence of moving objects and the like moving over a surface comprising means for transmitting ultrasonic energy towards the surface and for receiving reflected energy from the direction of the surface, a standard location provided in a memory unit for storing therein an echo time corresponding to the time from transmission of ultrasonic energy to the time of reception of reflected energy corresponding thereto from said surface, means for computing the difference a between an immediately preceding echo time stored in said standard location and a current echo time corresponding to the time of transmission of ultrasonic energy to the time of reception of reflected energy corresponding thereto, means for storing in said standard location said current echo time when the difference a is smaller than a predetermined time α , and means for generating a moving object detection signal when said difference a is larger than a preset time β which is larger than said time α .

2. A detection system as claimed in Claim 1, wherein said moving objects are vehicles.

3. A detection system as claimed in Claim 1 or 2 wherein said surface is a road surface.

4. A detection system as claimed in Claim 1, 2 or 3 further including detection gate means which is arranged to be open for a time period sufficient to receive reflected energy from an object moving over said surface.

5. A detection system as claimed in Claim 4, wherein said gate means is arranged to be selectively opened and closed by a micro-processor.

6. A detection system as claimed in Claim 1, 2, 3, 4 or 5, wherein said current echo time from transmission of ultrasonic energy till reception of reflected energy corresponding thereto is stored in said standard location only during an initial state of operation of the system and when said difference a is smaller than said preset time β .

7. A detection system as claimed in Claim 6, further including a first wave reception counter area in which the echo time from transmission of ultrasonic energy till reception of reflected energy corresponding thereto is stored and a second wave reception counter area in which said immediately preceding echo time is stored.

8. A detection system as claimed in any one of the preceding claims wherein said initial state of operation is determined by the number of moving objects to be detected.

9. A method of operating the detection system of Claim 1 comprising the steps of providing in a memory a standard location in which an echo time after transmission of



ON at the step (219), thus setting the data of the road-level counter in the reception counter II. Thus, after the initial state has ended, neither the road-level counter nor the reception counter II is updated insofar as $|a| \geq \alpha$ and $|a| > \beta$. Updating occurs only in the case of a $> \alpha$.

5 Thus, in the initial state of the system, the data of the reception counter II are updated 5
when the difference $|a|$ is smaller than the value α and, even if it is larger than the value α ,
but smaller than the value β , the data of the reception counter II being thus used as the
standard data for the determination that energy is reflected from a vehicle. However, after
10 the initial state, since the standard road level providing the basis for standard data has 10
already been set, the standard data are updated only when the value $|a|$ is smaller than α .
Moreover, there are provided a reception counter I, a road-level counter and another
reception counter II in such a manner that, in an initial state, the data of the road-level
counter and the reception counter II are both updated when the difference $|a|$ is smaller
15 than the value α but only the data of the reception counter II are updated at first when the 15
value $|a|$ is larger than the value α and has a positive sign and a value smaller than the value
 β and, subsequently, at the next reception of the reflected energy, the data of road-level
counter and reception counter II are both updated if the value $|a|$ is smaller than the value
 α . Let it be assumed that the difference a is smaller than the value β just once, e.g. as the
20 time-point t_2 , due to noise, for instance. In this arrangement, insofar as this erratic 20
operation is due to noise, the value a will be larger than the value α at the time-point t_3 .
According to this invention, therefore, the road-level counter is not updated in the above
case, thus precluding the possibility that erroneous standard data are entered.

It should be understood that, except at certain transient points, the road-level counter
and reception counter are identical in the contents of data. In the second aspect of this
25 invention, the road level counter is the standard plane. 25

It should be noted here that although the present invention is mainly described with
reference to a moving object detection system of vehicles in the foregoing embodiments,
the concept of the present invention is not limited in its application to such vehicles alone,
but may readily be applicable to detection of various other moving objects or articles within
30 the scope. 30

Although the present invention has been fully described by way of example with
reference to the accompanying drawings, it is to be noted that various changes and
modifications are apparent to those skilled in the art.

WHAT WE CLAIM IS:

- 35 1. A detection system for detecting the presence of moving objects and the like moving 35
over a surface comprising means for transmitting ultrasonic energy towards the surface and
for receiving reflected energy from the direction of the surface, a standard location
provided in a memory unit for storing therein an echo time corresponding to the time from
40 transmission of ultrasonic energy to the time of reception of reflected energy corresponding 40
thereto from said surface, means for computing the difference a between an immediately
preceding echo time stored in said standard location and a current echo time corresponding
to the time of transmission of ultrasonic energy to the time of reception of reflected energy
corresponding thereto, means for storing in said standard location said current echo time
45 when the difference a is smaller than a predetermined time α , and means for generating a 45
moving object detection signal when said difference a is larger than a preset time β which is
larger than said time α .
2. A detection system as claimed in Claim 1, wherein said moving objects are vehicles.
3. A detection system as claimed in Claim 1 or 2 wherein said surface is a road surface.
4. A detection system as claimed in Claim 1, 2 or 3 further including detection gate 50
50 means which is arranged to be open for a time period sufficient to receive reflected energy 50
from an object moving over said surface.
5. A detection system as claimed in Claim 4, wherein said gate means is arranged to be
selectively opened and closed by a micro-processor.
6. A detection system as claimed in Claim 1, 2, 3, 4 or 5, wherein said current echo time 55
55 from transmission of ultrasonic energy till reception of reflected energy corresponding 55
thereto is stored in said standard location only during an initial state of operation of the
system and when said difference a is smaller than said preset time β .
7. A detection system as claimed in Claim 6, further including a first wave reception
60 counter area in which the echo time from transmission of ultrasonic energy till reception of 60
reflected energy corresponding there is stored and a second wave reception counter area in
which said immediately preceding echo time is stored.
8. A detection system as claimed in any one of the preceding claims wherein said initial
state of operation is determined by the number of moving objects to be detected.
9. A method of operating the detection system of Claim 1 comprising the steps of 65
65 providing in a memory a standard location in which an echo time after transmission of 65

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ultrasonic energy till reception of a reflected energy corresponding to said energy from a road surface is stored, determining an echo time after transmission of ultrasonic energy till reception of reflected energy corresponding to said energy by means of a micro-processor, loading the micro-processor with data from said standard location to compute a difference a from a current echo time, storing said current echo time in said standard location when said difference a is smaller than a preset time α , storing data representing said current echo time in said standard location when said difference a is smaller than β which is a preset time larger than said time α and only in an initial state of operation of the system, and generating a vehicle detection signal when said difference a is larger than said time β .

10. A detection system for detecting the presence of moving objects, substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

11. A method of detecting objects substantially as hereinbefore described with reference to the accompanying drawings.

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