Air Traffic Control Secondary Radar

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Abstract

Air traffic control (ATC) radar has been the main sensor for the
detection and monitoring of commercial aircraft for aircraft traffic
management. The modern ATC radar consists of a primary radar and
secondary radar which is limited by high acquisition, installation and
maintenance cost. Automatic Dependence Surveillance Broadcast (ADS-B)
system is the next generation locating system to complement existing ATC
radar system. ADS-B is a technology that can be viewed either as a
complement or as an alternative to current radar based surveillance
techniques[1]. It is the surveillance technology in which an aircraft
determines its position via satellite navigation and periodically broadcast,
enabling it to be tracked. In this paper, ADS-B receiver setup is designed
using dipole antenna, Bandpass filter, RTL-SDR receiver, raspberry pi 3
and seven inch display. The method includes the steps of receiving the
signal from aircraft by antenna and it is processed in matlab via RTL-SDR
receiver.

Key Words: Dipole antenna, ATC,ADS-B,PSR, SSR, RTL-SDR receiver,
Raspberry pi3 and display.
1. Introduction

As air traffic increases yearly, the need for better surveillance systems is essential especially when navigating through noisy environment. Air traffic control (ATC) has uses radar based navigational system for air traffic control but due to exponential increase of air traffic, more sophisticated and advanced systems has been developed. The world of ATC is moving from uncooperative (PSR) to cooperative and dependent air traffic surveillance (SSR).[2] A radar system mainly classified as primary surveillance radar (PSR) and secondary surveillance radar (SSR). These surveillance technologies are coupled with radio communications to build a complete ATC system.

Primary surveillance radar (PSR) systems operate by sending out microwave signal towards the target and look for the reflected signal from the aircraft’s metallic surfaces. The reflected signal may contain the useful information like the aircraft speed, target radar cross section and distance. The primary surveillance radar systems may be either land-based or airborne. For land-based systems, the received information may be used by an air traffic controller to regulate the air traffic. However, land-based primary surveillance radar has limitations at low altitudes, does not work on the ground, and may also be influenced by atmospheric and weather conditions. Secondary surveillance radar (SSR) is an extension of primary surveillance radar and evolution of military identification friend or foe (IFF) to cater for most weaknesses of the PSR but still retains some weaknesses like poor resolution and various modes (A/C/S) indiscrimination[3]. Mode A/C basically provides identification and altitude while mode S in addition to previous functions of mode A/C allows unique addressing of targets with the aid of unique 24 bit aircraft addresses using a two-way data link between the ground station and aircraft for information exchange. Unlike PSR and SSR mode A/C, mode S has the ability to detect multiple aircraft located at same geographical position.

Current radar systems are reaching their maximum capacity because of reduction in bandwidth of signal and also the lack of digital data links. Synchronous garbling is another major concern in which the interrogation signal of SSR invokes a response from more than one aircraft, causing the replies sent by both aircraft to overlap at the receiver leading to loss of information at the ground station ATC facility. The above disadvantage and limitations has been overcome by a new surveillance referred to as automatic dependent surveillance broadcast (ADS-B). This technology typically involves airplanes constantly sending in real time position and flight data with the help of RF ADSB transmitter.[4].

ADS-B’s main purpose is to determine the aircraft position and broadcast into space. This information is broadcasted along with its call sign, heading, altitude and the identity of the aircraft automatically send to other aircraft and to air...
traffic control ground facilities. ADS-B is similar to mode S for the fact that it uses the same transmission frequency of 1090 MHz and squitter messages (messages that doesn’t require any interrogation while being transmitted). It differs from mode S in that the message is 112 bits, 120 micro seconds long and uses extended squitter.

2. Overview of ADS-B Technology

ADS-B is nothing but Automatic Dependent surveillance radar. It is an automatic system operate by its own without getting any input from the pilot. It is dependent because it relies on on-board equipment to gather the ADS-B data and broadcast it to other ADS-B users (aircraft or ground station).

General Overview of ADS-B System

ADS-B consist of two different services, they are ADS-B out and ADS-B in. ADS-B out provides the ATC with real time position information that is more accurate than the information available with current radar-based system[5]. An ADS-B transmit the signal in the form of packets. Each packet transmit at a rate of every second. The packets contains the information about the aircraft like latitude, longitude, heading and speed of the aircraft. The equipment used for ADS-B is also used by airplanes to receive other services called Traffic Information Services-Broadcast (TIS-B) and Flight Information Services-Broadcast (FIS-B). TIS-B is used to send additional information about the surrounding airspace to airplanes, and is particularly helpful when there are planes which are not equipped with ADS-B. The sent data is obtained by radar technology. FIS-B provides a better image of the surrounding meteorological and aeronautical situation.

One of the biggest advantages of ADS-B is the ability to provide coverage where radar could not reach. ADS-B gives clear picture about nearby flying aircraft to the ATC. It helps to reduces the time and work load of ATC during takeoff and landing.
ADS-B Message Format

ADS-B signals from aircraft to ATC and other ground control stations are transmitted at 1090MHz. They may contain 112 bits of data, encoded using PPM at a data rate of 1Mbps. Generally the ADS-B message is preceded by a 8us preamble bit which may serves as mark bit as well as start of a transmission and to allow the receiver to unambiguously determine aircraft information.

<table>
<thead>
<tr>
<th>Bits</th>
<th>3 Bits</th>
<th>3 Bits</th>
<th>24 Bits</th>
<th>56 Bits</th>
<th>24</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preamble</td>
<td>Downlink Format</td>
<td>Capability</td>
<td>Aircraft address</td>
<td>ADS-B data</td>
<td>Parity check</td>
</tr>
</tbody>
</table>

Figure 2: The components of an ADS-B message.

Preamble is the first field of the ADS-B message format as shown in figure 2. This field of 8 microsecond duration is a fixed bit sequence that allow the receiver to identify and synchronise with a message received. Next to preamble is the Downlink Format field which is the first field of the ADS-B message, it is used as an indicate the type of message that is being transmitted. For extended squitter messages, it is set to 17 or 10001(binary) \[7\]. The next field is the capability (CA) field or subtype field which is used a error detection and correction.

Following the capability field is the aircraft’s ID, which is 3-byte that contains the ICAO designation for each aircraft.

Following the aircraft ID are the 56bits of ADS-B data, containing information about the altitude, latitude, longitude, speed and heading of the aircraft. The last 24th bit in the frame is used for parity checking. Pulse position modulation (PPM) is used for encoding and transmitting the ADSB message[8] The PPM for each pulse results in the data occupying either the first or second half of the entire pulse, which in similar as that of Manchester encoding (Figure 3).

### 3. Design Methodology

Using various sources such as dipole antenna, Bandpass filter, RTL-SDR receiver, raspberry pi 3 and seven inch display, the ADS-B receiver constructed. The process include receiving the signal from the aircraft by dipole antenna and signal processing is done in MATLAB.
**Design of Dipole Antenna**

A dipole antenna is made up with straight electrical conductor measuring 1/2 wavelength from end to end and connected at the centre to a radio-frequency (RF) feed line. The dipole is inherently a balanced antenna, because it is bilaterally symmetrical.

Dipole antenna is half wavelength structure made of wire, tubing, PCB. Divided into two equal quarter wavelength and fed with a transmission line. Length of the dipole antenna is determined by the wavelength of radio waves used. Radiation pattern of the antenna is omnidirectional. For using dipole antenna as a ADS-B antenna i.e., to receive 1090MHz signal it should be mounted vertically.

\[
\text{Speed of light} = 3 \times 10^8 \text{ m/sec}
\]

\[
\text{Desired frequency} = 1090 \text{MHz} = 1090 \times 10^6 \text{Hz}
\]

\[
\text{antenna wavelength} = 3 \times 10^8 / 1090 \times 10^6
\]

\[
= 275mm
\]

Half of 275mm is 137mm more or less.

![Figure 4: Dipole antenna](image)

The antenna is made up of copper strip with a length of about 137mm and tuned to desired 1090MHz frequency. The efficiency of the designed dipole antenna has been determined by its standing wave ratio (SWR).

**Standing Wave Ratio (SWR)**

In radio engineering, standing wave ratio is the measure of impedance matching of loads to characteristics impedance of a transmission line. Vector Network Analyzer (VNA) is a type of RF network analyzer widely used for RF application to measure various S-parameters. The S-parameter measurement helps to effectively design the antenna and band pass filter. The Standing Wave
Ratio of the designed dipole antenna which is analyzed by an vector network analyzer shows as 1 : 1.2, at a frequency of about 1090MHZ.

4. Decoding ADS-B Signal with Rasspberry PI In Matlab

We may track the real time passes of aircraft by processing the Automatic Dependent Surveillance Broadcast(ADS-B) signals using MATLAB and Communication system toolbox.

Software Analysis

The required software and hardware for decoding the automatic dependent surveillance broadcast (ADS-B) signals.

Required Hardware

1. RTL-SDR receiver

Required Software

1. Communication system toolbox.
2. Communication system toolbox support package for RTL-SDR radio
3. Simulink support package for raspberry pi.

RTL-SDR Receiver with Raspberry PI Simulink in Matlab

Using the hardware RTL-SDR receiver and Raspberry pi, the support package such as communication system toolbox for RTL-SDR radio and Raspberry pi is installed in the MATLAB to construct the Simulink block (figure 5) for analyzing the ADS-B signal received.

![Figure 5: Block diagram](image)

RTL-SDR receiver block is a signal source that receives data from RTL-SDR radio and outputs a column vector signal of fixed length specified by the samples.
RTL-SDR radio receives signal from vertically polarised dipole antenna which is of frequency 1090MHz. RTL-SDR receiver receives data from RRTL-SDR radio.

After the signal is received by the RTL-SDR receiver, the baseband signal is forwarded to physical layer (Figure 7) of the Simulink block. In the physical layer the baseband samples are processed to produce different packets. At first the signal is interpolated by factor five to obtain practical sampling rate of 12 samples per packets. Then the signals are translated from baseband to intermediate frequency (IF) band. After that the magnitude of the signal is increased. Then it produces the packets that contain raw message bits. From the physical layer, the packets are fed into the Raspberry User datagram protocol by which the data’s from those packets get displayed. These data displayed can be seen in the map by launching map.

5. Decoding ADS-B Signals Using Hardware Setup

Automatic dependence surveillance broadcast (ADS-B) signal is received by the dipole antenna which is tuned to 1090MHz. These signals are received by the RTL-SDR receiver via Bandpass filter which is connected to the antenna.

Equipment required

1. RTL-SDR radio
2. Raspberry pi 3
3. Li-Po Battery
4. Dipole antenna
5. Bandpass filter

6. 7-inch display

Figure 8: Real time tracking of Aircraft

Vertically polarised dipole antenna is first designed and its efficiency has been verified through vector network analyser. 1090 MHz Band pass filter are also designed in order to improve the sensitivity of ADSB signal. The designed antenna is fed through a band pass filter and then connected to RTL-SDR. The complete setup is interfaced with seven inch display. After interconnecting the hardware system it is taken to a highly elevated region to capture the signals which are transmitted by the aircraft. Once the packets are successfully received and decoded the 7 inch display shows the real time position of the aircraft.

6. Conclusion

Automatic dependence surveillance broadcast (ADS-B) is the type of secondary surveillance radar technology for track the aircraft. This technology is responsible for communication between the air-air and air-ground traffic control. Each aircraft determines its own position by using GPS signal. This technology will replace the radar as the primary method of surveillance to detect the position of the aircraft. The ADS-B radar signal and hardware system design are discussed thoroughly in this paper, and MATLAB simulation demonstrates that the proposed approach allows the ADS-B radar system to track the aircraft.

The simulation done in MATLAB is implemented experimentally. From figure 8, the aircraft details such as aircraft ID represented as HEX and sqwk code, flight, altitude, speed, heading, latitude and longitude, message and time interval are determined. The frame work improves adaptability of ATC surveillance operations by leveraging the collected physical data from the aircraft [9][10].
References


