



UNIVERSITI PUTRA MALAYSIA

**SPEED ESTIMATION IN FORWARD SCATTERING RADAR USING
STANDARD DEVIATION AND IMPROVED ZERO-CROSSING METHOD**

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**Speed Estimation in Forward Scattering Radar Using Standard
Deviation and Improved Zero-crossing Method**

By

MUTAZ SALAH MOHAMED SADIG

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

February, 2009



DEDICATION

I dedicate this thesis to my parents. Without their patience, understanding, support, and most of all love, the completion of this work would not have been possible.



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

Speed Estimation in Forward Scattering Radar Using Standard Deviation and Improved Zero-crossing Method

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February 2009

Chairman: Raja Syamsul Azmir Bin Raja Abdullah, PhD

Faculty: Engineering

Current research on Forward Scattering Radar (FSR) dedicates to the target detection and classification. In the classification technique, the target's speed information is required prior to the classification processes. Unfortunately, the speed is hidden inside the received signal and cannot be extracted directly. This is due to the loss in range resolution in FSR system. This is the main disadvantage of FSR. Thus, this thesis presents a work on speed estimation in FSR. Theory of FSR systems is briefly described together with practical experiments to evaluate the feasibility of such a system in real-life scenarios. The data collected from the practical experimentation and typical ground vehicle is used as the target (e.g. car, lorry). The overall speed estimation system is described. For vehicle speed estimation, two methods are proposed: the first method applies Standard Deviation (STD) theory to the raw radar signal. In the second method, the number of zero-crossing in the received signal is analyzed for speed estimation. On top of that, de-noising pre-processing is introduced to increase the accuracy of speed result. These two methods show a good result in estimating the vehicle speed crossing FSR baseline.



From the analysis, speeds estimation using STD work best for high SNR value. By analyzing 917 experimentally obtained car signatures, the performance of the system is evaluated and the effectiveness of the system is confirmed.

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

**SPEED ESTIMATION DALAM PENYERAKAN FORWARD RADAR
MENGUNAKAN SISIHAN PIAWAI DAN KAEDAH-KAEDAH
IMPROVED ZERO LINTASAN**

Oleh

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Abstrak

Kajian terkini ke atas Forward Scattering Radar (FSR) tertumpu kepada teknik klasifikasi dan mengenalpasti sasaran. Maklumat kelajuan sasaran diperlukan dalam teknik pengelasan. Walaubagaimanapun, maklumat tersebut tersembunyi dalam isyarat penerimaan dan tidak boleh diekstrak secara langsung. Ini disebabkan oleh kehilangan julat resolusi sistem FSR dan ini merupakan kelemahan utama FSR. Tesis ini mengetengahkan kajian ke atas penganggaran kelajuan dalam FSR. Teori sistem FSR diterangkan secara ringkas disusuli dengan eksperimen bagi menilai kebolehan sistem. Data diperolehi daripada eksperimen menggunakan kenderaan bermotor sebagai sasaran (seperti kereta, lori). Sistem penganggaran kelajuan diperihalkan. Dua kaedah dicadangkan bagi menganggarkan kelajuan kenderaan. Kaedah pertama mengaplikasi teori Sisihan Piawai (STD) kepada sasaran radar asal manakala bagi kaedah kedua, bilangan lintasan sifar dalam isyarat penerimaan dianalisis bagi menganggarkan kelajuan. Selain itu, de-noising sebelum pemprosesan



diperkenalkan untuk meningkatkan ketepatan hasil kelajuan. Ini dua kaedah-kaedah menunjukkan satu kebaikan mengakibatkan mengangarkan kelajuan kenderaan lintasan garis tapak FSR. Daripada analisis, mempercepatkan anggaran menggunakan STD bekerja paling baik untuk nilai SNR tinggi. Dengan menganalisa 917 tandatangan-tandatangan kereta yang memperolehi secara eksperimen, prestasi sistem adalah dinilai dan keberkesanan sistem penyampaian disahkan.

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APPROVAL

I certify that an Examination Committee has met on 27 FEB 2009 to conduct the final examination of Mutaz Salah Mohamed on his Master of Science thesis “Speed Estimation in Forward scattering Radar using Standard Deviation and Improved Zero-crossing methods” 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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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.

**MUTAZ SALAH
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LIST OF ABBREVIATION

ADC	Analogue to D igital C onverter
BPF	B and P ass F ilter
CPF	C omplex P rofile F unction
CW	C ontinuous W ave
DSP	D igital S ignal P rocessing
EM	E lectromagnetic
FSCS	F orward S cattering C ross S ection
FSR	F orward S cattering R adar
GMM	G aussian M ixture M odelling
HPF	H igh P ass F ilter
IC	I ntegrated C hip
IF	I ntermediate F requency
ISAR	I nverse S ynthetic A perture R adar
ISM	I ndustrial, S cientific and M edical
LNA	L ow N oise A mplifier
LO	L ocal O scillator
LPF	L ow P ass F ilter
RAM	R adar A bsorbing M aterial
RCS	R adar C ross S ection
RF	R adio F requency
SAR	S ynthetic A perture R adar
SISAR	S hadow I nverse S ynthetic A perture R adar
StD	S tandard D eviation
SNR	S ignal to N oise R atio
WE	W alker E rror

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
$Z(t)$	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_{abr}	Doppler Frequency
f_{dma}	Maximum Doppler Frequency
$\hat{h}_{k,0}$	Scaling Filter (low pass)
$\hat{h}_{k,1}$	Wavelet Filter (high pass)
$\mathcal{G}_{L,0}$	Reconstruction Filter (Low Pass)
$\mathcal{G}_{k,1}$	Reconstruction Filter (high Pass)
A_j	Approximation at Level j
D_j	Detail at Level j

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