LabVIEW Based ADS-B Receiver and Decoder

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Abstract

In this project, we develop a system that intercepts and interprets Mode S communications between aircraft and ground stations. These Mode S messages can contain information about the identity, location, altitude, heading, and velocity of the aircraft, encoded according to the FAA's ADS-B specification. This information can then be used to create a map of aircraft in the surrounding area. We built the system using an NI-USRP programmable radio receiver and a LabVIEW based decoder to enable the capturing and decoding of message is real time.

Mode S Encoding Format

Mode S signals from aircraft to ground stations are transmitted at 1090 MHz. They contain either 56 or 112 bits of data, encoded using Pulse Position Modulation with a data rate of 1 Mbps. The Mode S message is preceded by a 8 us preamble which serves to both mark the start of a transmission and to allow the receiver to unambiguously determine the position of the high and low bits within a message. Transmitters complying with the ADS-B standard laid out in the document DO 260A will transmit an average of 6.2 messages per second.

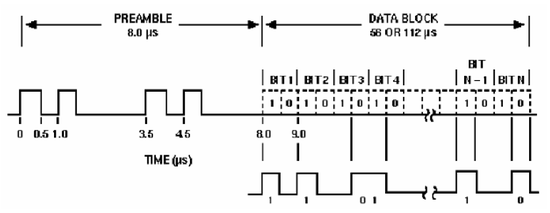

Figure 1:Mode S Message Format

ADS-B Specification

The ADS-B message transmission format will be required on all aircraft in United States aircraft starting in 2020. The specification requires all airborne aircraft to transmit 6.2 messages per second, including 2 position messages, 2 velocity messages, and one status message per second.

Airborne position messages contain the altitude of the aircraft together with the GPS position, encoded using Compact Position Reporting (CPR). Any single CPR encoded position message gives an unambiguous position within a radius of approximately 360 NM, which can be made globally unambiguous after receiving a position message encoded in both the "even" and "odd" CPR formats, and are accurate to within 5 meters of true position.

Overview of Receiver and Demodulator System

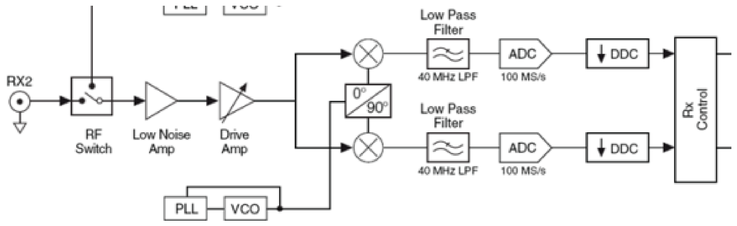

Figure 2. NI USRP-2920 System Block Diagram

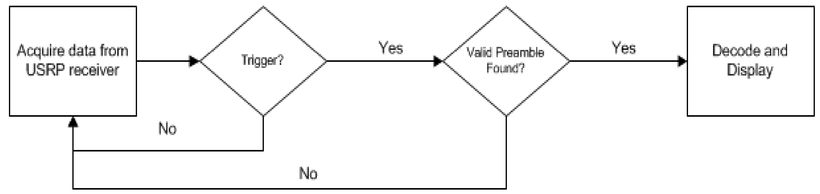

Figure 3: Data flow through Decoder

Incoming RF data is picked up by an antenna tuned specifically to 1090 MHz, then passed through the amps and filters built into the USRP hardware. The 40 MHz of incoming bandwidth are then converted to a digital signal, then down-sampled at a user defined rate by the digital down-converter before being passed into the software decoder. We sampled at 4 Megasamples/s, giving us 4 samples per bit entering into the decoder. This signal is then decimated, cutting it down to 2 samples/bit. We use a pattern matching algorithm to search for a valid Mode-S preamble within our data, and if one is detected, the remaining message bits are demodulated and then passed to a decoder which extracts the information from the message.

Decoding Example

We received the following frame of binary data after demodulation:

1000110110101100110100111011010101100011000000000100111000110101000101111000110010110100100000100

The first 5 bits contain the DownLink format, and DF = 17 identifies it as an ADS-B Extended Squitter broadcast, which consists of a 112 bits total.

Bits 8-32 contain the aircrafts registration information under the International Civil Aviation Organization (ICAO). This aircraft's ICAO address is ACD3B5, which identifies it as a Mooney M20 owned by Wagner Enterprises.

The first 8 bits of the message field give TypeCode = 12, subtype code = 3, which is one of the identifiers for an airborne position message, and the remaining bits encode the location itself, giving the coordinates 38.4049 N, 89.6434 W. The straight line distance from our receiving station on the Washington University campus to the airplane's location is approximately 60 km, which is well within the unambiguous range of CPR encoded location, so we can be sure that this was in fact the location of the airplane when the message was received.

The final 24 bits of the ADS-B message are a parity check and contain no additional information.

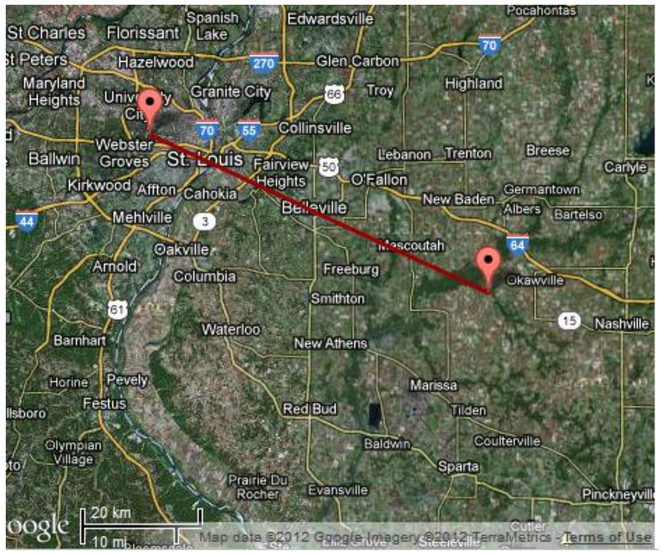

Figure 4: Receiving station (left) and Aircraft location (right).

CPR Decoding Algorithm

Given a zoneXCoord and zoneYCoord extracted from the ADS-B message, and the latitude and longitude of the receiver latS and lonS, the latitude and longitude of the aircraft can be decoded as follows:

dLat = 360 / (60 – cprFormat) where cprFormat = 1 for "odd" frames and 0 for "even" frames.

j = floor(latS / dLat) + floor(1/2+ latS mod dLat / dLat – zoneYCoord / 2^17

Latitude = dLat * (j + zoneYCoord / 2^17)

dLon = 360 / (NL(rLat) – cprFormat)

m = floor(lonS / dLon) + floor(1/2+ lonS mod dLon / dLon – zoneXCoord / 2^17

Longitude = dLon * (m + zoneXCoord / 2^17)