RADAR PERFORMANCE ANALYSIS IN THE PRESENCE OF SEA CLUTTER

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Dedicated to my beloved parents
(Hj Abdul Aziz Hj Hassan, Hjh Shaharom Sharin,
Hj Mansor Abdul Rahman & Hjh Maliha Ghazali)
to my loving husband, Muhammad Muslim Mansor
and to my adorable son, Muhammad Luqman Al-Hakim

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ABSTRACT

Radar has been used for decades for surveillance purposes, originally meant for target detection and early warning. During the early days, radar detector has been developed by assuming the radar clutter is Gaussian distributed. However, as modern technology emerges, the radar distribution is seen to deviates from the Gaussian assumption. Thus, detectors designed based on Gaussian assumption are no longer optimum for detection in non-Gaussian nature. Lots of researches have been carried out for optimum target detection in non-Gaussian clutter distributions. Neyman-Pearson detector is proven to be the best detector for radar detection due to the unknown cost and prior probabilities. 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. Thus, this thesis aims to serve as a basis in understanding performance analysis of target detection in the presence of sea clutter. In the thesis, the performance model in terms of ROC plots of probability of detection against signal to noise ratio for different sea clutter distributions are obtained and analyzed.

ABSTRAK

Sejak beberapa dekad yang lampau, radar telah digunakan untuk tujuan pengawasan terutama dalam mengesan sasaran dan memberikan amaran awal. Kalau dahulunya, taburan Gaussian telah dipilih sebagai asas / model pengesan radar. Tetapi seiring dengan perkembangan teknologi, taburan lain yang bukan berasaskan Gaussian didapati lebih memenuhi ciri-ciri pengesanan bagi sesetengah situasi. Contohnya pengesan Neyman-Pearson dibuktikan lebih optimum bagi mengesan sasaran dengan kebarangkalian awal yang tidak diketahui. Selain itu, penyelesaian bagi bentuk tertutup untuk taburan bukan Gaussian lebih sukar didapati berbanding dengan taburan Gaussian. Maka, kajian ini disediakan sebagai asas dalam menganalisa prestasi radar yang digunakan untuk mengesan sasaran di laut. Kajian ini menumpukan objektif menghasilkan plot ROC untuk kebarangkalian pengesanan dibandingkan dengan SNR bagi setiap taburan dan setiap plot ini dianalisa untuk kesesuaian penggunaan dalam pengesanan sasaran di laut.

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LIST OF SYMBOLS

α	-	Size of decisive rule
β	-	Power of decisive rule
λ	-	Lagrange multiplier
η^2	-	Peak Signal-to-Noise Ratio
$\Gamma(.)$	-	Gamma function
K_v	-	v^{th} order of modified Bessel function of second kind
$\theta_1(t)$	-	Phase modulation
ω_c	-	Carrier frequency
$\tilde{b}$	-	Reflection gain
ω_d	-	Doppler shift
$\tilde{g}_i(t)$	-	Basis function
γ	-	Threshold
$\Lambda(.)$	-	Likelihood ratio
$I_0(.)$	-	Modified Bessel function of first kind of order zero
σ^2	-	Variance
μ	-	Mean
$\Phi(\rho)$	-	Characteristic function

LIST OF ABBREVIATIONS

APDF	-	Amplitude Probability Density Function
CF	-	Characteristic Function
D_i	-	Decision
E_r	-	Received energy
E_T	-	Transmitted energy
H_i	-	Hypothesis outcome
H_0	-	Null hypothesis
H_1	-	Alternative hypothesis
LRT	-	Likelihood Ratio Test
MGF	-	Moment Generating Function
P_D	-	Probability of Detection
P_F	-	Probability of False Alarm
P_M	-	Probability of Miss Target
R_0	-	Decision region correspond to H_0
R_1	-	Decision region correspond to H_1
RADAR	-	RAdio Detection And Ranging
ROC	-	Receiver Operating Characteristic
SF	-	Survival Function
SNR	-	Signal to Noise Ratio

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

This thesis aims to serve as a basis in performance analysis of target detection in the presence of sea clutter. It is explained in such simple manner so that any of the interested audience for this document can understand it fully. This chapter discussed in brief the fundamentals of radar system, the research objective, the scope, the problem statement and the methodology used through out the period of research.

1.1 FUNDAMENTALS OF RADAR SYSTEM

The term RADAR is an acronym 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 one 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. Figure 1.1 illustrates the basic principle of radar [1].

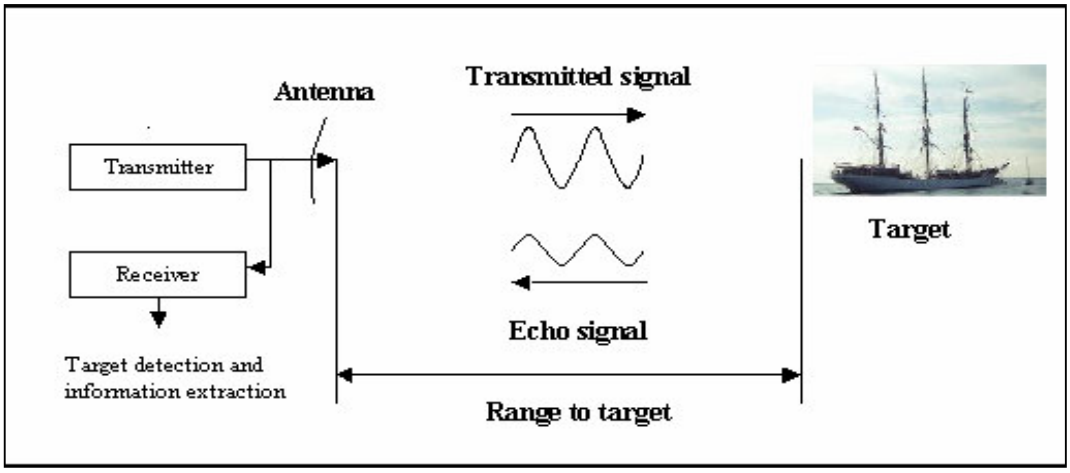

Figure 1.1: Basic principle of radar

The concept of radar dates back to 1886, when Hertz discovered the metallic and dielectric objects reflect radio waves [2]. 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 in other various applications such as navigation, mapping and speed measuring.

1.2 RESEARCH OBJECTIVE

As the title suggest, the main objective of this research is to theoretically measure the performance of radar system with the ocean as the physical environment of interest.

In radar, the detection of a target depends on two probabilities; the probability of radar will detect a specified target at a particular range (Probability of Detection, P_D) and probability of radar making a false detection when actually no target echo is present (Probability of False Alarm, P_F). The performance of radar is best analyzed through a parametric plot of P_D versus Signal to Noise Ratio (SNR), with P_F as the parameter called the Receiver Operating Characteristic (ROC).

In analyzing the radar performance in the presence of sea clutter, these two objectives should meet:

i. To analyze the effect of low SNR

ii. To analyze the effect of different clutter distributions

1.3 RESEARCH SCOPE

As mentioned in the research objective, this research aims to measure the theoretical performance of radar concentrating in two main factors of radar performance, the SNR and clutter distribution. The list of other factors that can affect radar performance is given in Appendix A. Although radar performance is usually measured based on its ability to detect and estimate the location of objects accurately, it is important to note that this research only focus on the detection part of radar.

Since this research aims to obtain the theoretical measure of radar performance, there will be no hardware and software components involved except some aid of MATLAB programming. It is assumed in this research that all radar equipments (hardware and software) are designed and working ideally and are set to the maximum performance. It is also assumed that no internal noise is present.

1.4 RESEARCH PROBLEM

Radar operating in maritime application has serious limitation imposed in their performance by unwanted sea echoes. The main motivation to come out with this research is due to the practical problem faced by our surveillance radar (at Tanjung Piai) on difficulties to detect small objects (small boats). This problem inspired me to go into details on radar performance in the presence of sea clutter.

During early stage of radar development, the clutter echoes were considered as Gaussian distributed. However, with the development of modern radar system where radar is operating at low grazing angle with high-resolution capacities, the statistic of sea clutter is observed to deviates from the normality. The disturbance of sea clutter is spikier than the Gaussian distribution and forces the radar target detector to process them as targets, which is not. Thus, cause the false alarm to increase.

The unknown prior probabilities, distribution and presence of sea clutter make detecting a target difficult in radar detection. Small objects have low Signal to Noise Ratio (SNR). In Receiver Operating Characteristic (ROC) of Likelihood Ratio Test (LRT), the lower the SNR, the smaller the separation between the two hypotheses (presence or absence of a target), and hence, Probability of Detection (P_D) for a fixed Probability of False Alarm (P_F) will be smaller, which indicates the correct detection for small objects is harder to be achieved.

1.5 RESEARCH METHODOLOGY AND PLAN

This research is being carried out in two semesters. The first semester is to get familiar and to obtain as much information about the research topic via literature review. During the second semester, the implementation of the research is done. The fundamental interest of this research is to come out with parametric plot of P_D versus SNR (ROC) of small target detection in Gaussian and non-Gaussian clutter distribution for optimum detection in maritime radar application. These plots will then be used for analysis of the radar performance.

Listed below is the chronological methodology on how this research being carried out:

1. Learn the fundamentals of radar system
2. Technology review
3. Literature review on research area
4. Evaluate ROC under Gaussian distribution (coherent)
5. Evaluate ROC under Gaussian distribution (non-coherent)
6. Evaluate ROC under non-Gaussian distributions (Rayleigh and K)
7. Study the effect of small target size
8. Analyze the radar performance under different clutter distributions
9. Draw conclusion based on findings
10. Thesis writing

Table 1.1: First Semester Research Plan

Tasks	**June**				**July**				**August**				**September**			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Choose topic	/															
Topic review	/	/														
Discussion with supervisor		/	/	/		/			/		/					
Research proposal submission				/												
Literature on radar				/	/	/										
Literature on research area				/	/	/	/	/	/	/						
Theoretical foundation					/	/	/	/	/	/	/	/				
Research proposal report writing				/	/	/	/	/	/	/	/	/	/	/		
Research proposal report submission														/		
Research proposal presentation															/	

Table 1.2: Second Semester Research Plan

Tasks	December				January				February				March			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Calculation of ROC (Gaussian distribution)	/	/														
Calculation of ROC (Rayleigh distribution)			/	/												
Calculation of ROC (K distribution)					/	/										
Study on effect of low SNR							/	/								
Analysis on effect of different clutter distribution									/	/						
Draw conclusion											/	/				
Thesis presentation														/		
Thesis writing	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	
Thesis draft submission															/	
Thesis submission																/

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