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Detection of Signal for Radar Navigational System Using MATLAB

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***Abstract*—This paper aims to evaluate the performance of target detection in the presence of sea clutter. Radar detection of a target against a background of unwanted clutter due to echoes from sea clutter or land is a problem of interest in the radar field. Radar detector has been developed by assuming the radar clutter is Gaussian distributed. However, as technology emerges, the radar distribution is seen to deviates from the Gaussian assumption. Thus, detectors designs based on Gaussian assumption are no longer optimum for detection in non-Gaussian nature. The theory of target detection in Gaussian distributed clutter has been well established and the closed form of the detection performances can be easily obtained. However, that is not the case in non-Gaussian clutter distributions. The operation of radar detection is determined by radar detection theory with different types of Swerling target models; such as Swerling I, II, III, IV and V. By using MATLAB, these signal detection techniques are developed.**

***Keywords*—Signal Performance, Radar Navigational System, Target Detection, Evaluation, MATLAB Simulink.**

I. INTRODUCTION

The term RADAR is an abbreviation for Radio Detection and Ranging. Radar is an electromagnetic system that usually operates at microwave frequencies. It is a method of using radio waves to detect the existence of an object and its position with respect to a known point, the radar antenna. Radar rotates and transmits thousands of radio waves in a second; each these waves could reach a target and return to the radar. The target maybe localized (point target) such as ship, building or personnel or distributed such as rain and ocean [3]. Radar data provides information about how many Earth's complex systems those processes that control the movement of land, water, carbon and heat, work together to make this a livable planet.

There are many different types of radar systems that can be used for scientific exploration. Imaging radar is also called synthetic aperture radar (SAR), which means the instrument transmits pulses of microwave energy toward Earth and measures the strength and time delay of the energy that is scattered back to the antenna. The most rapid development of radar occurred during the Second World War, originally meant for target detection and early warning. As the technology emerges, radar is being used, especially in military operations, and other various applications such as navigation, mapping and speed measuring.

Fig. 1 shows the overall block diagram of the radar GUI system. The radar GUI (graphical user interface) operates the find target around the radar, set the GUI data and generate random targets, found target control function, radar control and radar display. The radar analyses each range cell in buffer in search of a target and estimates the relative velocity between the target and the radar. Afterwards, the result can be displayed on CRT/LCD devices.

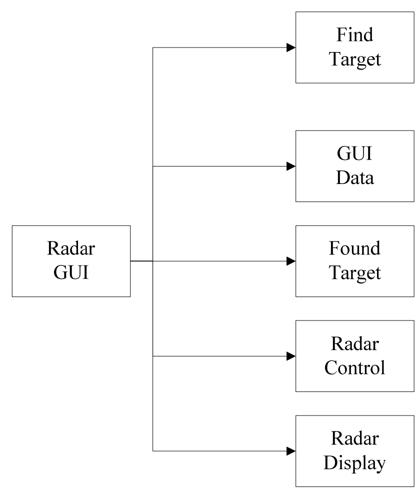

Fig. 1 Block diagram of a radar GUI system

Radar detection of a target against a background of unwanted clutter due to echoes from sea clutter or land is a problem of interest in the radar fields [9]. The understanding and modelling of radar clutter is the central in many aspect of radar system design and performance evaluation. The theory of radar detection in clutter is well established for the case, which the clutter is a complex Gaussian process. The optimum detection can be simply implemented in all instances of practical interest, let be it coherent or non-coherent detection. Detection is the most fundamental function of a radar system. After emitting the electromagnetic waveform, the radar receives the reflected signal. To detect the target, it is necessary to distinguish the signal reflected from the target, from the signal containing only noise. After detecting the target, it can be further calculated the range.

II. Radar Navigational System

Radar determines distance to an object by measuring the time required for a radio signal to travel from a transmitter to an object and return. Since most radars use directional antennae, they can also determine to an object's bearing. However, radar's bearing measurement will be less accurate than its distance measurement. Understanding this concept is crucial to ensuring the optimal employment of the radar for safe navigation.

In most marine navigation applications, the radar signal is pulse modulated. Signals are generated by a timing circuit so that energy leaves the antenna in very short pulses. When transmitting, the antenna is connected to the transmitter but not the receiver. As soon as the pulse leaves, an electronic switch disconnects the antenna from the transmitter and connects it to the receiver. Another pulse is not transmitted until after the preceding one has had time to travel to the most distant target within range and return. Since the interval between pulses is long compared with the length of a pulse, strong signals can be provided with low average power. The duration or length of a single pulse is called pulse length, pulse duration, or pulse width. This pulse emission sequence repeats a great many times, perhaps 1,000 per second. This rate defines the pulse repetition rate (PRR). The returned pulses are displayed on an indicator screen.

III. Signal Performance Evaluation

Radar systems often utilize a finite number of pulse widths (waveforms) to accomplish all designated modes of operations. Some of these waveforms are used for search and detection; others may be used for tracking, while a limited number of wideband waveforms may be used for discrimination purposes. During the search mode of operation, for example, detection of a certain target with a specific RCS value is established based on a pre–determined probability of detection P_D. The probability of detection, P_D, is used to calculate the required detection SNR.

Often, it may be the case that none of the available radar waveforms may be able to guarantee the minimum required SNR for a particular RCS value at a particular detection range. In this case, the radar has to wait until the target is close enough in range to establish detection; otherwise pulse integration (coherent or non-coherent) can be used. Alternatively, cumulative probability of detection can be used [3].

A. Detection in the Presence of Noise

The simplest detection problem is to decide the presence of a signal. For example, in radar detection problem, the radar return is observed and a decision has to be made whether a target was presence or not.

Detection of a radar signal is based on establishing a threshold at the output of the receiver. If the receiver output is large enough to exceed the threshold, a target is said to be present. If the condition is noise free and there is no distortion, then it can be simply determined the presence of the object by observing the peak in the received signal. However, in real life, noise free condition is impossible. Thus, in the presence of noise or interference, the peaks of the received waveform might produce erroneous peaks, which might leads to incorrect conclusion. Fig. 2 illustrates the situation.

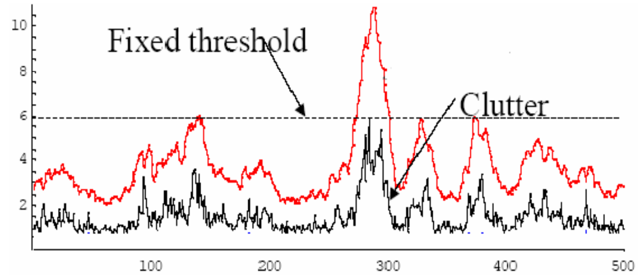

Fig. 2 Illustration of radar returns [5]

The input signal to the receiver is composed of the radar echo signal s (t) and additive zero means white Gaussian noise n(t), with variance φ^2. The input noise is assumed to be spatially incoherent and uncorrelated with the signal.

A target is detected when r (t) exceeds the threshold value V_T, where the decision hypotheses are

$s(t) + n(t) > V_T$ Detection

$n(t) > V_T$ False alarm

The case when the noise subtracts from the signal (while a target is present) to make r(t) smaller than the threshold is called a miss.

B. Probability of False Alarm

The probability of false alarm P_{fa} is defined as the probability that a sample R of the signal r(t) will exceed the threshold voltage V_T when noise alone is present in the radar,

$$P_{fa} = \int_{V_T}^{\infty} \frac{r}{\Psi^2} \exp\left(-\frac{r^2}{2\Psi^2}\right) dr = \exp\left(-\frac{V_T^2}{2\Psi^2}\right) \quad (1)$$

$$V_T = \sqrt{2\Psi^2 \ln\left(\frac{1}{P_{fa}}\right)} \quad (2)$$

C. Probability of Detection

The probability of detection P_D is the probability that a sample R of the signal r(t) will exceed the threshold voltage in the case of noise plus signal.

$$P_D = \int_{V_T}^{\infty} \frac{r}{\Psi^2} I_0\left(\frac{rA}{\Psi^2}\right) \exp\left(-\frac{r^2+A^2}{2\Psi^2}\right) dr \quad (3)$$

D. Pulse Integration

When a target is located within the radar beam during a single scan it may reflect several pulses. By adding the returns from all pulses returned by a given target during a single scan, the radar sensitivity (SNR) can be increased. The number of returned pulses depends on the antenna scan rate and the radar PRF.

The process of adding radar returns from many pulses is called radar pulse integration. Pulse integration can be performed on the quadrature components prior to the envelope detector. This is called coherent integration or pre-detection integration. Coherent integration preserves the phase relationship between the received pulses. Thus a build up in the signal amplitude is achieved. Alternatively, pulse integration performed after the envelope detector (where the phase relation is destroyed) is called non-coherent or post-detection integration.

A comprehensive analysis of pulse integration should take into account issues such as the probability of detection P_D, probability of false alarm P_{fa}, the target statistical fluctuation model, and the noise or interference statistical models.

E. Coherent Integration

In coherent integration, when a perfect integrator is used (100%efficiency), to integrate pulses the SNR is improved by the same factor. Otherwise, integration loss occurs, which is always the case for non-coherent integration. Coherent integration loss occurs when the integration process is not optimum. This could be due to target fluctuation, instability in the radar local oscillator, or propagation path changes.

F. Non-Coherent Integration

Non-coherent integration is often implemented after the envelope detector, also known as the quadratic detector. Non-coherent integration is less efficient than coherent integration. Actually, the non-coherent integration gain is always smaller than the number of non-coherently integrated pulses. This loss in integration is referred to as post detection or square law detector loss [2].

G. Clutter

The EM waves reflected from the objects around the target are referred to as clutter. These returns may be from the surface surrounding the target (ground), or from the volume of space around it (rainfall).

Clutter is thus defined as the undesired return from a physical object or a group of objects. Clutter may be divided into sources distributed over a surface (land or sea), within a volume (weather or chaff), or concentrated at discrete points (structures, birds, or vehicles). The magnitude of the signal reflected from the surface is a function of the material, roughness, and angle. Two main scattering types of clutter are diffuse and specular. Rain and dust are the two main contributors of volume backscatters. In addition to detecting the target range, radar is also used extensively to detect the speed of a target. The detection of target speed is primarily based on the detection of Doppler frequency [1].

IV. Radar Target Models

So far the probability of detection calculations assumed a constant target cross section (non-fluctuation target). This work was first analysed by Marcum1. Swerling 2 extended Marcum's work to four distinct cases that account for variations in the target cross section. These cases have come to be known as Swerling models. They are: Swerling I, Swerling II, Swerling III, and Swerling IV. The constant RCS case analysed by Marcum is widely known as Swerling 0 or equivalently Swerling V. Target fluctuation lowers the probability of detection, or equivalently reduces the SNR. Swerling I targets have constant amplitude over one antenna scan; however, a Swerling I target amplitude varies independently from scan to scan according to a Chi-square probability density function with two degrees of function with two degrees of freedom. The amplitude of Swerling II targets fluctuates independently from pulse to pulse according to a Chi-square probability density function with two degrees of freedom. Target fluctuation associated with a Swerling III model is similar to Swerling I, except in this case the target power fluctuates independently from pulse to pulse according to a Chi-square probability density function with four degrees of freedom. Finally, the fluctuation of Swerling IV targets is from pulse to pulse according to a Chi-square probability density function with four degrees of freedom.

Swerling showed that the statistics associated with Swerling I and II models apply to targets consisting if many small scatterers of comparable RCS values, while the statistics associated with Swerling III and IV models apply to targets consisting of one large RCS scatterer and many small equal RCS scatterers. Non-coherent integration can be applied to all four Swerling models; however, coherent integration cannot be used when the target fluctuation is either Swerling II or Swerling IV. This is because the target amplitude de-correlates from pulse to pulse (fast fluctuation) for Swerling II and IV models, and thus phase coherency cannot be maintained [2].

V. Experimental Results

In the radar simulation process, the targets around the radar are scanned and then computed the expected return pulses and add noise. The radar operates at the intermediate frequency (IF) level and perfect phase reconstructions are produced random targets such as coordinates, velocity, acceleration and Radar Cross Section (RCS) by the simulation experiments.

For each radar pulse the radar simulation calculates the returns that the radar will receive from all the radar formula (taking into account transmission power, antenna gain, targets distance & target RCS). The radar simulation also calculates the amplitude & phase of the return signal (according to the IF frequency).The radar builds a vector of its samples as complex signals (representing amplitude and phase delay) and adds it to complex random RF noise. The vector goes through a LPF representing the receiver BW and then adds it to complex random noise representing the radar's thermal noise (in the digitizer).

The radar saves several reception periods to a buffer and then processes the entire buffer. The radar can perform a match filter over the received signal. The radar analyses each statics (a sort of Constant False Alarm Rate (CFAR)). In the Moving Target Indicator (MTI) is used the target detection is done in the frequency plane of the complex signal.

Each detected target is plotted on the main radar display. In case the MTI is used as the representation of the targets velocity is also plotted (stationery targets are plotted as mountains). The radar can only estimate the relative velocity between the target and the radar.

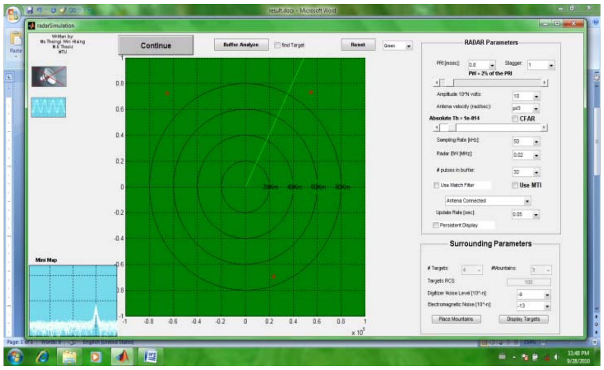

Fig. 3 The radar simulation GUI after transmission

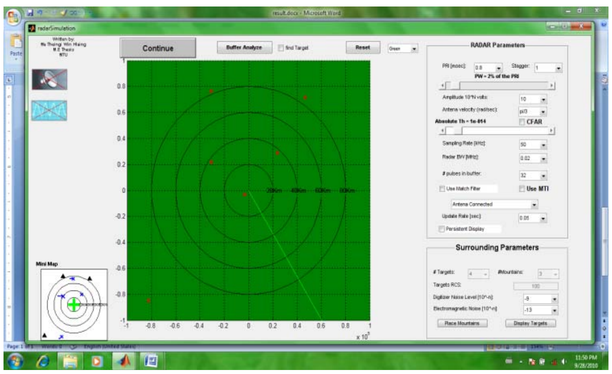

Fig. 4 The radar simulation GUI target tracking

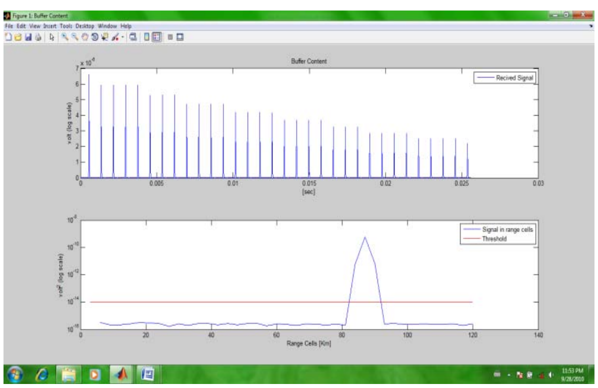

Fig. 5 The radar simulation GUI buffer containing received signal and signal in range cells compared with threshold

Fig. 3 describes the radar simulation GUI after transmission. The Mini Map shows the transmitted and reflected waveform. In Fig. 4, the Mini Map displays the real position of the targets and radar display screen shows the targets while tracking.

Fig. 5 shows the radar simulation GUI buffer containing received signal and signal in range cells compared with threshold (in this figure, radar detects a target between 80 km and 100 km).

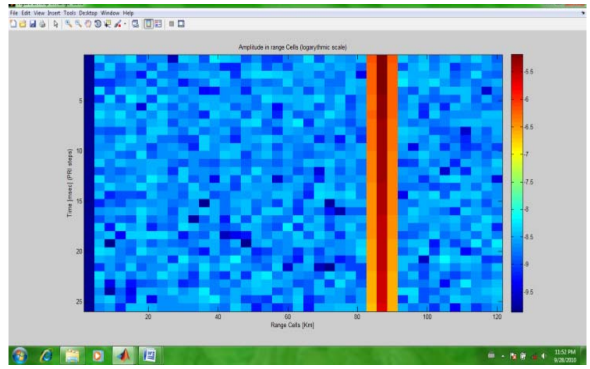

Fig. 6 The radar simulation GUI with amplitude in range cells

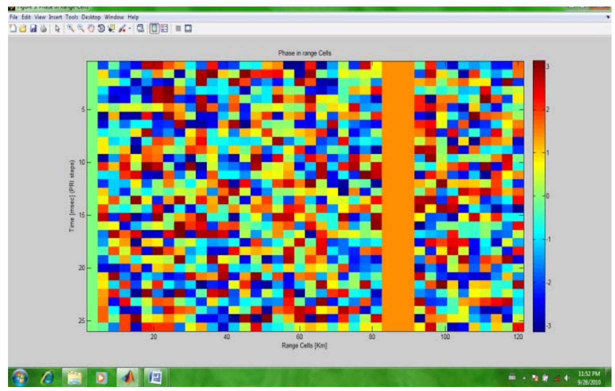

Fig. 7 The radar simulation GUI with phase in range cells

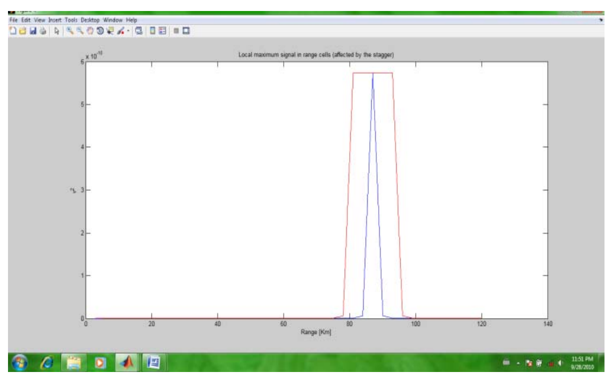

Fig. 8 The radar simulation GUI with local maximum signal in range cells affected by the stagger

VI. Conclusion

Better detection performance (especially on the detection of small target) can be achieved if the real sea clutter is known. Performance degradation can be resulted if the clutter model is not matched the real clutter distribution. The Earth's atmosphere plays a central role in radar operations as it is the medium of propagation for the radio waveforms. The Doppler Effect also plays a vital role in practical radar systems. Properties of the radar, the target and the environment all contribute to determine the maximum range at which the radar can detect a target. Radar has numerous applications. Understanding the physical and theoretical underpinnings of radar systems is essential to understand radar system themselves.

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REFERENCES

[1] Bu Chin Wan, Digital Signal Processing Techniques and Applications in Radar Image Processing. A John Wiley & Sons, Inc., Publication, 2008.

[2] Mahafza, B.R. 2004. Matlab Simulations for Radar Systems Design. New York: Chapman & Hall/CRC CRC Press LLC.

[3] Van Trees, H. L., Optimum Array Processing, Part IV of Detection, Estimation, and Modeling Theory, Wiley & Sons, Inc., New York, 2002.

[4] S. Hara and R. Prasad, Multicarrier Techniques for 4G Mobile communications. Artech House, Inc., 2001.

[5] Skolink, M. I. Introduction to Radar Systems. McGraw-Hill. International Edition., 2001

[6] Durham, J.T and Younan, N. H. Neyman Pearson Detector Design for Steady Point Targets with Known Phase Detection. IEEE. 1998.

[7] Kay, S.M. Fundamentals of Stastical Siganl Processing – Detection Theory. Prentice Hall. Vol. 2.1998.

[8] Leszek, J. Bayesian State Modelling of Spatio-Temporal Non-Gaussian Radar Return. Corpus Christi College. December 1998.

[9] Peebles, Jr., P. Z., Radar Principles, John Wiley & Sons, New York, 1998.

[10] Stutzman, G. E., Estimating Directivity and Gain of Antennas, IEEE Antennas and Propagation Magazine 40, August 1998, pp 7-11.

[11] Srinath, M. D., Rajasekaran, P.K. and Viswanathan, R. Introduction to Statistical Signal Processing with Applications. Prentice Hall. 1996.

[12] Scheer, J. A. and Kurtz, J. L., Editors, Coherent Radar Performance Estimation, Artech House, Norwood, MA, 1993.

[13] Conte, E., Longo, M., Lops, M. and Ullo, S. L. Radar Detection of Signals with Unknown Parameters in K-Distributed Clutter. IEE Proceedings-F. Vol.138. No. 2. April 1991.

[14] Skillman, W. A., DETPROB: Probability of Detection Calculation Software and User.s Manual, Artech House, Norwood, MA, 1991.

[15] Skolnik, M. I., Editor, Radar Handbook, 2nd edition, McGraw-Hill, New York, 1990.