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MTD Signal Processing for Surveillance Radar Application

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***Abstract*—In normal Radars, detection of moving targets proves to be very difficult, due to the presence of clutter and other unfavourable conditions. Thus, we make use of Moving Target Indicator MTI Radar, which is the most widely used radar which makes use of the principle of Delay line cancellers, to eliminate Clutter. The working of MTI Radar and its application in detecting targets and various methods of reducing noise is shown.**

Keywords: MTI radars, Noise reduction.

I. INTRODUCTION

Our paper is based on the functioning of MTI radar in order to develop MTD processing, indicating the use of Delay Line Canceller and application of Doppler frequency shift so as to eliminate occurrences of clutter and reflections from stationary objects which is an hindrance in detection of moving objects. Also, we make use of the Fast Fourier Transform (FFT) algorithm, which is used to find discrete Fourier transform, to determine the position and velocity of moving objects, thus providing a tool in the application of MTI radars. The main objective is to show the MTD process and make use of it in detection of moving targets in surveillance of a given area. The scope of the project is wide and can be used in several applications ranging from weather forecasting to military applications.

Firstly we dwell into the basics of radar. The basic principle of radar can be explained as follows:

The position of a target, its velocity and direction of movement can be determined with the help of radars.

Targets in surveillance radars can be objects that we track and objects which have to be monitored on a continuous basis. Whereas in weather radars, the target may be things like monitoring of moisture content in air, wind directions, cyclone centre etc. which determine weather at a particular place.

In a pulse Doppler radar, a sequences of pulses generated by the transmitter, is propagated towards the target and the echo signal is received and analysed using signal processing algorithms.

Other important factors to consider in the functioning of radar are:

Noise figure, $F_N = \frac{\text{noise out of practical receiver}}{\text{noise out of ideal receiver at T0}}$ (1)

$$F_N = \frac{\text{Nout}}{\text{KTBGa}} \quad (2)$$

Thus we can obtain the relation,

$$S_{min} = KT_0BF_n \frac{\text{Sout}}{\text{Nout}}_{min} \quad (3)$$

Here, k represents the Boltzmann’s constant,

T_0 represents the Temperature,

B is the Bandwidth of the signal.

Substituting in Radar Range equation,

$$R^4_{\ max} = \frac{PtGAes}{(4\pi)2KTBFn\left(\frac{S}{N}\right)min} \quad (4)$$

Here $(S/N)_{min}$ represents the minimum signal to noise ratio.

Among all the clutter, a moving target is indicated by the MTI radar, which makes use of the principle of Doppler frequency shift to determine the velocity of objects, where

$$f_d = \frac{2Vr}{\lambda}, \quad (5)$$

f_d indicating the Doppler frequency.

MTI radars make use of delay line cancellers, to eliminate reflections from stationary objects, thus eliminating clutter.

II. DIFFERENT TECHNIQUES OF TARGET DETECTION

Moving target indicator (MTI) causes degradation in the performance of pulse radar for target velocities uniformly distributed over the unambiguous range. It can be described in terms of a reduction in effective number of independent pulses integrated.

Databases such as these are used for the characterization of interference (including noise, sea clutter and land clutter, among others) in radar systems, and the development of signal processing techniques that reduce the detrimental effects of this unwanted interference. The data can also be used for the development and evaluation of signal processing techniques aimed at detecting and tracking man-made objects by separating targets from interference based on Doppler and amplitude characteristics. These signal processing techniques include moving target indication (MTI), pulse-Doppler, space-time adaptive processing, track-before- detect (TkBD), and constant false alarm rate (CFAR) processing.

The databases described in this column are specifically designed to support continued development of statistically accurate sea clutter models and radar detection and tracking schemes used in a maritime environment. Statistical models of sea clutter as well as the performance of the detection and tracking schemes are highly dependent on environmental conditions, the geometry of the radar deployment site relative to the area of interest, and the radar system operating parameters. Consequently, it is of paramount importance that the required database contains sea clutter data recorded with varying geometries, under varying environmental conditions, with a range of radar system parameters and targets of interest performing various maneuvers in this environment.

The data available in this database were recorded with the purpose of aiding in the development of a persistent ubiquitous maritime surveillance system using radar as the primary sensor. This database can be used to address several of the radar-related signals processing topics mentioned earlier, but more specifically those related to the detection and tracking of small boats in a maritime environment, including the littoral.

To develop detection and tracking techniques applicable to the maritime environment, it is essential to characterize the sea clutter and to characterize the return from objects of interest. Estimation theory can be applied, for example, to determine the amplitude statistics and Doppler characteristics of the sea clutter and to develop a process to perform these estimations in real time.

Detection theory can be applied to discern between the return from sea clutter and the return from other objects. These objects may include targets of interest, such as small boats, or objects that are not of interest (such as birds). In a non stationary environment, detectors are designed to carry out this process adaptively to obtain a CFAR. Declared detections that are deemed to be of interest (based on position, radial speed, or amplitude, for example) may be extracted from the output of the detection algorithm whereby spurious and interfering signals are discarded. Tracks are then formed on the detections of interest. This tracking involves the association of detections with existing tracks or creating new tracks with detections that cannot be associated with any existing track, smoothing/filtering of all the tracks, estimating the speed and heading of the targets, predicting the new position, and providing estimates on the errors in these predictions.

Another approach that can be evaluated on the available data is the concept of tracking a signal before it is declared as a target. In this approach, called TkBD, the sensor data originating from a tentative target are integrated over time. This integration may yield detections in cases where the amplitude return from the target at any particular time instance is such that, when compared to the sea clutter amplitude return, detections will not be obtained with more prevalent detection algorithms.

The foregoing discussion demonstrated that a large number and variety of signal processing techniques can be applied to and evaluated on the data available in our given database.

Since present day tactical radars must perform in a heavy clutter environment, many of these radars utilize a moving-target indicator or radar filter to extract moving targets from the clutter background. In MTI radars, the Doppler shift in frequency is used to discern moving targets even when the echo signal from fixed targets is orders of magnitude greater. Fixed-target echoes or clutter are included within the same radar pulse-packet as the target, but the signals from fixed targets are not shifted in frequency.

Thus, any target moving with a relative velocity larger than zero produces signals shifted in frequency by a certain predictable amount. A vital process in such systems is filtering.

The characteristic feature of the MTI radar is its delay line canceller, which, in reality, is a radar filter that extracts the Doppler frequency shift and rejects the clutter frequency. Some MTI radar filters can extract the moving target echo from a clutter echo that is 70-90 dB larger. There is a high level of interest in digital implementation of cancellers and more development in the field of pulse Doppler radars.

III. ADVANTAGES OF DIGITAL FILTER

The advantages of the digital MTI filter have already been mentioned in the discussion of multi pulse cancellers, weighting constants, and variable inter pulses. Further general comments, however, are appropriate before we complete our discussion of this feature. Feedback can be used in digital MTI filters for improvement in velocity response. Feedback ratios near unity can be used without fear of oscillations. Although the transfer function will consist of both poles and zeros in the complete frequency plane and the velocity response can be made more rectangular by this process, the response to pulse interference from other radars or jammers may be degraded. This is a system trade-off for each application.

Digital feedback is being investigated, primarily toward implementation with fewer store location requirements.

It is practical, in a digital MTI filter, to implement quadrature channels to avoid the loss in detectability due to blind phases. This requires doubling the amount of digital storage, but would not double the cost. The computation circuitry can be multiplexed if time is available, or doubled if it is not.

The digital filter approach is compatible with frequency diversity, which may be desirable for additional clutter de-correlation or for ECCM purposes. Separate store locations are necessary for each frequency. Frequency diversity, in combination with different VIP programs per frequency and multi pulse cancellers, leads to a wide variety of very interesting radar system concepts.

Some forms of radar pulse coding, such as Barker phase coders, are especially compatible with digital MTI. The DMTI can be applied to the received information first and then followed by a digital pulse compression network. This approach keeps the system dynamic range requirement at a minimum and the digital pulse compression uses the information that is already in binary form.

For radar systems that are mounted on moving platforms, it is often necessary to provide motion compensation to keep the filter response centered on the clutter spectrum as a function of antenna azimuth.

In addition, to handle weather clutter, it is sometimes desirable to change the velocity position of the rejection filter as a function of range. By proper sampling and weighting of the phase information within the digital MTI processing network, it is feasible to generate the necessary corrections with digital techniques.

The digital implementation of signal processing functions, such as filtering of fixed targets, opens the door to a wide variety of system options that were not practical in analog form. It is an important step to the adaptive radar systems of the future.

IV. PROPOSED SYSTEM

The above diagram indicates MTD process which obtains signal from an MTI radar, and further processes it using Delay Line Cancellers and FFT filter banks, thus providing an efficient method to detect moving Targets and processing of the targets.

A simple MTI radar doesn't involve processing of signals, thus failing to satisfy requirements in several applications. Hence arises the need for signal processing techniques, among which the FFT algorithm is efficient due to its advantages over other techniques.

Thus with the combination Of MTI radars and the application of FFT we obtain the MTD processor.

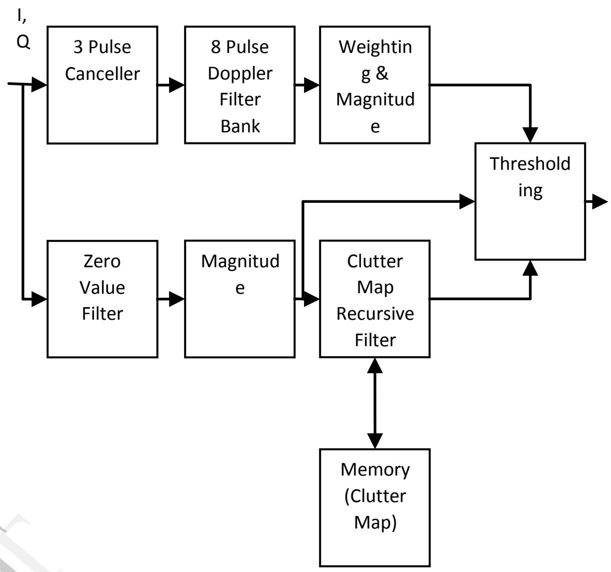

Fig.1 proposed system

V. RESULTS AND DISCUSSION

A sample MTI radar simulation is shown below which indicates the position of moving objects in the presence of a clutter environment. MATLAB provides an efficient tool in studying the nature and behavior of a MTI radar functioning.

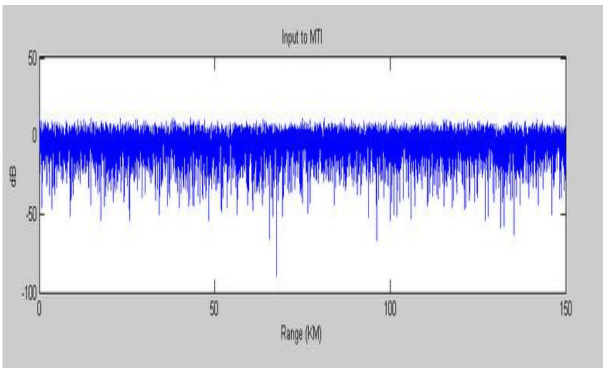

Fig.2 Input to MTI radar

There is a considerable of unwanted noise termed as clutter present in a sample of signal. So it requires an efficient digital filter to be implemented so as to reduce noise and detect the moving targets.

The input to the MTI radar that is the signals obtained back at the receiver after reflections from a particular environment is shown in the Fig.2.

As we can clearly see we cannot make out the difference between the signals obtained from moving objects and those obtained from stationary objects which comprises the clutter.

The signal thus obtained is given as input to the MTI radar which makes use of the principles of delay line cancellers so as to eliminate signals coming from stationary objects.

After undergoing noise reduction in the MTI radar the moving targets can be efficiently detected and its features can be studied.

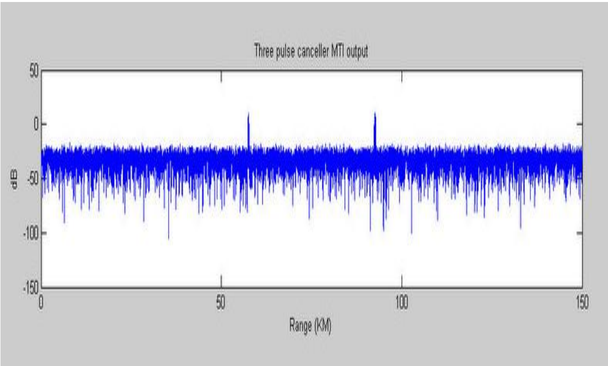

Fig.3 Output of MTI radar

The output that is obtained after signal processing in the MTI radar is shown in the Fig.3.

Clutter from the surrounding environment is efficiently reduced and the signal from moving objects is seen.

Thus we can conclude that the functioning of MTI radar has been realized and its working is studied. With the help of the given simulation we can conclude that Moving Targets are detected and its improvement factor is studied. Theoretically, the Improvement Factor of MTI radar for the considered parameters is **45 dB**. That is a noise reduction of up to 45 db can be obtained with the ideal parameters and implementation.

Through the given Simulation, we found that the practical value of improvement factor is found to be **40 dB.**

The MTI improvement factor varies with wavelength, sampling frequency, and PRF jitters as shown in the following figure. Hence there is a decrease in practical value of the improvement factor which is also demonstrated in the simulation.

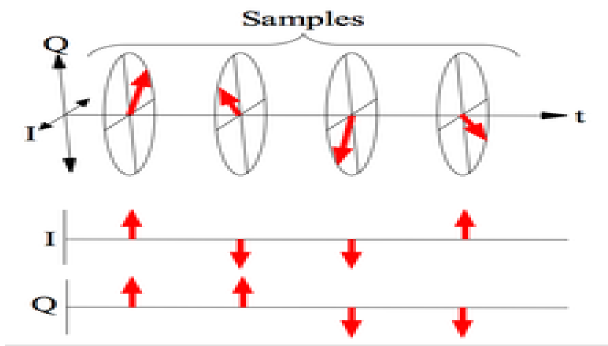

Fig.4 Variation in the improvement factor of an MTI radar

In the given fig.4 we can see how there is practical variation in the values of improvement factor.

VI. FUTURE SCOPE

We have realized the Radar A- Scope Display in our simulation.

The display can also be realized with the help of a PPI display which shows the fluctuation of moving objects, indicating the variation of Azimuth angle of the targets. A PPI display can be realized as shown.

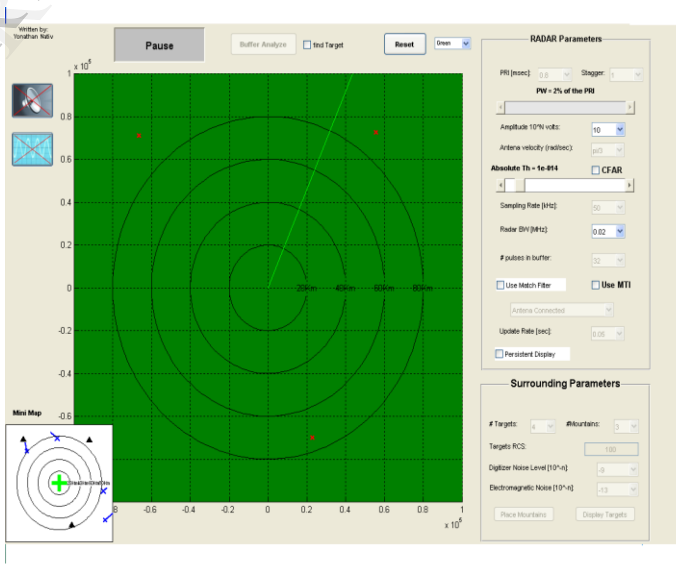

Fig.5 Plan Position Indicator Display

VII. CONCLUSION

The problem of extracting radar target information from a heavy clutter environment has been and still is a very difficult one. It remains one of the major problems of every radar systems engineer. The digital filter technique described in this paper opens the door to many system options that were not previously available in analog delay-line cancellers. These new options give a potential to greatly improved overall system performance. This potential has been demonstrated in practical radar systems. In addition to the performance advantages, the digital filter technique gives high system availability through high reliability and ease of maintenance. It is also compatible with the tactical concept of light weight, small volume, and high mobility. Further, the digital filter technique is compatible with most other signal processing techniques, which are or will be performed in digital form. This technique is a very important weapon in the battle of radar versus clutter.

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