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Radar Echo Signal Multipath Fading

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Abstract**:** *Multipath propagation is a fact of life in any terrestrial radio scenario. While the direct or line of sight path is normally the main wanted signal, a radar receiver will receive many signals resulting from the signal taking a large number of different paths. These paths may be the result of reflections from buildings, mountains or other reflective surfaces including water, etc. that may be adjacent to the main path. Additionally other effects such as ionosphere reflections give rise to multipath propagation as does tropospheric ducting .The multipath propagation resulting from the variety of signal paths can give rise to interference in a variety of ways including distortion of the signal, loss of data and multipath fading.*
This paper deals with the processing of the received signals in the radar receiver in order to minimize the effects of the multipath signals. The line-of-sight (LOS) echo is considered the main signal to represent the target.
Index Terms**:** *Radar , multipath propagation , fading , line of sight path , target.*

I. INTRODUCTION

Multipath radio signal propagation occurs on all terrestrial radio links. The radar echo signals not only travel by the direct line of sight path, but as the transmitted signal does not leave the transmitting antenna in only one direction , but over a range of angles even when a directive antenna is used. As a result, the transmitted signals spread out from the transmitter and they will reach other objects: hills, buildings reflective surfaces such as the ground, water, etc. The signals may reflect of a variety of surfaces and reach the receiving antenna via paths other than the direct line of sight path.The overall signal received is the sum of all the signals appearing at the antenna. Sometimes these will be in phase with the main signal and will add to it, increasing its strength. At other times they will interfere with each other. This will result in the overall signal strength being reduced.

At times there will be changes in the relative path lengths. This could result from any of the objects that provide a reflective surface moving. This will result in the phases of the signals arriving at the receiver changing, and in turn this will result in the signal strength varying. It is this that causes the fading that is present on many signals.Multipath propagation can give rise to interference that can reduce the signal to noise ratio and reduce bit error rates for digital signals. One cause of a degradation of the signal quality is the multipath fading. However there are other ways in which multipath propagation can degrade the signal and affect its integrity. Using the latest signal processing techniques, a variety of methods can be used to overcome the problems with multipath propagation and the possibilities of interference.

II. THE RADAR TARGET DETECTION

Radar is the acronym of Radio Detection and Ranging. It is an electromagnetic system for the detection and location of objects. It operates by transmitting a particular type of waveform, a pulse-modulated sine wave for example, and detects the nature of the echo signal. The radar equation relates the range of radar to the characteristics of the transmitter, receiver, antenna, target, and environment. It is useful not just as a means for determining the maximum distance from the radar to the target, but it can serve both as a tool for understanding radar operation and as a basis for radar design. The simple form of the radar range equation derivation is:

If the transmitter power p_t is radiated by an isotropic, the power density at a distance (R) from the radar is equal to the radiated power divided by the surface area $4\pi R^2$ of an imaginary sphere of radius R, or :

$$\text{Power density} = \frac{P_t}{4\pi R^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

The power (P_r) returning to the receiving antenna is given by the Radar equation:

$$P_r = \frac{P_t G_t A_r \sigma F^4}{(4\pi)^2 R_t^2 R_r^2}$$

Where;

G_t = gain of the transmitting antenna

A_r = effective aperture (area) of the receiving antenna

σ = radar cross section, or scattering coefficient, of the target

F = pattern propagation factor

R_t = distance from the transmitter to the target

R_r = distance from the target to the receiver.

In the common case where the transmitter and the receiver are at the same location, ($R_t = R_r$) and the term ($R_t^2 R_r^2$) can be replaced by (R^4) , where (R) is the range. For vacuum without interference (F = 1). The propagation factor accounts for the effects of multipath and shadowing and depends on the details of the environment. In a real-world situation, pathloss effects should also be considered .This yields to:

$$p_r = \frac{PtGtAr\sigma}{(4\pi)^2 R^4} \quad \ldots\ldots\ldots\ldots\ldots (2)$$

Equation (2) shows that the received power declines as the fourth power of the range, which means that the reflected power from distant targets is very, very small. The distance to the target (range) is determined by measuring the time taken for the radar signal to travel to the target and back. The direction or angular position (azimuth), of the target may be determined from the direction of arrival of the reflected wave-front. The usual method of measuring the direction of arrival is with narrow antenna beams. If relative motion exists between target and radar, the shift in the carrier frequency of the reflected wave (Doppler Effect) is a measure of the target's relative (radial) velocity and may be used to distinguish moving targets from stationary objects. In radars which continuously track the movement of a target, a continuous indication of the rate of change of target position is also available. The name radar reflects the emphasis placed by the early experimenters on a device to detect the presence of a target and measure its range. Radar is a contraction of the words radio detection and ranging. It was first developed as a detection device to warn of the approach of hostile aircraft and for directing antiaircraft weapons. Although a well-designed modern radar can usually extract more information from the target signal than merely range, the measurement of range is still one of radar's most important functions. The most common radar waveform is a train of narrow, rectangular-shape pulses modulating a sine wave carrier.

Figure (1) shows the transmitted electromagnetic waves from the radar transmitter and the different paths of the reflected signals. These multipath reflections arrive at the receiver antenna. The main component in these signals is the line of sight signal. The other components that arrive at the receiver antenna have less amplitudes compared to the value of the line of sight signal.

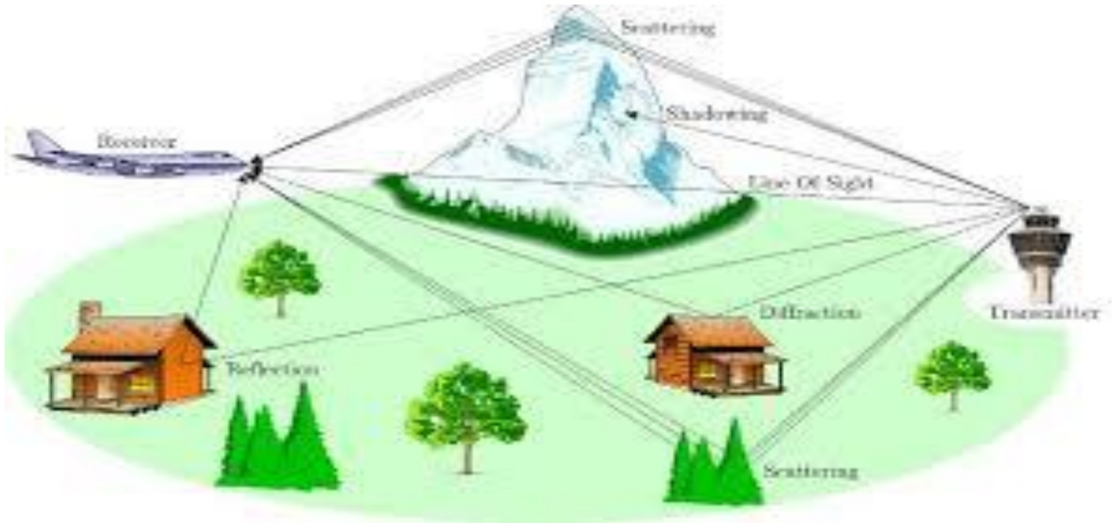


Fig. (1): Line of sight (LOS) signal and (NLOS) multipath signals

III. APPROACH

Let us say that the line of sight signal is x[n]. Now it is desired to construct a a matrix for the multipath.. Let us say that the first echo is going to be 5 seconds away, and attenuates the amplitude by 50%. The second echo is going to be 8 seconds away, and attenuates the amplitude by 70%". The third echo is going to be 11 seconds away, and attenuates the amplitude by 80%". The fourth echo is going to be 14 seconds away, and attenuates the amplitude by 90%".

Now, the matrix is going to be simply a vector, such that:

Vector = [1 0 0 0 0 0.5 0 0 0.3 0 0 0 0.2 0 0 0 0.1] ……….. (3)

The (1) in the beginning of the vector, represents the 'line of sight' co-efficient. That is, the signal without any echoes.

Now, we simply filter the signal x[n] with channel, and we get a multipath response.

The proposed approach in this paper deals with the assumed values represented in the vector of equation (3). The main objective is to pass to the receiver the line of sight component only and discard the other components in the vector .To realize capturing the line of sight component ,the following steps are to be done:

. Capture the arrived signals at the radar receiver antenna.
. Analyze the arrived signals.
. Evaluate the amplitude of each signal.
. Keep the highest component signal .
. Discard the delayed and less value signals.

A very fast processor is needed to accomplish this task. A real time processing has to be performed in order to minimize the effects of multipath echo signals.

IV. SYSTEM COMPONENTS

The system components in the design contain two parts. The first part is the hardware and the second part is the software. The details of the hardware and the software are:

A. HARDWARE:

The hardware components for the design are:

A.1) Microcontroller:

Microcontrollers are frequently used devices in embedded electronic systems in which the applications vary from computing, calculating, smart decision-making capabilities, and processing the data. A very fast microcontroller is used in this application .The microcontroller have an in build analog to digital converter(ADC) .The ADC is used to convert the analog signal into digital format.

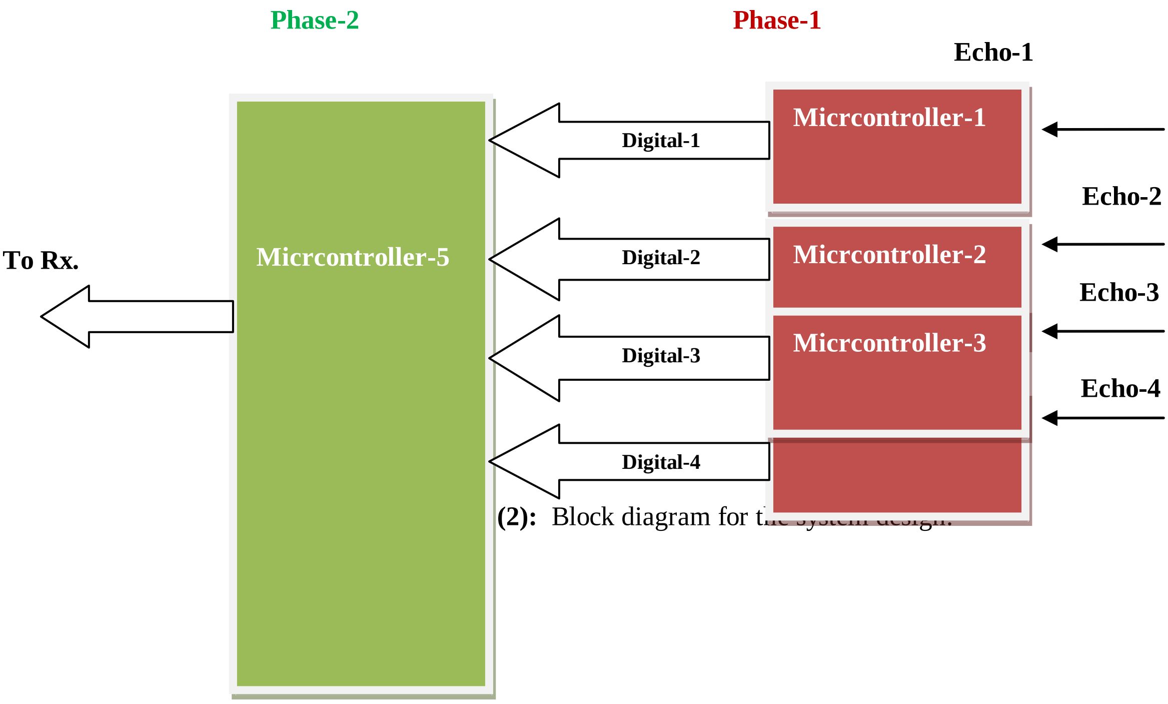
A.2) Computer:
To program the microcontroller; an IBM PC or compatible computer system is used.

A.3) Lab link cable:
The lab link cable is used to connect the computer to the microcontroller for downloading the (**.hex**) file into the microcontroller.

B. SOFTWARE:
The language used for programming the microcontrollers is Bascom language. The downloading software is the (Pony Prog) program.

V. SYSTEM DESIGN & MODEL

Figure (2) shows the block diagram for the system design. The design contains two phases for the capture and analysis of the received echoes from the target in order to pass the line of sight component to the receiver. The first phase captures the received signals (echo-1,echo-2,echo-3,echo-4) via four microcontrollers .The captured echoes are transferred into digital format and supplied to the second phase .The second phase contains a microcontroller which analyses the four digital received echoes and accordingly pass the line of sight component to the receiver. This means that the less amplitude and delayed components do not arrive at the receiver.



(2): Block diagram for the system design.

VI. ALGORITHM

The proposed algorithm includes a real time processing of the arrived signals at the radar receiver antenna .Decision making is performed by the program for minimizing the effects of the multipath echo signals arriving to the radar receiver.

Phase -1 microcontrollers execute real time processing for capturing signals and transform them into digital format. The algorithm is:

Start
Capture echo :
.. Capture the echo from the antenna.
.. Transform the analog signal into digital format.
.. Output the digital value to (port B) of the microcontroller.
.. go to capture echo.
End.

Phase -2 processes the four incoming digital values (digital-1 to digital-4) and passes the line of sight component. The algorithm is :

Start
Analyze dig-1 to dig-4 :
.. If the [(dig-1 > dig-2) & (dig-1 > dig-3) & (dig-1 > dig-4)] , then call subroutine -1.
.. If the [(dig-2 > dig-1) & (dig-2 > dig-3) & (dig-2 > dig-4)] , then call subroutine -2.
.. If the [(dig-3 > dig-1) & (dig-3 > dig-2) & (dig-3 > dig-4)] , then call subroutine -3.
.. If the [(dig-4 > dig-1) & (dig-4 > dig-2) & (dig-4 > dig-3)] , then call subroutine -4.
.. Go to Analyze dig-1 to dig-4.
End

Subroutine -1:
Start
.. Output (dig-1) signal to the receiver.
Return

Subroutine -2:
Start
.. Output (dig-2) signal to the receiver.
Return
Subroutine -3:
Start
.. Output (dig-3) signal to the receiver.
Return

Subroutine -4:
Start
.. Output (dig-4) signal to the receiver.
Return

VII. RESULTS

The result of capturing four echo signals by the antenna ends up by supplying the microcontroller-5 with four digital values (digital-1 to digital-4). Microcontroller-5 in its turn analyses the four digital values and extracts the maximum digital value. The outcome of the real time processing is to extract the line of sight signal and pass it to the receiver .Table (1) below shows the results obtained from processing by microcontroller-5.

Table (1): The results of capturing four echo signals by the antenna

Digital-1	**Digital-2**	**Digital-3**	**Digital-4**	**Output to Rxr.**
1	**0.5**	**0.3**	**0.2**	**1**
0.4	**1**	**0.3**	**0.2**	**1**
0.6	**0.4**	**1**	**0.1**	**1**
0.8	**0.5**	**0.3**	**1**	**1**

Note: One (1) in the table indicates the maximum signal reception (line of sight signal).

VIII. CONCLUSION

Multipath phenomena happen in the communications technologies all the time. The radar transmitted signal arrive the targets in line of sight direction and reflection directions. The echoes from the targets arrive at the radar receiver in many paths as well. These multipath echoes effect the radar target detection in the receiver. The best way is to capture the echo signals and process them before they get into the radar receiver. It is evident that we need a very fast processor to accomplish this task in real time. Such processing eliminates or minimizes the effects of multipath echo signals on the radar target detection.

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