EFFECT OF VARIATION OF SEPARATION BETWEEN THE ULTRASONIC TRANSMITTER AND RECEIVER ON THE ACCURACY OF DISTANCE MEASUREMENT

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ABSTRACT

Accuracy of distance measurement of an object from an observation point such as a stationary or moving vehicle, equipment or person is most important in large number of present day applications. Ultrasonic sensors are most commonly used due to its simplicity and low cost. The accuracy of the measured distance is dependent on the separation between the ultrasonic transmitter and receiver. This dependency has been studied and reported in this paper. The result shows that the accuracy of distance measured is dependent on the separation between the transmitter and the receiver.

KEYWORDS

Accuracy of distance measurement, Ultrasonic sensor, distance measurement, microcontroller, sewer pipeline inspection, sewer pipeline maintenance, robotics.

1. INTRODUCTION

Distance measurement of an object in front or by the side of a moving or stationary entity is required in a large number of devices and gadgets. These devices may be small or large and also quite simple or complicated. Distance measurement systems for such applications are available. These use various kinds of sensors and systems. Low cost and accuracy as well as speed are important in most of the applications. Hence ultrasonic sensors are most commonly used. To maintain the accuracy of measured distance the separation between transmitter and receiver is very important.

In this paper, we describe the results of a study on the variation of error of measurement of distance of an object by varying the separation between the transmitter and receiver of the ultrasonic sensors by using microcontroller P89C51RD2.

Ultrasound sensors are very versatile in distance measurement. They are also providing the cheapest solutions. Ultrasound waves are suitable both for air and underwater use [1].

Ultrasonic sensors are also quite fast for most of the common applications. In simpler system a low cost version of 8- bit microcontroller can be used to implement the system to lower the cost.

We are applying this system for sewer inspection system. Sewer blockages have become quite common. The blockages have become more frequent due to the dumping of polythene bags, hair and solid materials into the sewer system [2], [3].

There has been no work done in this direction. This is a new study which is useful to find out the optimal separation between ultrasonic transmitter and receiver to measure small distances.

2. PRINCIPLE

Ultrasonic transducer uses the physical characteristics and various other effects of ultrasound of a specific frequency. It may transmit or receive the ultrasonic signal of a particular strength. These are available in piezoelectric or electromagnetic versions. The piezoelectric type is generally preferred due to its lower cost and simplicity to use [5]. The transmitter and receiver are available either as single unit or as separate units.

The Ultrasonic wave propagation velocity in the air is approximately 340 m/s, the same as sonic velocity. To be precise, the ultrasound velocity is governed by the medium, and the velocity in the air is calculated using the formula given below (1).

$$V = 340 + 0.6(t-15) \text{ m/s} \qquad (1)$$

t:temperature, °C

In this study, we assumed the temperature to be 20°C, so the velocity of ultrasound in the air is 343 m/s. Because the travel distance is very short, the travel time is little affected by temperature. It takes approximately 29.15µsec for the ultrasound to propagate through 1cm, so it is possible to have 1cm resolution in the system [6].

3. EXPERIMENTAL SETUP

The system consists of a transmitter and a receiver module controlled by a microcontroller P89C51RD2. We have used a microcontroller development kit for testing of the system. We are using 40Khz ultrasound sensors for our experiments. The Simplified block diagram of the system is shown in Fig.1.

In Fig. 1, the interrupt1 signal initiates the system. When the interrupt1 signal is generated, MCU starts the timer1 to measure time and simultaneously generates the controlled 40Khz pulses having a train of specific number of pulses. These pulses are applied to the amplifier circuit and after amplification the ultrasound transmitter transmits the pulse train in the direction of the object. These ultrasonic pulses are reflected from the object and travels back in different directions.

These reflected waves arrive at receiver. After amplification and processing it generates signal interrupt. This is applied as interrupt2 to the MCU. Interrupt2 stops the timer1, and MCU calculates the time elapsed between the generation of the wave and reception of the wave. This time is proportional to the distance travelled by the waves. Using the formula, MCU calculates the distance of the obstacle and display it or transfer it to the part of the total system where it is used for further control. Using this elapsed time, we calculate the distance of the object from the ultrasonic sensors.

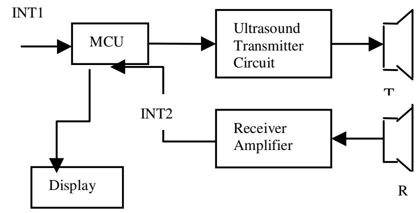

Fig 1: Block Diagram of the System

4. EXPERIMENTAL RESULTS

The waveforms of the transmitted and received waveforms of the ultrasonic signal is stored in Digital Storage Oscilloscope.

We have taken the readings for various separation between tranmitter and reciever. We have measured the distance in the interval of 5cm. For every measured distance three reading have been taken. The table shows the average of the three readings. The maesured distance is calculated on the basis of travelled time. The formula to calculate the distance is given below:

$$\text{Dist. (cm)} = (\text{Travelled Time} * 10^{-6} * 34300) / 2 \qquad (2)$$

The ultrasonic waves travelled from the transmitter to the object and from the object back to the receiver hence the whole distance is divided by two.

Values of %Error have also been calculated and shown. The error result shows that there is some error in recording the start and finish times in the system. When the distance increases the error is distributed in a larger distance and hence the %error decreases. We have taken the measurements for various separations of transmitter and receiver renging from 2cm to 15cm. The Table 1 shows the results when separation between tranmitter and reciever is 2cm.

Table 1: Experimental Results (For 2cm Separation between Transmitter and Reciever)

S.No.	Actual Distance(cm)	Travelled Time (µSec)	Measured Distance (cm)	% Error
1	5	400	6.86	37.20
2	10	690	11.83	18.34
3	15	1050	18.01	20.05
4	20	1250	21.44	7.19
5	25	1650	28.30	13.19
6	30	1930	33.10	10.33
7	35	2180	37.39	6.82
8	40	2400	41.16	2.90
9	45	2700	46.31	2.90
10	50	3000	51.45	2.90

The result shows that the acuracy of measured distance is increses for longer distances. The %error becomes constant for measured distances above 40cm. The highest %error is occured in small distance of 5cm. It is also shown by Fig.2.

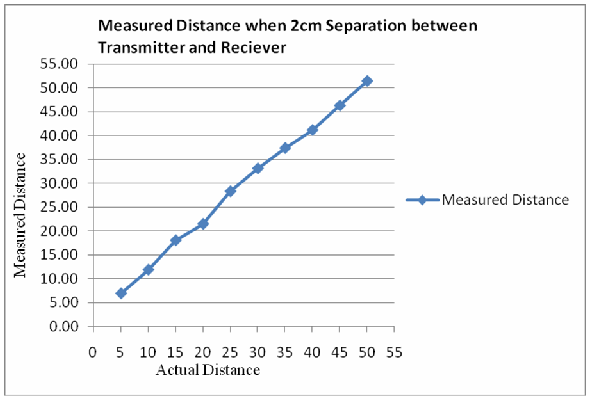

Fig. 2: Graph of Actual Distance versus Measured Distance for 2cm Separation between Transmitter and Reciever.

The Table 2 shows the result when separation between transmitter a reciever is 5cm.

Table 2: Experimental Results for 5cm Separation between Transmitter and reciever)

S.No.	Actual Distance(cm)	Travelled Time (µSec)	Measured Distance (cm)	% Error
1	5	410	7.03	40.63
2	10	700	12.01	20.05
3	15	1000	17.15	14.33
4	20	1300	22.30	11.48
5	25	1600	27.44	9.76
6	30	1870	32.07	6.90
7	35	2220	38.07	8.78
8	40	2500	42.88	7.19
9	45	2780	47.68	5.95
10	50	3120	53.51	7.02

The resluts shows that the accuracy is incresed in camparison to the previous results. This is also shown by the Fig. 3.

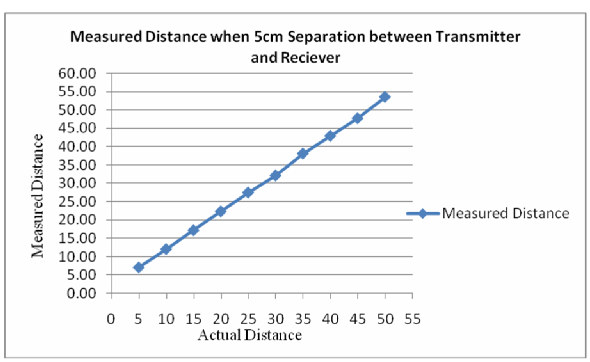

Fig. 3: Graph of Actual Distance versus Measured Distance when Separation between Transmitter and Reciever is 5 cm.

The Table 3 shows the results when separation between transmitter and reciever is 10 cm. These results indicates that when we increase the separation between transmitter and receiver the %error increses for small measured distances.

Table 3: Experimental Results for Separation of 10cm between Transmitter and reciever)

S.No.	Actual Distance(cm)	Travelled Time (µSec)	Measured Distance (cm)	% Error
1	5	620	10.63	112.66
2	10	750	12.86	28.63
3	15	1010	17.32	15.48
4	20	1310	22.47	12.33
5	25	1600	27.44	9.76
6	30	1870	32.07	6.90
7	35	2200	37.73	7.80
8	40	2400	41.16	2.90
9	45	2680	45.96	2.14
10	50	3000	51.45	2.90

Again the accuracy increases with the distance but the small distances are not so accurate. The error is high for small distances. It is also shown by the Fig. 4.

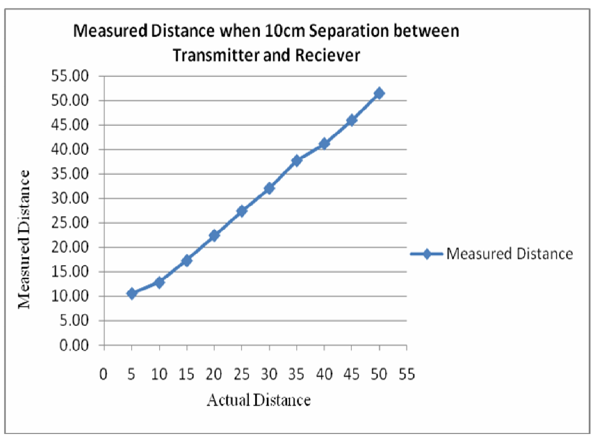

Fig. 4: Graph of Actual Distance versus Measured Distance when Separation between Transmitter and Reciever is 10 cm.

The Table 4 is showing the result of measured distance when 15cm separation between transmitter and reciever. These results shows that when we increase the separation between transmitter and receiver the %error increses. This increase is very high in small measured distances like 5cm in our experiment. The lowest %error observed for the measured distance of 45cm and again it is increasing for the measured distance of 50cm.

The results shows that we have to stop the increament of seaparation between transmitter and receiver in our experiment.

Table 4: Experimental Results for 15cm Separation between Transmitter and Reciever)

S.No.	Actual Distance(cm)	Travelled Time (µSec)	Measured Distance (cm)	% Error
1	5	1300	22.30	345.90
2	10	930	15.95	59.50
3	15	1180	20.24	34.91
4	20	1350	23.15	15.76
5	25	1620	27.78	11.13
6	30	1900	32.59	8.62
7	35	2200	37.73	7.80
8	40	2420	41.50	3.76
9	45	2700	46.31	2.90
10	50	3200	54.88	9.76

Again the error for the small distance say 5cm is very high. It is also showing that the graph between actual distance versus measured distance is not a straight line. This graph is shown in Fig. 5.

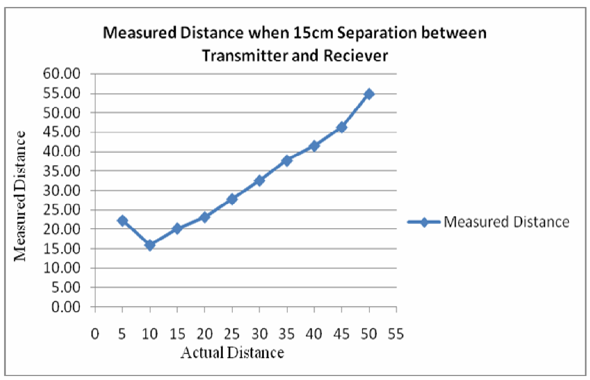

Fig. 5: Graph of Actual Distance versus Measured Distance for 15cm Separation between Transmitter and Reciever.

The graph between the measured distance the actual distance indicates that the measured distance is proportional to the actual distance.

5. ANALYSIS OF THE RESULTS

The experimental results shows that the distance measured for different separations between transmitter and receiver are accurate for long distances e.g. more than 20cm. For small actual distances say 5cm, the small transmitter and receiver distances are better in comparison to the long distances between transmitter and receiver. If we place the transmitter and receiver at 15cm separation than the small distance like 5cm are not going to be measured correctly. Result shows the error of 345%. Hence we have to place the transmitter and receiver at proper distance like 5-10cm. For long distances the distance between transmitter and receiver has very low impact on the accuracy.

We have compared the all measured distances for different separations between transmitter and receiver and the results are shown in the Table 5.

Table 5: Comparison of Measured Distances for different Separations between Transmitter and Reciever

S. No.	Actual Dist. (cm)	Measured Distance (in cm) when Separation between Transmitter and Reciever is =			
		2cm	5cm	10cm	15cm
1	5	6.86	7.03	10.63	22.30
2	10	11.83	12.01	12.86	15.95
3	15	18.01	17.15	17.32	20.24
4	20	21.44	22.30	22.47	23.15
5	25	28.30	27.44	27.44	27.78
6	30	33.10	32.07	32.07	32.59
7	35	37.39	38.07	37.73	37.73
8	40	41.16	42.88	41.16	41.50
9	45	46.31	47.68	45.96	46.31
10	50	51.45	53.51	51.45	54.88

As we can see in the table that small measured distance like 5cm is measured accurately when 2cm separation between transmitter and receiver. It has the lowest error. When we increase the distance to be measured, the accuracy of measured distance are high and it the highest for 10cm separation between transmitter and receiver. Hence for the range of 5cm to 50cm, as we taken in our experiments, the separation between transmitter and receiver are 2cm to 10cm. If we increase this than the error percentage also increases.

The Fig.6 shows the graph between actual distance and the different measured distances for various separations between transmitter and receiver.

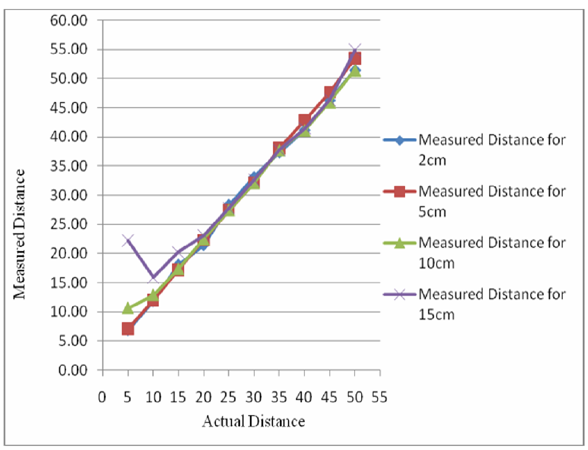

Fig. 6: Graph for Comparison of Measured Distances for different Separations between Transmitter and Reciever

This graph is also showing that the graph plotting of measured distance when separation between transmitter and receiver is 2cm, 5cm and 10cm is almost on the same points. The graph plotting when 15cm separation between transmitter and receiver, is not very encouraging for this range of 5cm to 50cm.

6. CONCLUSIONS

We have done the experiments on our ultrasonic measurement system for the various separations between transmitter and receiver and the result shows that the measured distance is satisfactory for our study. When the distance increases the error becomes constant and very less. A correction may be applied to calculate the correct distance.

Interrupt1 initiates the system and interrupt2 stops the timer and on the basis of the travelled time distance calculated. In future, the whole system will be mounted on the one PCB.

This study shows that for small distances the separation between transmitter and receiver should be 5cm to 10cm. Hence this study will help in fixing the separation between transmitter and receiver in the robotic vehicle for blockage detection so we are able to calculate the more accurate distance of the blockage in the sewage filled sewer lines. Hence we can prevent human labour to go in the sewage filled sewer lines to detect the blockage which are very dangerous to the human as they contain the poisonous gases.

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