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

MOHAMED KHALAF ALLA.H.M.H

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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

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

By

MOHAMED KHALA ALLA.H.M.H

April 2009

Chairman: RajaSyamsul 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

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

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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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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:
TABLE OF CONTENTS

DEDICATION ii
ABSTRACT iii
ABSTRAK v
ACKNOWLEDGEMENTS vii
APPROVAL ix
DECLARATION xi
LIST OF TABLES xiv
LIST OF FIGURES xiv
LIST OF ABBREVIATIONS/ SYMBOLS xix

CHAPTER

1 INTRODUCTION 1
1.1 Background 1
1.2 Brief History of Forward Scattering Radar 3
1.3 problem statement and motivation for present work 5
1.4 Aims and objectives 6
1.5 Thesis Organization 7

2 LITERATURE REVIEW 10
2.1 Introduction 10
2.2 Basic principles of Forward Scattering Radar 10
2.2.1 Forward Scattering Radar equation 12
2.2.2 Forward Scattering Radar Cross Section 13
2.2.3 Doppler Effects 15
2.2.4 Literature survey on Forward Scattering Radar 18
2.3 Signal processing and Detection Technique in FSR 21
2.4 Signal processing and signal de-noise overview 22
2.4.1 Time- Frequency signal processing 23
2.4.2 Short-Time Fourier Transform(STFT) 23
2.5 Hilbert Transformation 26
2.6 The Instantaneous Frequency 27
2.7 Wavelet Transform 29
2.7.1 Continues Wavelet Transform 32
2.8 Wavelet De- noise 35
2.8.1 Decompositions 36
2.8.2 Tershoold Detail Coefficient 37
2.8.3 Reconstruction 37
2.9 Summary 37

3 METHODOLOGY 39
3.1 Introduction 39
3.2 The Ground Forward Scattering System 39
3.3 Received Doppler Frequency in Forward Scattering Radar 42
<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1</td>
<td>65</td>
</tr>
<tr>
<td><strong>Components and Equipments Used in Outdoor Experiment</strong></td>
<td></td>
</tr>
<tr>
<td>4.2</td>
<td>68</td>
</tr>
<tr>
<td><strong>The different set up between the two layouts</strong></td>
<td></td>
</tr>
<tr>
<td>4.3</td>
<td>71</td>
</tr>
<tr>
<td><strong>Example of Vehicle Types Used in Experiment Layout 2</strong></td>
<td></td>
</tr>
<tr>
<td>5.1</td>
<td>93</td>
</tr>
<tr>
<td><strong>Statistics for the obtained results from layout 2</strong></td>
<td></td>
</tr>
<tr>
<td>5.2</td>
<td>95</td>
</tr>
<tr>
<td><strong>values to drive the supportive threshold equation</strong></td>
<td></td>
</tr>
</tbody>
</table>
## LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>(a) Radar systems based on the transmitter-receiver topology, (b) FSR topology</td>
<td>2</td>
</tr>
<tr>
<td>1.2</td>
<td>Methodology flow chart for the study of FSR for ground target Detection</td>
<td>8</td>
</tr>
<tr>
<td>1.3</td>
<td>Scope of the work</td>
<td>9</td>
</tr>
<tr>
<td>2.1</td>
<td>Forward scattering radar condition i.e. when bistatic angle, $\beta \approx 180^\circ$</td>
<td>11</td>
</tr>
<tr>
<td>2.2</td>
<td>Forward scattering radar geometry showing the diffraction angles $\alpha$, and $\alpha_h$</td>
<td>14</td>
</tr>
<tr>
<td>2.3</td>
<td>Babinet’s model for the forward scatter case with $\beta = 180^\circ$</td>
<td>14</td>
</tr>
<tr>
<td>2.4</td>
<td>Doppler Effect</td>
<td>16</td>
</tr>
<tr>
<td>2.5</td>
<td>Geometry for forward scattering radar target Doppler calculation</td>
<td>17</td>
</tr>
<tr>
<td>2.6</td>
<td>Forward scattering radar performance</td>
<td>19</td>
</tr>
<tr>
<td>2.7</td>
<td>Common signal processing system</td>
<td>22</td>
</tr>
<tr>
<td>2.8</td>
<td>Windowing approach (short time Fourier transforms)</td>
<td>24</td>
</tr>
<tr>
<td>2.9</td>
<td>(a) time domain signal (15Hz) and (4Hz), (b) STFT for (a)</td>
<td>25</td>
</tr>
<tr>
<td>2.10</td>
<td>Hilbert transform of sine wave</td>
<td>26</td>
</tr>
<tr>
<td>2.11</td>
<td>(a) time domain chirp signal, (b) its instantaneous frequency</td>
<td>29</td>
</tr>
<tr>
<td>2.12</td>
<td>(a) sine wave, (b) wavelet</td>
<td>31</td>
</tr>
<tr>
<td>2.13</td>
<td>(a) Scaling property of the wavelets, (b) Sym8, (c) dB6</td>
<td>32</td>
</tr>
<tr>
<td>2.14</td>
<td>Step 1 and 2</td>
<td>32</td>
</tr>
<tr>
<td>2.15</td>
<td>Step 3</td>
<td>33</td>
</tr>
<tr>
<td>2.16</td>
<td>Step 4</td>
<td>33</td>
</tr>
<tr>
<td>2.17</td>
<td>(a) time domain signal (b) time-scale representation</td>
<td>34</td>
</tr>
<tr>
<td>2.18</td>
<td>Details and approximations at different levels of resolution</td>
<td>36</td>
</tr>
<tr>
<td>3.1</td>
<td>Forward Scattering Radar System Simplified Block Diagram for Vehicle Detection</td>
<td>40</td>
</tr>
</tbody>
</table>
3.2 (a) Overall FSR system layout from above (a, b and c are the vehicle positions) And (b) experimentation scenario during test day 43
3.3 Target in the xMz-plane 44
3.4 Sinc function pattern 45
3.5 Doppler frequency variation relative to the scattering point on the vehicle 47
3.6 Analytical Signal in (a) time domain and (b) its instantaneous frequency after Hilbert 49
3.7 Analytical signal from three targets in (a) time domain and (b) its Instantaneous Frequency 50
3.8 Approximations and Details at Different Levels of Resolution 53
3.9 Sym8 wavelet and scaling function and its associated coefficients 54
3.10 Selection of best Threshold Technique for FSR 55
3.11 The Overall Process of Decomposing a Signal $s(t)$ and Reconstructing the Approximations and the details 56
4.1 Forward Scattering Radar Outdoor Experimental Set-up for Vehicle detection 59
4.2 FSR Experimentation Layout 60
4.3 Simplified Block Diagram for Doppler Extraction by Diode and LPF 61
4.4 (a) Receiver Components used for Outdoor Experiment and (b) receiver block Diagram 62
4.5 The BPF Frequency Response. 63
4.6 Omni Directional Antenna Elevated Directly on the Ground 67
4.7 Transmitter side of the experiment in Layout 2 68
4.8 Experiment scene layout 2 (a), (b) Vehicle passing the Tx-Rx base line, (c) Two cars pass through the base line 70
4.9 Sample of the received signal from Layout 2 71
4.10 Receiver Components used for Outdoor Experiment Layout 2 71
5.1 Resulted Signal (Astra) from Layout 1 (RSA) 73
5.2 Resulted signal (Astra) Vehicle Moves through Sensor (reducing Doppler shift) In layout 1 (b) its instantaneous frequency 74
5.3 (a) Resulted signal (Combi) Vehicle Moves through Sensor (reducing Doppler shift) in layout 1 (b) its instantaneous frequency 75
5.4 Resulted signal (Myvi) Vehicle moves through Sensor (reducing Doppler shift) in layout 2 with SNR 10 dB (b) its instantaneous frequency 79
5.5 Resulted signal (Myvi) Vehicle moves through sensor (reducing Doppler shift) in layout 2 with SNR 13 dB (b) its instantaneous frequency 80
5.6 Resulted signal (Myvi and saga) Vehicle moves through sensor (reducing Doppler shift) in layout 2 with SNR 13 dB (b) its instantaneous frequency 81
5.7 Approximation and details at level 5 for Myvi car SNR 10 dB figure (5.4a) 83
5.8 De-noised signal for Myvi car SNR 10 dB [Figure (5.4a)] 84
5.9 De-noised signal for Mercedes car SNR 13 dB [Figure (5.5a)] 84
5.10 De-noised signal for Myvi and Mercedes [figure (5.5a)] 85
5.11 (a) Resulted signal (Myvi) in layout 2 SNR-10 dB (b) its instantaneous frequency,(c) de-noised signal 86
5.12 (a) Resulted signal (Myvi) in layout 2 SNR -8 dB (b) its Instantaneous frequency, (c) de-noised signal 90
5.13 (a) Received signal for Saga and Savvy with separation distance 40m SNR -9 dB(b) It’s instantaneous frequency,(c)de-noised signal 88
5.14 (a) Received signal for Saga and Myvi with separation distance 40m SNR -8 dB(b) It’s instantaneous frequency,(c)de-noised signal 89
5.15 (a) Signal contains high noise and low SNR and (b) after de-noised
**LIST OF ABBREVIATIONS/ SYMBOLS**

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>RADAR</td>
<td>Radio Detection and Ranging</td>
</tr>
<tr>
<td>EM</td>
<td>Electromagnatic</td>
</tr>
<tr>
<td>FSR</td>
<td>Forward Scattering Radar</td>
</tr>
<tr>
<td>RCS</td>
<td>Radar cross Section</td>
</tr>
<tr>
<td>RAM</td>
<td>Radio Absorbing Material</td>
</tr>
<tr>
<td>CW</td>
<td>Continues Wave</td>
</tr>
<tr>
<td>OTH</td>
<td>Over The Horizon</td>
</tr>
<tr>
<td>ATD</td>
<td>Automatic Target Detection</td>
</tr>
<tr>
<td>FS</td>
<td>Forward Scattering</td>
</tr>
<tr>
<td>SNR</td>
<td>Signal to Noise Ratio</td>
</tr>
<tr>
<td>MIT</td>
<td>Moving Target Indication</td>
</tr>
<tr>
<td>KNN</td>
<td>K-Nearest Neighbours</td>
</tr>
<tr>
<td>PCA</td>
<td>Principle Components Analysis</td>
</tr>
<tr>
<td>FFT</td>
<td>Fast Fourier Transform</td>
</tr>
<tr>
<td>DFT</td>
<td>Discrete Fourier Transform</td>
</tr>
<tr>
<td>AD</td>
<td>Amplitude Detector</td>
</tr>
<tr>
<td>NF</td>
<td>Notch Filter</td>
</tr>
<tr>
<td>LPF</td>
<td>Low Pass Filter</td>
</tr>
<tr>
<td>ADC</td>
<td>Analogue to Digital Converter</td>
</tr>
<tr>
<td>STFT</td>
<td>Short Time Fourier Transform</td>
</tr>
<tr>
<td>CWT</td>
<td>Continues Wavelet Transform</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
</tr>
<tr>
<td>--------------</td>
<td>-------------</td>
</tr>
<tr>
<td>DWT</td>
<td>Discrete Wavelet Transform</td>
</tr>
<tr>
<td>GPR</td>
<td>Ground Penetrating Radar</td>
</tr>
<tr>
<td>MRA</td>
<td>Multi Resolution Analysis</td>
</tr>
<tr>
<td>SISAR</td>
<td>Shadow Inverse Synthetic Aperture Radar</td>
</tr>
<tr>
<td>FSCS</td>
<td>Forward Scattering Cross Section</td>
</tr>
<tr>
<td>EM</td>
<td>Electromagnetic Field</td>
</tr>
<tr>
<td>IDWT</td>
<td>Inverse Discrete Wavelet Transform</td>
</tr>
<tr>
<td>ISM</td>
<td>Industrial Scientific Medical</td>
</tr>
<tr>
<td>LNA</td>
<td>Low Noise Amplifier</td>
</tr>
<tr>
<td>HPBW</td>
<td>Half Power Beam width</td>
</tr>
</tbody>
</table>
## LIST OF SYMBOLS

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta$</td>
<td>Bistatic Angle</td>
</tr>
<tr>
<td>$E_{\text{sum}}$</td>
<td>Total Electrical field</td>
</tr>
<tr>
<td>$E_s$</td>
<td>Self Scattering Fields</td>
</tr>
<tr>
<td>$E_{\text{sh}}$</td>
<td>Shadow Field</td>
</tr>
<tr>
<td>$P_T$</td>
<td>Transmitted Power</td>
</tr>
<tr>
<td>$G_T$</td>
<td>Transmitter Gain</td>
</tr>
<tr>
<td>$G_R$</td>
<td>Receiver Gain</td>
</tr>
<tr>
<td>$\lambda$</td>
<td>Wavelength</td>
</tr>
<tr>
<td>$\sigma_B$</td>
<td>Target’s Bistatic RCS</td>
</tr>
<tr>
<td>$F_T$</td>
<td>Constants defined by Willis</td>
</tr>
<tr>
<td>$F_R$</td>
<td>Constants defined by Willis</td>
</tr>
<tr>
<td>$K_b$</td>
<td>Boltzman’s constant</td>
</tr>
<tr>
<td>$T_o$</td>
<td>Reference temperature (290K)</td>
</tr>
<tr>
<td>$F$</td>
<td>Noise figure</td>
</tr>
<tr>
<td>$R_T$</td>
<td>Transmitter to Target Distance</td>
</tr>
<tr>
<td>$R_R$</td>
<td>Receiver to Target Distance</td>
</tr>
<tr>
<td>$d$</td>
<td>Distance</td>
</tr>
<tr>
<td>$L_T$</td>
<td>Transmitter Loss</td>
</tr>
<tr>
<td>$L_R$</td>
<td>Receiver Loss</td>
</tr>
<tr>
<td>$\sigma_F$</td>
<td>Forward scattering RCS</td>
</tr>
<tr>
<td>$\alpha_v$</td>
<td>Receiver Vertical Diffraction Angle of the Target under Observation</td>
</tr>
</tbody>
</table>
\( \alpha_h \) 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

\( f_{cs} \) 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

$f_{dbf}$  Doppler Frequency

$f_{dma}$  Maximum Doppler Frequency

$h_{k,0}$  Scaling Filter (low pass)

$h_{k,1}$  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].