UNIVERSITI PUTRA MALAYSIA

FOREIGN OBJECT DEBRIS DETECTION BASED ON CONTINUOUS WAVE FORWARD SCATTERING RADAR DOPPLER EFFECT

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By

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Chairman : Y.M. Raja Syamsul Azmir B. Raja Abdullah, PhD

Faculty : Engineering

Surveillance system has become necessity for many working areas such as civil, military, defense, security, industry, flight, etc. This research concerns about the using of radar to detect ground non-moving objects that become hazardous objects in a specified environment. These kinds of objects are usually known as Foreign Object Debris (FOD). Any unwanted objects lying on roads, bus ways, taxi ways, or the airplane runways can be categorized as FOD. Especially for flight, FOD has become a vital problem that can cause fatal damage or even an accident for an aircraft.

This study is specially aimed to detect and localize the existence of FOD in a covered area using a special mode of bistatic radar system known as Forward Scattering Radar (FSR). The method is by analyzing the Doppler signal extracted from the received signal scattered by the target. The received signal comprises direct signal

from the transmitter and scattered signal from the target, therefore by analyzing the Doppler signal at the receiver could give the information about the existing of target.

This research is a development of the previous research which was Forward Scattering Radar for moving ground target detection. The difference between current research and the previous research is that in the previous research the Doppler shift is caused by the moving target, while in the current research the Doppler shift is created by intentionally moving the transmitter antenna.

A hardware setup and an experimental scenario have been chosen to carry out this research. A transmitter antenna is set to move in an angular direction for scanning the covered area, while in the other side a receiver is located to receive the transmitted signal. An object – supposed to be the FOD – is then located between the transmitter and the receiver. The transmitter antenna is fed into a continuous wave signal generator and moved using a controlled stepper motor. While, the received signal at the receiver will be passed through a receiving circuit to extract its Doppler signal.

A computer simulation in accordance with this experimental scenario is also designed to confirm the analysis result of this research. Any parameters used in the experimental will also be adopted in the computer simulation. An FSR formulation will be applied to perform this simulation.

FOD detection will be performed both in time domain and frequency domain of the Doppler signal. A subtraction and statistical correlation of several no-target Doppler

and with-target Doppler signals will be performed in this case. Both theoretical and experimental signals will be analyzed to confirm the result. The power – frequency extraction will be done using standard Fourier Transform.

Analyses of FOD detection on time domain are done. Subtraction of with-target by no-target Doppler signals results on scattered Doppler signal, and the existing of this scattered Doppler signal has proven the existing of FOD. By performing cross correlation between no-target and with-target Doppler signals, a line plot of correlation coefficient is resulted. The average of correlation coefficient is significantly different compared to the cross correlation between no-target Doppler signals, and this is enough to conclude that the FOD does exist. While, analyses on frequency domain of those signals give proportional results as on time domain signals.

FOD localization will be performed using the time-frequency analysis of the scattered Doppler signal. The existence of target will be represented by the existing of zero Doppler at the time-frequency characteristic of the scattered Doppler signal. FOD localization will be performed for both theoretical and experimental signal. An optimized Hilbert – Huang transform will be used to analyze the time-frequency properties of the signals. The elaboration about the Hilbert – Huang transform optimization will be discussed.

By analyzing two different Doppler signals of different target location, different zero Doppler positions are identified. By relating the time position of zero Doppler with

the angular velocity of transmitter antenna, the direction angle in which the target was located could be calculated.

After all, this research will have contribution on introducing the theoretical and experimental system design of FSR for non-moving object detection. Moreover, this research also contributes on optimization of the existing well-known Hilbert-Huang Transform, by removing the cyclic error.

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

PENGESANAN SERPIHAN OBJEK ASING BERDASARKAN KESAN DOPPLER FORWARD SCATTERING RADAR GELOMBANG BERTERUSAN

By

ARIS MUNAWAR

Mei 2011

Pengerusi : Y.M Raja Syamsul Azmir B. Raja Abdullah, PhD

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Sistem pengawasan telah menjadi salah satu keperluan bagi kebanyakan bidang pekerjaan, antaranya awam, ketenteraan, pertahanan, keselamatan, industri, penerbangan dan sebagainya. Penyelidikan ini menitikberatkan tentang penggunaan radar untuk mengesan objek tanah yang tidak bergerak, di mana ia akan menjadi objek berbahaya dalam satu kawasan yang tertentu. Objek jenis ini biasanya dikenali sebagai *Foreign Object Debris (FOD)*. Mana-mana objek tidak diingini yang terletak di jalan raya, jalan bas, jalan teksi, atau landasan kapal terbang boleh dikategorikan sebagai FOD. Terutamanya untuk sesuatu penerbangan, FOD menjadi satu masalah penting yang boleh menyebabkan kerosakan teruk atau kemalangan pesawat.

Kajian ini mensasarkan untuk mengesan dan menempatkan FOD di kawasan tertutup menggunakan cara khas sistem radar bistatic yang dikenali sebagai Forward Scattering Radar (FSR). Menerusi kaedah ini, penganalisaan isyarat Doppler diekstrak daripada isyarat yang diterima oleh sasaran. Isyarat yang diterima terdiri daripada isyarat terus daripada pemancar dan isyarat yang diserak daripada sasaran. Oleh itu, dengan menganalisis isyarat Doppler pada penerima boleh memberikan maklumat berkenaan sasaran yang wujud.

Kajian ini merupakan satu perkembangan daripada penyelidikan sebelumnya iaitu Forward Scattering Radar untuk mengesan sasaran yang bergerak di atas tanah. Perbezaan diantara penyelidikan semasa dan penyelidikan sebelumnya adalah dalam penyelidikan sebelumnya anjakan Doppler disebabkan oleh sasaran bergerak. Manakala dalam penyelidikan semasa pula peralihan Doppler sengaja dicipta dengan cara memindahkan antena pemancar.

Bagi menjalankan kajian ini, satu persediaan perkakasan dan senario eksperimen telah ditentukan. Sebuah antena pemancar ditetapkan untuk bergerak ke arah sudut tertentu untuk mengimbas kawasan tertutup. Sementara itu, pada bahagian lain pula penerima diletakkan untuk menerima isyarat yang dihantar. Objek - sepatutnya FOD - kemudian diletakkan di antara pemancar dan penerima. penjana Isyarat gelombang berterusan dihantar kepada antenna penerima dan bergerak menggunakan stepper motor terkawal. Manakala isyarat penerima dihantar menerusi litar penerima untuk mengeluarkan isyarat Doppler itu.

Satu simulasi komputer mengikut senario eksperimen ini juga direka untuk mengesahkan hasil analisis kajian ini. Parameter yang sama akan diguna pakai untuk simulasi komputer. Satu formula FSR akan diguna pakai untuk menjalankan simulasi ini.

Pengesanan kewujudan FOD akan dilakukan dalam domain masa dan domain frekuensi Doppler. Sebuah operasi pengurangan dan korelasi statistik pada beberapa isyarat Doppler dengan sasaran dan isyarat Doppler tanpa sasaran akan dilakukan. Kedua-dua isyarat teori dan eksperimen akan dianalisis untuk mengesahkan keputusan hasil. Pengekstrakan kuasa-frekuensi akan dilakukan menggunakan standard Transformasi Fourier.

Analisis pengesanan FOD pada domain masa telah dilakukan. Pengurangan isyarat Doppler dengan sasaran dan isyarat Doppler tanpa sasaran menghasilkan isyarat Doppler terserak, dan kewujudan isyarat Doppler terserak ini membuktikan kewujudan FOD. Dengan melaksanakan hubungan silang antara isyarat Doppler dengan sasaran dan isyarat Doppler tanpa sasaran, satu pertalian garis dihasilkan. Purata pertalian garis korelasi ini jauh berbeza berbanding hubungan silang antara isyarat Doppler tanpa sasaran. Ini membuktikan kewujudan FOD. Sementara itu, analisis isyarat pada domain frekuensi memberikan hasil yang berkadar langsung seperti isyarat pada domain masa.

Lokasi FOD akan dilakukan menggunakan analisis frekuensi masa oleh isyarat Doppler terserak. Kewujudan sasaran akan disahkan dengan kewujudan Doppler

sifar pada ciri-ciri isyarat frekuensi masa Doppler terserak. Penempatan FOD akan dilakukan untuk kedua-dua isyarat teori dan isyarat eksperimen. Pengubah optimum Hilbert-Huang akan digunakan untuk menganalisis ciri-ciri isyarat frekuensi masa. Penjelasan berkenaan pengoptimuman Transformasi Hilbert - Huang akan dibincangkan.

Dengan menganalisis dua isyarat Doppler yang berlainan dan lokasi sasaran yang berbeza, kedudukan sifar Doppler yang berbeza dikenal pasti. Dengan menghubungkan kedudukan masa sifar Doppler dengan halaju sudut antena pemancar, sudut arah di mana sasaran terletak boleh dikira.

Penyelidikan ini akan mempunyai sumbangan kepada memperkenalkan sistem teori dan reka bentuk eksperimen FSR untuk mengesan objek tidak bergerak. Selain itu, kajian ini juga menyumbang kepada pengoptimuman Transformasi Hilbert-Huang sedia ada, dengan menghapuskan pusingan kesilapan.

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I certify that an Examination Committee met on …….. to conduct the final examination of Aris Munawar on his Master of Science thesis entitled "Foreign Object Debris Detection Based On Forward Scattering Radar Doppler Effect Using Continuous Wave" 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 degree of Master of Science.

Members of the Examination Committee are as follows:

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirements for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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DECLARATION

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

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ARIS MUNAWAR

Date: 3 May 2011

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