OPTIMUM RECEIVER FOR DECODING AUTOMATIC DEPENDENT SURVEILLANCE BROADCAST (ADS-B) AND MODE-SELECT(S) SECONDARY RADAR SIGNALS.

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To my esteemed and cherished family, friends and
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ABSTRACT

Air traffic control (ATC) radar has been the main sensor for the detection and monitoring of commercial aircrafts for air traffic management. Typical modern ATC radar consists of a primary radar and secondary radar. The primary radar locates aircrafts based on the time-delay between the transmit pulses and the returns off the aircrafts. Since only location is provided, the secondary radar receives identification and flight parameters based on mode A, C or S by interrogating the transponder on board incoming aircrafts. Extensive use of radar is limited by high acquisition, installation and maintenance cost. Also, the coverage is limited by blockage due to obstacles such as buildings and mountains. Automatic Dependent Surveillance-Broadcast (ADS-B) system is the next generation locating system to complement existing ATC radar system. The proposed project looks into the design of an optimum receiver to decode both ADS-B and mode S secondary radar signal. The project will consist of three parts namely; modulator, demodulator and performance verification. To ensure compatible to the industrial standards, the message format and its verification process will be based on the ICAO (International Civil Aviation Organizations) standards. A non-coherent detection structure (based on energy detection) will be adopted at the receiver to improve performance at low signal-to-noise ratio (SNR) condition.

ABSTRAK

Radar kawalan lalu lintas udara (ATC) telah menjadi pengesan utama untuk mengesan dan memantau pesawat komersial untuk pengurusan trafik udara. Radar ATC moden yang biasa terdiri daripada radar utama dan radar sekunder. Radar utama mengesan pesawat berdasarkan masa yang tertangguh antara gelombang penghantar dan gelombang yang pulang daripada pesawat. Oleh kerana hanya lokasi yang disediakan, radar sekunder menerima parameter pengenalan dan penerbangan berdasarkan mod A, C atau S dengan menyoal siasat transponder di atas kapal pesawat yang masuk. Penggunakan radar yang banyak adalah terhad oleh pengambilalihan tinggi, kos pemasangan dan kos penyelenggaraan. Selain itu, liputan adalah terhad oleh sekatan kerana halangan-halangan seperti bangunan dan gunung. Automatik Pergantungan Pengawasan-Penyiaran (ADS-B) sistem adalah sistem pengesan untuk generasi akan datang yang melengkapkan sistem radar ATC yang sedia ada. Projek yang dicadangkan meneliti kepada reka bentuk penerima optimum untuk menyahkan kedua-dua kod ADS-B dan isyarat radar sekunder mod S. Projek ini akan terdiri daripada tiga bahagian iaitu; modulator, penyahmodulat dan pengesahan prestasi. Untuk memastikan serasi dengan piawaian industri, format mesej dan proses pengesahan akan berdasarkan piawaian ICAO (Organisasi Penerbangan Awam Antarabangsa). Satu struktur pengesanan bukan-koheren (berdasarkan pengesanan tenaga) akan diguna pakai pada penerima untuk meningkatkan prestasi pada keadaan nisbah isyarat-kepada-bunyi (SNR) yang rendah.

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LIST OF ABBREVATIONS

AWGN	-	Additive White Gaussian Noise
ADS-B	-	Automatic Dependent Surveillance Broadcast
ATC	-	Air Traffic Control
ARQ	-	Automatic Repeat Request
ATCRBS	-	Air Traffic Control Radar Beacon System
BPPM	-	Binary Pulse Position Modulation
BER	-	Bit Error Rate
CRC	-	Cyclic Redundancy check
CA	-	Capability
CPR	-	Compact Position Reporting
DF	-	Downlink Format
FAA	-	Federal Aviation Administration
FIS-B	-	Flight Information Services Broadcast
FEC	-	Forward Error Correction
FCS	-	Frame Check Sequence
GPS	-	Global Positioning System
GNSS	-	Global Navigation Sattelite System
IF	-	Intermidiate Frequency
IFF	-	Identification Friend or Foe
ITT	-	International Telephone and Telegraph
ID	-	Identification
ICAO	-	International Civil Aviation Organization
LSB	-	Least Significant Bit
MSB	-	Most Significant Bit
NextGen	-	Next Generation
NL	-	Number of Longitude Zone

PPM	-	Pulse Position Modulation
PSR	-	Primary Surveillance Radar
PDF	-	Probability Density Function
PER	-	Packet Error Rate
PPI	-	Plan Position Indicator
RADAR	-	Radio Detection and Ranging
SAR	-	Synthetic Aperture Radar
SNR	-	Signal-to-Noise Ratio
SSR	-	Secondary Surveillance Radar
TIS-B	-	Traffic Information Service Broadcast
UAT	-	Universal Access Tranceiver
USA	-	United State of America
UTC	-	Coordinated Universal Time
VFR	-	Visual Flight Rules

CHAPTER 1

INTRODUCTION

1.1 ADS-B background

Aircraft need to be prevented from coming in to contact during flight. In the past, various different technologies have been used to achieve this. This technology is usually radar technology, but now there is advent of a new technology commonly referred to as automatic dependent surveillance broadcast (ADS-B). This technology typically involves airplanes constantly sending in real time position and flight parameters. The aircrafts use Global Positioning System (GPS) to locate their position information and then broadcast it around so that any ADS-B installed aircraft or receiver at the ground station that are sufficiently close to the aircraft can receive it to prevent collision between the planes [1].

ADS-B's main purpose is to determine the position of an aircraft and then broadcast same Information. This information is broadcasted along with its call sign, heading, altitude and the identity of the aircraft automatically (i.e., without secondary surveillance radar (SSR) interrogation signal) to other aircraft and to air traffic control ground facilities. ADS-B is automatic in that it does not require any action or input by the pilot and no interrogation from the ground is required. It is also dependent because it relies on on-board equipment to gather the ADS-B data and broadcast it to other ADS-B users and it is a means of providing surveillance and traffic coordination [2]. The Federal Aviation Administration (FAA) has initiated actions to overhaul the traditional radar based surveillance system. This is an effort to save fuel and cost while enhancing aircraft safety with a next generation (NextGen) solution based on ADS-B technology. This technology will replaced the ground based radar technology in determining aircraft's position, because a unit on-board the aircraft determines the exact coordinates of the aircraft using the GPS satellite constellation. The information is then automatically transmitted through air-to ground and air-to-air data communication links at a fixed rate which depends on the aircraft's present state. Presently, aircraft traffic volume is increasing at an exponential rate which is approaching the limits of the current radar based systems, this necessitates the need for the swift implementation of a new system, the ADS-B.

ADS-B was created with compatibility and ease of transition in mind. It was built using similar aspects of the current aircraft surveillance transmission mode called mode select (mode S). Mode S works by interrogating aircraft by a specific aircraft identification number. Only the aircraft possessing the correct identification number will reply to an interrogation with its flight parameters, getting rid of issues related with synchronous garbling. Transmission types prior to mode S include mode A and mode C. In comparison to mode S that provides greater capabilities in terms of aircraft information which include its identity, capability and location, Mode A provides aircraft identification while Mode C provide aircraft's altitude [2].

ADS-B is similar to mode S for the fact that it uses the same transmission frequency of 1090 MHz. It differs from mode S in that the message is 112 bits, 120 micro seconds long and are "squitter" messages [3] [4]. A squitter message is simply a message that doesn't require any interrogation while being transmitted. Each packet is either formed of 7bytes (for mode S short squitter transmission) and 14byte (for 1090 MHz mode S Extended squitter) which includes a 56 bits data field to carry ADS-B information. The interesting packets are the extended squitter messages because it is this message that contain the data about the planes altitude, position, velocity as well as aircraft address. Unlike the (mode S short squitter) that carries only the ICAO 24bits aircraft address, which is a unique aircraft identifier used in mode S.

1.2 Problem Statement

- Limitation due to noise is inevitable in any given system, and as such leads to high bit error rate (BER) in the ADS-B system propagation path, which effectively limits the range of reception.
- There is need to analyse the decoded bit stream at the receiver in other to determine magnitude of the fligh parameters.

1.3 Objectives

The objectives of the project are described as follows:

- To implement ADS-B data to pulse position modulation techniques (PPM) during both encoding and decoding process.

- To apply cyclic redundancy check (CRC) error detection techniques for receiving ADS-B signal at the ground control station.

- To develop an algorithm for decoding and interpreting the received demodulated ADS-B signal.

- Monte Carlo simulation is performed at a given range of signal-to-noise ratio (SNR) to determine the accuracy of the system

1.4 Scope of work

The scope of the project is described below:

- MATLAB® will be used to implement the project objectives.

- ADS-B data used in this project is from commercial aircraft with data format (DF 17).

- A non-coherent detection structure (based on energy detection) using binary pulse position modulation is considered at the receiver in this project.

- For error detection , cyclic redundancy check (CRC) methods is used.

- For analysis of the received signal, it is assumed that the 1090 MHz signal from aircraft is down converted to intermediate frequency (IF) of 10 MHz with sampling frequency of 40 MHz.

- 1090 MHz link is used for ADS-B data communication in this project, even though 978 MHz universal access transceiver (UAT) link is used by general aviation aircraft flying at lower altitude

- The communication between the ADS-B installed aircraft and receiver at ground station is assumed to be Modelled as an additive white Gaussian noise (AWGN) channel.

1.5 Research Methodology

The project was carried out according to the following order. Firstly, a literature review on decoding of ADS-B and mode –S secondary radar signals was carried out, based on message type and format. This is done in other to ensure that appropriate bits are used for interpreting the altitude, longitude, latitude and aircraft identity.

Secondly using various sources, most notably, International Civil Aviation Organization (ICAO) [2], a system was created with the ability to received ADS-B messages and subsequently decodes them. In conjunction with a digital signal processing application, Matlab code was written to generate the messages and perform proper preparations to decode those messages. The process included multiple encoding equations and finally the transformation into hexadecimal representation to ensure the proper waveform for ADS-B messages.

After building the system, performance evaluation is then carried out in the presence of noise, leading to Monte Carlo simulation at a given range of signal-to-noise ratio (SNR) to determine the accuracy of ADS-B decoding system. It is then worthy to mention that all of the aforementioned steps are carried out through construction of the appropriate Matlab functions.

1.6 Organization of the Project

This project is outlined in the following manner. Chapter II provides an in-depth literature review on aircraft surveillance history and ADS-B. Chapter III describes the steps involved in achieving the project objectives. Chapter IV contains results, discussion, and analysis of the system’s capabilities. Finally, Chapter V contains conclusions and recommendations for future research related to ADS-B message exploitation.

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