UNIVERSITI PUTRA MALAYSIA

GROUND TARGET DETECTION IN FORWARD SCATTERING RADAR USING HILBERT TRANSFORM AND WAVELET TECHNIQUES

MOHAMED KHALAF ALLA.H.M.H

Ground Target Detection in Forward Scattering Radar Using Hilbert Transform and Wavelet Techniques

By

MOHAMED KHALAF ALLA.H.M.H

Thesis Submitted to the School of Graduate Studies, University Putra Malaysia, in Fulfillment of the Requirement for the Degree of Master of Science

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DEDICATION

This thesis is dedicated to

ALL WHOM I LOVE

Specially

MY BELOVED PARENTS

Abstract of thesis presented to the Senate of University Putra Malaysia in fulfillment of the requirement for the degree of Master of Science

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April 2009

Chairman: **Raja Syamsul Azmir Bin Raja Abdullah, PhD**

Faculty: **Engineering**

This thesis analyzed the electromagnetic signal scattered from the target crossing the Forward Scattering Radar system baseline. The aim of the analysis was to extract the Doppler signal of the target, under the influence of high ground clutter and noise interference. The scattered Doppler signal was processed by the proposed signal processing techniques to predict the existence of a target for the automatic target detection (ATD) in the FSR system. This thesis is dedicated to the detection of ground target, and for this purpose, a typical car was used as target. Two signal processing techniques, namely Hilbert Transform and Wavelet Technique, were used for target detection. The results gathered in this study showed that the detection using Hilbert Transform was only applicable for some conditions and it was used to confirm the wavelet efficiency in the detection process. Similarly, it was also found that the detection using Wavelet Technique became more robust to higher clutter and noise level. At the worst condition of the scenario, the successful detection rate is more than 75%. This good result suggest that the transmit signal can be as low as possible and open a new horizons for FSR to be applied in real applications for example in Radar Sensor Network and Microwave Fence .Two sets of field experimentations were carried out, and the target's signal under the influence of the high clutter was successfully detected using the proposed method. Finally, an algorithm for an automatic detection of the ground target detection in FSR is proposed.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master of Sains

PENGESANAN SASARAN DARAT DALAM 'FSR' MENGGUNAKAN TRANSFORMASI 'HILBERT' DAN TEKNIK 'WAVELET'

Oleh

MOHAMED KHALAF ALLA HASSAN MOHAMED

April 2009

Chairman: Raja Syamsul Azmir Bin Raja Abdullah, PhD

Faculty: Kejuruteraan

Tesis ini menganalisis isyarat elektromagnet yang diserakkan daripada sasaran kepada tapak sistem FSR. Analisis ini bertujuan untuk penyarian isyarat ‘Doppler’ di bawah pengaruh sepahan tanah yang tinggi dan gangguan hingar. Isyarat ‘Doppler’ yang terhasil di proses untuk meramal kewujudan sasaran bagi pengesanan sasaran automatik dalam sistem FSR. Tesis ini bertujuan untuk mengesan sasaran di tanah dimana kenderaan tipikal telah digunakan sebagai sasaran. Dua jenis pemproses isyarat iaitu ‘Hilbert Transform’ dan ‘Wavelet Technique’ digunakan sebagai pengesan sasaran. Keputusan yang diperolehi menunjukkan pengesanan menggunakan ‘Hilbert Transform’ hanya boleh digunakan untuk beberapa keadaan dan ini megesahkan kecekapan ‘wavelet’ dalam pengesanan sasaran. Tambahan lagi, pengesanan menggunakan ‘Wavelet Technique’ menjadi lebih kuat kepada sepahan tanah yang tinggi dan hingar. Dua set eksperimen dijalankan dan isyarat sasaran di bawah pengaruh sepahan yang tinggi telah berjaya

dikesan oleh pengesan yang dicadangkan. Akhir sekali algoritma untuk pengesanan sasaran secara automatik telah diperkenalkan.

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Finally, my warm thanks go all of my friends, especially Ahmed, Mutaz, Ashraf, Khalid, Omar and all those whom I've shared beautiful memories with.

APPROVAL

I certify that an Examination Committee has met on 3 April 2009 to conduct the final examination of Mohamed Khalaf Alla Hassan Mohamed on his Master of Science thesis entitled, "Ground Target Detection In Forward Scattering Radar Using Hilbert Transform and Wavelet Technique," in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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This thesis submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Master of Science.
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Date: 8 June 2009

DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

MOHAMED KHALAF ALLA.H.M.H

Date:

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LIST OF ABBREVIATIONS/ SYMBOLS

RADAR	Radio Detection and Ranging
EM	Electromagnatic
FSR	Forward Scattering Radar
RCS	Radar cross Section
RAM	Radio Absorbing Material
CW	Continues Wave
OTH	Over The Horizon
ATD	Automatic Target Detection
FS	Forward Scattering
SNR	Signal to Noise Ratio
MIT	Moving Target Indication
KNN	K-Nearest Neighbours
PCA	Principle Components Analysis
FFT	Fast Fourier Transform
DFT	Discrete Fourier Transform
AD	Amplitude Detector
NF	Notch Filter
LPF	Low Pass Filter
ADC	Analogue to Digital Converter
STFT	Short Time Fourier Transform
CWT	Continues Wavelet Transform

DWT	Discrete Wavelet Transform
GPR	Ground Penetrating Radar
MRA	Multi Resolution Analysis
SISAR	Shadow Inverse Synthetic Aperture Radar
FSCS	Forward Scattering Cross Section
EM	Electromagnetic Field
IDWT	Inverse Discrete Wavelet Transform
ISM	Industrial Scientific Medical
LNA	Low Noise Amplifier
HPBW	Half Power Beam width

LIST OF SYMBOLS

β	Bistatic Angle
E_{sum}	Total Electrical field
E_s	Self Scattering Fields
E_{sh}	Shadow Field
P_T	Transmitted Power
G_T	Transmitter Gain
G_R	Receiver Gain
λ	Wavelength
σ_B	Target's Bistatic RCS
F_T	Constants defined by Willis
F_R	Constants defined by Willis
K_b	Boltzman's constant
T_o	Reference temperature (290K)
F	Noise figure
R_T	Transmitter to Target Distance
R_R	Receiver to Target Distance
d	Distance
L_T	Transmitter Loss
L_R	Receiver Loss
σ_F	Forward scattering RCS
α_v	Receiver Vertical Diffraction Angle of the Target under Observation

α_h	Receiver horizontal Diffraction Angle of the Target under Observation
A	Area of the Aperture
σ_M	Monostatic RCS
v	Velocity Vector
f_{dbr}	Doppler Frequency
δ	Angle between Target Trajectory and Speed Vector
z_a	Receiver to imaginary line of Target Trajectory
z_b	Transmitter to imaginary line of Target Trajectory
ψ	Angle between imaginary line of Target Trajectory and Transmitter Receiver Distance
α_T	Diffraction Angle with respect to Transmitter
α_R	Diffraction Angle with respect to Receiver
$Z(\mathrm{t})$	Analytical signal
$\theta(t)$	The phase
$x(t)$	Input Signal
$\psi\ (t)$	Wavelet Function
$\psi_{a,b}(t)$	Wavelet Function with Scale *(a)* and Translation *(b)*
a	Scale
b	Translation
j	Level of Decomposition
$\psi_{2^j}(t)$	Dyadic wavelet
f_c,	Centre Frequency
d	Transmitter Receiver Separation Distance
E	Electrical Field

ϕ	Magnetic Field
E_r	Electrical Field in r direction (cylindrical coordinates)
E_θ	Electrical Field in θ direction (cylindrical coordinates)
E_y	Electrical Field in y direction (cylindrical coordinates)
l	Length of the Target
h	High of the Target
c	Speed of Light
θ	Transmitter Horizontal Diffraction Angle
f_{Tgt}	Target Frequency
f_{dbr}	Doppler Frequency
f_{dma}	Maximum Doppler Frequency
$\hbar_{k,0}$	Scaling Filter (low pass)
$\hbar_{k,1}$	Wavelet Filter (high pass)
$g_{L,0}$	Reconstruction Filter (Low Pass)
$g_{k,1}$	Reconstruction Filter (high Pass)
A_j	Approximation at Level j
D_J	Detail at Level j

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

The word RADAR is an acronym for ***R**adio* ***D**etection* and ***R**anging*. The radar systems and radar stations are intended for detecting various objects in space and establishing their current position, as well as determining velocities and trajectories for moving objects [1].

From the basic point of view, this is achieved by transmitting an electromagnetic (EM) wave from the transmitting antenna. If the target is present within the radar coverage area, the wave will be reflected back to the receiving antenna, and all the information collected at the receiver will then be analysed to determine the above parameters [2].

There are different types of radar systems, based on the transmitter-receiver topology shown in Figure 1.1 in the monostatic radar, the transmitter and the receiver are spatially combined. On the other hand, the multistatic radar designates a single radar with one transmitter and several spatially distributed receiving stations with joint processing of received information. Multisite radar is radar which has several specially separated transmitting-receiving facilities in such a way information gathered from each target (from all sensors) can be fused and jointly processed. Bistatic radar consists of a single transmitter and single receiver which are separated specially by a distance, which is comparable to that of the maximum range of target [3].