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Small Scale Replication of RADAR Scenario using SONAR

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Abstract—*Simulation of a radar system with complete resemblance to its field results has always been a challenge for designers. Several factors drive the difference between the virtual simulation and real world scenario of a Radar scenario. Among them, primary ones are unpredictable behavior of electromagnetic waves during reflections from targets and difficulty in producing a complete replica of a large and uneven terrain. There have been recent developments in the field of radar simulation and more accurate simulators for radar environments are being continuously designed. But challenges increase manifolds as system complexity increases along with increase in development costs dampens the efforts to a great extent. In order to have a closer resemblance with the physical phenomenon of creating a radar environment, this project takes the approach of replicating a radar environment using a ultrasonic sensor based system built for the mentioned purpose. This method allows scaling down of a large terrain to a small terrain, with real waves reflected from real objects and with a very low cost.*

1. INTRODUCTION

Owing to the fact that radar and sonar are both based on the phenomenon of reflection gives us the room to facilitate their interoperability and inter-represent ability. Technological advancements have allowed us today to emerge into fields that have until recent not been worked upon. Inter-represent ability of radar and sonar is crucial for understanding radar behaviour with the help of small scale sonar model. Radar is a system that detects the presence of distant objects by sending electromagnetic waves and receives their echo from those objects. The distance of the object is derived by calculating the time taken by these echo to reach back to its origin. The data obtained from the echo are processed exhaustively to obtain as much knowledge about the reflecting entity as possible to have information processes like identification of the object, separation from the clutter, identification of its course, its velocity, and azimuthal altitude and so on. This leads the using organisation to attain a position to be able to take responsive decisions. Radars are of two types: Passive radars and Active radars. Passive radars send continuous stream of high power electromagnetic energy and receives the Doppler shifted echo from the moving objects. Active radar sends out a high energy electromagnetic pulse and waits for an echo. Here we are concerned more about the second kind.

Sound **N**avigation **A**nd **R**anging (SONAR) is a technique that uses sound propagation (usually)underwater, as in submarine navigation) to navigate, communicate with or detect objects on or under the surface of the water, such as other vessels. SONAR operation is affected by variations in sound speed. Sound travels more slowly in fresh water than in sea water, though the difference is small. The speed is determined by the water's bulk modulus and mass density. SONAR is of two types active and passive SONAR. Here in our project we demonstrated the active SONAR; active sonar is emitting pulses of sounds and listening for echoes. The term SONAR is also used for the equipment used to generate and receive the sound. It is being used since, to detect different obstacles, Anti-submarine warfare, Torpedoes, Mining, Mine countermeasures, Submarine navigation, Aircraft, Underwater communications, underwater security etc. SONAR also provides underwater conditions. The detection, classification and localization performance of SONAR depends on the environment and the receiving equipment, as well as the transmitting equipment in active SONAR. When active SONAR is used, scattering occurs from small objects in the sea as well as from the bottom and surface. This can be a major source of interference. Active SONAR creates a pulse of sound, and then listens for reactions (echo) of the pulse. This pulse of sound is generally created electronically using a sonar projector consisting of a signal generator, power amplifier and electro-acoustic transducer array.

As you can see the two technologies are based on the same principle of reflection. We attempt to do imitate a radar environment using a sonar technology. Therefore we have designed and built a sonar system which acts similar to scaled down radar. To measure the distance to an object, the time from transmission of a pulse to reception is measured and converted into a range by knowing the speed of sound. To measure the bearing, several hydrophones are used, and the set measures the relative arrival time to each, or with an array of hydrophones, by measuring the relative amplitude in beams formed through a process called beam forming. Use of an array reduces the spatial response so that to provide wide cover multi-beam systems are used. The target signals (if present) together with noise is then passed through various forms of signal processing, which for simple SONAR may be just energy measurement. It is then presented to some form of decision device that calls the output either the required signal or noise. This decision device may be an operator with 2 headphones or a display, or in more sophisticated SONAR this function may be carried out by software. Further processes may be carried out to classify the target and localise it, as well as measuring its velocity. The pulse may be at constant frequency or a chirp of changing frequency (to allow pulse compression on reception). Simple SONAR generally use the former with a filter wide enough to cover possible Doppler changes due to target movement, while more complex ones generally include the latter technique. Since digital processing became available pulse compression has usually been implemented using digital correlation techniques. Military SONAR often have multiple beams to provide all-round cover while simple ones only cover a narrow arc, although the beam may be rotated, relatively slowly, by mechanical scanning. Particularly when single frequency transmissions are used, the Doppler effect can be used to measure the radial speed of a target. The difference in frequency between the transmitted and received signal is measured and converted into a velocity. Since Doppler shifts can be introduced by either receiver or target motion, allowance has to be made for the radial speed of the searching platform.

2. WORKING PRINCIPLE

The Working Model is a device that provides us the information of distance of the object in front of its sensor. The sensor is rotated 360 degrees with an angular velocity of 20 rpm. Its sensor is an ultrasonic transceiver. It has a microcontroller based control unit used with a USB to UART connector and display unit. The transceiver sends a sound signal of frequency 40 KHz for a time period of 10usto detect an object in front of it. The sensor is rotated to sense the distance of its surrounding. The sensor sends out an ultrasonic sound pulse and waits for an Echo. The Sensor is connected to a microcontroller PIC-18F26K22 mounted on an embedded board. When an echo is received, it provides a signal to the microcontroller which calculates the time taken by the echo to arrive and calculate the distance of object by using the following formula:

Range = high-time x speed(340m/s)/2

The calculated value is then fed via UART port of the embedded board. As the sensor rotates, it senses the objects and their distances are measured correspondingly. As a result, we have the distances of all obstacles surrounding the device. The following block diagram explains the working of the model:

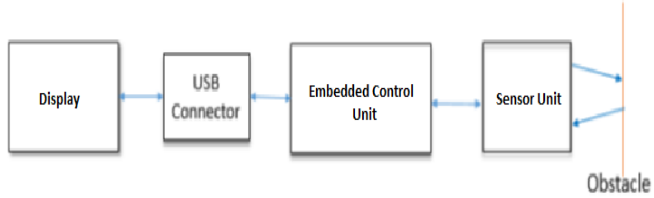

Fig. 1: Basic layout of the system

3. SCALE FACTOR

We have scaled down a radar to a sonar based platform. The ratio of the scaled down factor is different for different factors:

As we replaced electromagetic waves with ultrasonic sound, the ratio of scale down of wave velocity is-

$$Scale\ = \frac{330}{3x10\text{^}8} = 1{:}100000 \text{ (approx)}$$

Range of a radar of 200 km to 2m of the device-

$$Scale\ = \frac{2}{200x10\text{^}3} = 1{:}\ 100000$$

Therefore the behavior of a radar senario is expected to be same as the designed sonar environment in a scaled down manner. Hence, the given system can replicate a radar senario at a small scale.

4. SYSTEM DESCRIPTION:

The system that we have designed consists of three major functional units that makes it performs as required. The units are: The Sensor unit, the control unit, and communication and display unit. There is another underlying unit called support unit which gives support, provides mechanical robustness and facilitates rotation and communication while it rotates. We shall discuss it after we bestow contemplation upon each of these primary functional units.

The sensor unit is a transceiver that composes of an ultrasonic speaker, an ultrasonic receiver, a duplexer, a crystal oscillator, a pulse modulator, a rectifier/filter, an amplifier and a pulse recognizer. The architecture of the sensor unit is described in the Fig. below. The crystal oscillator generates a 40 kHz signal which is modulated with the pulse of time period 10us using a modulator. This modulator is then fed to an amplifier that makes the signal powerful enough to drives an ultrasonic speaker. The speaker and the mic are both connected to the duplex. The duplexer channels the signal to the speaker and when an echo is received, it channels that signal to the receiving unit. The receiving component has pre-stage amplifier which provides strength to the signal so that it can be filtered. The signal is then fed to the filter/rectifier unit which then filters through only the signals at 40 kHz which are likely to be the echoes. The echo is then reshaped by a pulse recognizer and buffered at the echo pin which is communicated to the control unit.

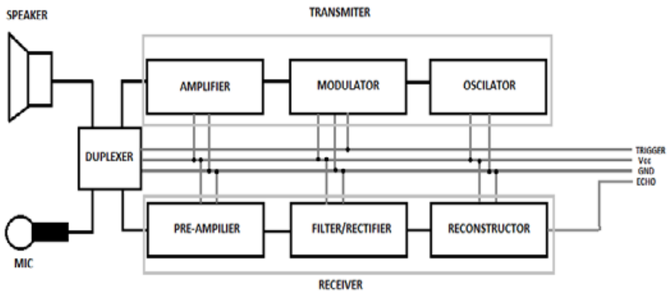

Fig. 2: Architecture of sensor unit

The sensor unit communicates with the control unit with the help of a communication port consisting of four lines. These four lines are: Trigger, Vcc, Ground and Echo. Vcc and Ground are essential to drive the sensor unit. The control unit commands the trigger pin through the trigger line. When trigger goes high, the transmitter is turned on and it emits sound pulse of 10us. When a pulse is received back, it is sent to the control unit using ECHO.

The control unit consists of a microcontroller PIC-18F26K22. It is an advanced 8-bit microcontroller from the PIC family. We use an 8 MHz crystal oscillator to con Fig. the microcontroller along with other configuring components and it is driven by a power supply of 5 V. The microcontroller is programed using MP-lab IDE and hardwired using PICkit3. Two of its General Purpose Input Output (GPIO), RC2 and RB5 are configured as Echo and Trigger respectively. The programmed microcontroller follows the following algorithm: It triggers the sensor every 60 milliseconds. It records the time at which echo is heard every cycle and calculates the distance of the reflecting object/surface. It communicates with the display unit using USART communication. The Baud rate of USART communication is set at 9. 8 Kbps.

The display unit can be any display device that facilitates USART/USB communication. In the system we built, we used a Laptop. The software's that we used to view the data are H-term and Matlab. H-term enabled us to access the unprocessed serial data at real time. We used Matlab serial port to map the obtained data into S-plot real time plotter using GUI in sync with the rotation speed of the system.

5. RESULTS

The unprocessed output obtained using H-term is:

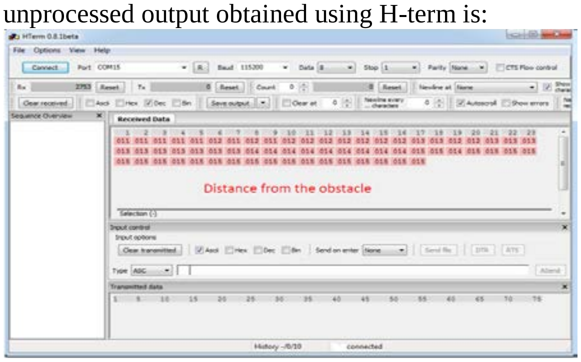

Fig. 3: Output viewed at H-term

The output obtained from the serial port is channelled to Matlab and processed using signal integration process and then plotted in a polar form. The obtained output is as follows:

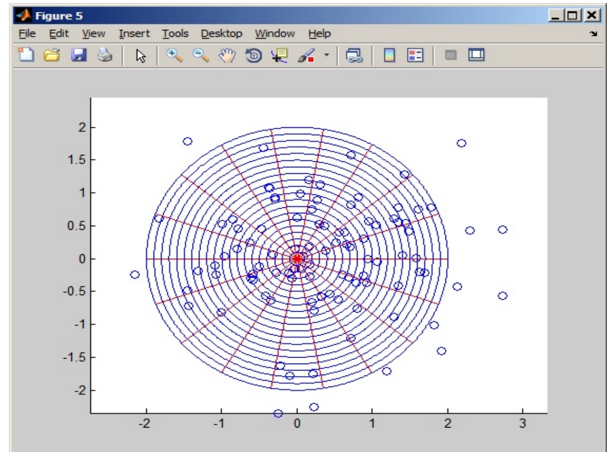

Fig. 4: Output viewed in Matlab

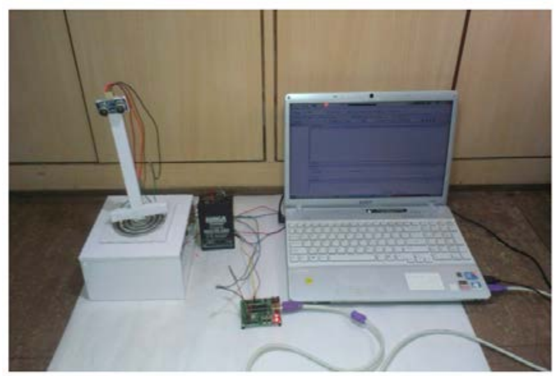

Fig. 5: Snapshot of the system

6. CONCLUSION

The project is based on the principle of SONAR i. e. Sound Navigation And Ranging. Variables such speed and frequency determines the quality and sensitivity of the SONAR operation. This system determines the distance of closest obstacle by sensing the echo. The sonar constructed is a high precision range detection and scanning system that can be used effectively to sense and understand the nature of the surrounding. This device helps us to understand the basic model and function of large scale radars. It resembles radar at small scale and can be effectively used to simulate real scenario in a controlled and portable manner using small scale models of terrains to optimise radar designs. It can also be used to simulate military and air force strategies before execution. It can also be used to simulate plans of air traffic management in civil aviation at airports

Here we are able to put forward a system that successfully replicates a radar system with the help of ultrasound in a small scale manner. Results have shown us a scaled down output of approximately 1:100000 in all fields. Fast growing sensor technology, fast processors and a much evolved analytical algorithm has led us to a make better systems for future generation tools to understand the behavior of both radar and sonar.

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