



**UNIVERSITI PUTRA MALAYSIA**

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

**MOHAMED KHALAF ALLA.H.M.H**

**FK 2009 60**



**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**

**April, 2009**



# 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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**MOHAMED KHALA ALLA.H.M.H**

**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 sephan 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 sephan tanah yang tinggi dan hingar. Dua set eksperimen dijalankan dan isyarat sasaran di bawah pengaruh sephan yang tinggi telah berjaya

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

## ACKNOWLEDGEMENTS

This work would have not been accomplished without the help of so many people.

Here, a brief account of some of the people who deserve my thanks:

First, I would like to thank **Dr. Raja Syamsul Azmir Bin Raja Abdullah** for the help, inspiration, guidance, motivation and support he gave to me throughout my studies and for taking the burden of supervising me in this research.

Secondly, I would like to thank Dr. Mohamed Fadle for his help and advice.

My deepest gratitude and appreciation goes to Dr. Abubakar Mustafa Mohamed, the chairman of Computer Man College, Sudan, for sponsoring me throughout my study period.

My sincere gratitude also goes to all of my family members, especially to my father KHALAF ALLA HASSAN, my mother AMNA AHMED ALI, as well as my brother and sisters, for their continuous support.

I also want to thank all of my second family members in Malaysia, including the colleges' students and the staff, for providing me with a great experience in both my academic and social life.

Special thanks from me to MALAYSIA and to the Malaysian people in general, for their perfect hospitality in their green land during my studies there.



I will never forget to the guidance and assistance rendered by Dr. Waleed Sultan in supporting me during in my studies.

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:

**Chairman, PhD**

Professor  
Faculty of Graduate Studies  
Universiti Putra Malaysia  
(Chairman)

**Examiner 1, PhD**

Professor  
Faculty of Graduate Studies  
Universiti Putra Malaysia  
(Internal Examiner)

**Examiner 2, PhD**

Professor  
Faculty of Graduate Studies  
Universiti Putra Malaysia  
(Internal Examiner)

**External Examiner, PhD**

Professor  
Faculty of Graduate Studies  
Universiti Putra Malaysia  
(External Examiner)

---

**HASANAH MOHD GHAZALI, PhD**

Professor /Deputy Dean  
School Of Graduate Studies  
University Putra Malaysia

Date:



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.  
The members of the Supervisory Committee are as follows:

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

Lecturer  
Faculty of Engineering  
Universiti Putra Malaysia  
(Chairman)

**Mohamed Fadlee B.A.Rashid, PhD**

Lecturer  
Faculty of Engineering  
Universiti Putra Malaysia  
(Member)

---

**HASANAH MOHD GHAZALI, PhD**

Professor and Dean  
School of Graduate Studies  
Universiti Putra Malaysia

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.

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**MOHAMED KHALAF ALLA.H.M.H**

Date:

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## LIST OF ABBREVIATIONS/ SYMBOLS

RADAR	Radio Detection and Ranging
EM	Electromagnetic
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

$\beta$	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
$\lambda$	Wavelength
$\sigma_B$	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
$\sigma_F$	Forward scattering RCS
$\alpha_v$	Receiver Vertical Diffraction Angle of the Target under Observation

$\alpha_h$	Receiver horizontal Diffraction Angle of the Target under Observation
$A$	Area of the Aperture
$\sigma_M$	Monostatic RCS
$v$	Velocity Vector
$f_{dbr}$	Doppler Frequency
$\delta$	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
$\psi$	Angle between imaginary line of Target Trajectory and Transmitter Receiver Distance
$\alpha_T$	Diffraction Angle with respect to Transmitter
$\alpha_R$	Diffraction Angle with respect to Receiver
$Z(t)$	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

$\phi$	Magnetic Field
$E_r$	Electrical Field in $r$ direction (cylindrical coordinates)
$E_\theta$	Electrical Field in $\theta$ 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
$\theta$	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 *Radio Detection* and *Ranging*. 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].