MODULATION TECHNIQUES FOR GPR SYSTEM RADARGRAM

ARIFFUDDIN BIN JORET

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Universiti Tun Hussein Onn Malaysia

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Especially for my father and mother whom I love the most,

JORET Bin Ali and Chik Binti Jaapar

And my lovely wife and kids

Norizan Binti Jafar, Nurin Falisha Amani Binti Ariffuddin, Lutfil Hadi Bin Ariffuddin and Nurin Batrisya Imani Binti Ariffuddin

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ABSTRACT

Ground Penetrating Radar (GPR) system ability to detect embedded object underground is dependent on the ultra-wideband antenna use. Based on this antenna type, the *fractional bandwidth* used by the GPR system is usually greater or equal to 1. On the other hand, the GPR system using *fractional bandwidth* less than 1 will produce unsmooth GPR radargram, as the consequences of high signal ripples generated in the system output signals. Based on *fractional bandwidth* parameter, this study focuses in developing a digital signal processing of the GPR system to produce a smooth GPR radargram. The proposed GPR signal processing system is based on envelope detector technique of Asynchronous Half-Wave (AHW), Asynchronous Full-Wave (AFW) and Asynchronous Real Square Law (ARSL). The Pulse Modulation (PM), Stepped Frequency Continuous Wave (SFCW) and Hybrid GPR system simulation are modeled using CST Studio Suite and MATLAB software. The selected *fractional bandwidth* of the GPR system simulation modeled is 0.46 and 0.4 for Microstrip Vivaldi and Horn antennas respectively. In addition, a practical implementation of the SFCW and Hybrid GPR system using fabricated Microstrip Vivaldi antenna having a *fractional bandwidth* of 0.46 and VNA equipment, was conducted. Based on the analysis results of the proposed PM GPR system simulation, the AFW technique produces clearer PM GPR radargram. The detection rate for PM GPR system simulation using AFW technique is 87% and 51.3% using Horn and Microstrip Vivaldi antennas respectively. Practical implementation of SFCW and Hybrid GPR systems using AFW technique and Microstrip Vivaldi antenna can detect an iron and a bottle filled with water object.

ABSTRAK

Keupayaan sistem *Ground Penetrating Radar* (GPR) untuk mengesan objek di dalam bumi bergantung kepada penggunaan antena ultra-wideband. Berdasarkan kepada antena jenis ini, *fractional bandwidth* antena yang sering digunakan oleh sistem GPR adalah lebih besar atau bersamaan 1. Namun, sistem GPR yang menggunakan nilai *fractional bandwidth* kurang daripada 1 akan menghasilkan radargram GPR yang tidak lancar disebabkan oleh riak isyarat keluaran sistem yang tinggi. Berdasarkan nilai *fractional bandwidth*, kajian ini memfokuskan untuk membangunkan sistem pemprosesan isyarat digital untuk sistem GPR dalam menghasilkan radargram GPR yang lancar. Sistem pemprosesan isyarat GPR yang dicadangkan adalah menggunakan teknik pengesan sampul jenis Asynchronous Half-Wave (AHW), Asynchronous Full-Wave (AFW) dan Asynchronous Real Square Law (ARSL). Simulasi sistem GPR jenis Modulasi denyut (PM), Stepped Frequency Continuous Wave (SFCW) dan Hybrid telah dibangunkan menggunakan perisian CST Studio Suite dan MATLAB. Merujuk kepada *fractional bandwidth*, simulasi sistem GPR yang dibangunkan ini mempunyai nilai 0.46 untuk antena Microstrip Vivaldi dan 0.4 untuk antena Horn. Perlaksanaan sistem GPR jenis SFCW dan Hybrid telah dibuat menggunakan pakej antena Microstrip Vivaldi yang direka dengan nilai *fractional bandwidth* sebanyak 0.46 dan peralatan VNA. Merujuk kepada hasil analisis pembangunan simulasi sistem PM GPR, teknik pengesan sampul AFW menghasilkan radargram PM GPR yang lebih jelas. Kadar pengesanan sistem PM GPR menggunakan sistem AFW dan antena Horn adalah 87% manakala menggunakan antena Microstrip Vivaldi adalah 51.3%. Pembangunan peralatan sistem GPR jenis SFCW dan Hybrid dalam kajian ini menggunakan teknik AFW dan antena Microstrip Vivaldi mampu mengesan objek besi dan botol berisi air.

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LIST OF SYMBOLS AND ABBREVIATIONS

ω	-	Signal Phase
λ	-	Wavelength
μ_r	-	Relative Permeability
ε_r	-	Relative Permittivity
2D	-	2 Dimension
3D	-	3 Dimension
A	-	Signal Amplitude
AFW	-	Asynchronous Full-Wave
AHW	-	Asynchronous Half-Wave
AM	-	Amplitude Modulation
ANN	-	Artificial Neural Network
ARSL	-	Asynchronous Real Square Law
cm	-	centimeter
CSIRO	-	Commonwealth Scientific and Industrial Research Organization
CST	-	Computer Simulation Technology
dB	-	decibels
dBi	-	decibels relative to isotropic
ETS	-	Early-Time Signal
FCC	-	Federal Communications Commission
FDTD	-	Finite Difference Time Domain
FFT	-	Fast Fourier Transform
FIR	-	Finite Impulse Response
GHz	-	Gega Hertz
GPR	-	Ground Penetrating Radar
IIR	-	Infinite Impulse Response

ITC	-	Information Theoretic Criterion
m/s	-	meter per second
MHz	-	Mega Hertz
mm	-	millimeter
MSE	-	Mean Squared Error
NDT	-	Non-Destructive Technique
PEC	-	Perfect Electric Conductor
PM	-	Pulse Modulation
PSNR	-	Peak Signal to Noise Ratio
ROC	-	Receiver Operating Characteristic
S_{11}	-	Reflection Signal Parameter
SFCW	-	Stepped Frequency Continuous Wave
SVD	-	Singular Value Decomposition
TSVD	-	Truncated Singular Value Decomposition
UWB	-	ultra-wideband
UXO	-	unexploded ordnance
VNA	-	Vector Network Analyser

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