

Mode-S Receiver and ADS-B Decoder

Group 24 - *Sand5*

Michael Vose

Sean Koceski

Long Lam

Motivation

In this ever changing world of technology, the need for accuracy and security is becoming ever more important. Automatic Dependent Surveillance – Broadcast (ADS–B) is an element of the U.S. Next Generation Air Transportation System. By using ADS-B, an aircraft determines its position by GPS coordinates and periodically broadcasts it, enabling it to be tracked by air traffic control ground stations. This digital signal can also be received by other ADS-B equipped aircraft to provide situational awareness. The conversion of aircraft transponders to the ADS-B standard is underway in the United States and several other nations. However, ADS-B data is not encrypted and represents an exposure of highly precise and potentially exploitable commercial aircraft location information.

This is a problem that is specific to non-military aviation. Military aircraft transponders and ground stations already implement an encrypted digital protocol referred to as Mode-5. In contrast, commercial aircraft transponders use non-encrypted protocols known as Mode-A and Mode-C. A more general form of this protocol is Mode-S. Mode-S also allows civilian aircraft and ground support to participate in the use of this digital signal. We intend to use the Mode-S protocol to receive and decode the ADS-B transponder information from all commercial and civilian aircraft in our local airspace.

However, more can be gained than just a personal view of local airspace. The benefit to be demonstrated is an encryption of the information to protect the location data of such aircraft from being used by criminals, terrorist and enemy combatants to target the aircraft. This is the same type of benefit offered by Mode-5 for military aircraft, but extended to commercial and civilian flights. To this end, we plan to simulate the broadcasts of an encrypted ADS-B transponder in software, as an actual ADS-B broadcast would be forbidden. Bypassing our Mode-S receiver, our enhanced ADS-B decoder would then decrypt the signal and demonstrate the communication link. Meanwhile a standard ADS-B decoder would not be able to determine the aircraft's location.

Goal and Objectives

The goal of this project is to develop a programmable Mode-S receiver to obtain an ADS-B data stream. From the data stream, we will develop software that shall use the information to display it in near real-time. Ultimately, our program shall encrypt that data stream so the information can be protected.

Objectives:

- Low Cost (less than \$500).
- Portable (battery-powered with a mobile antenna system).
- Accurate (100km detection range and position resolution to 25m).
- Responsive (decoded position information with no more than a 5-second delay).

The Project Team

Since group-24 intends to enhance Mode-S with the benefits of Mode-5, then *Sand5* seems like an appropriate team name.

The *Sand5* team members and their background are:

- Sean Koceski, Undergraduate Program - Computer Engineering.
- Long Lam, Undergraduate Program - Computer Engineering.
- Michael Vose, Undergraduate Program - Computer Engineering

Michael will act as principal contact and team lead.

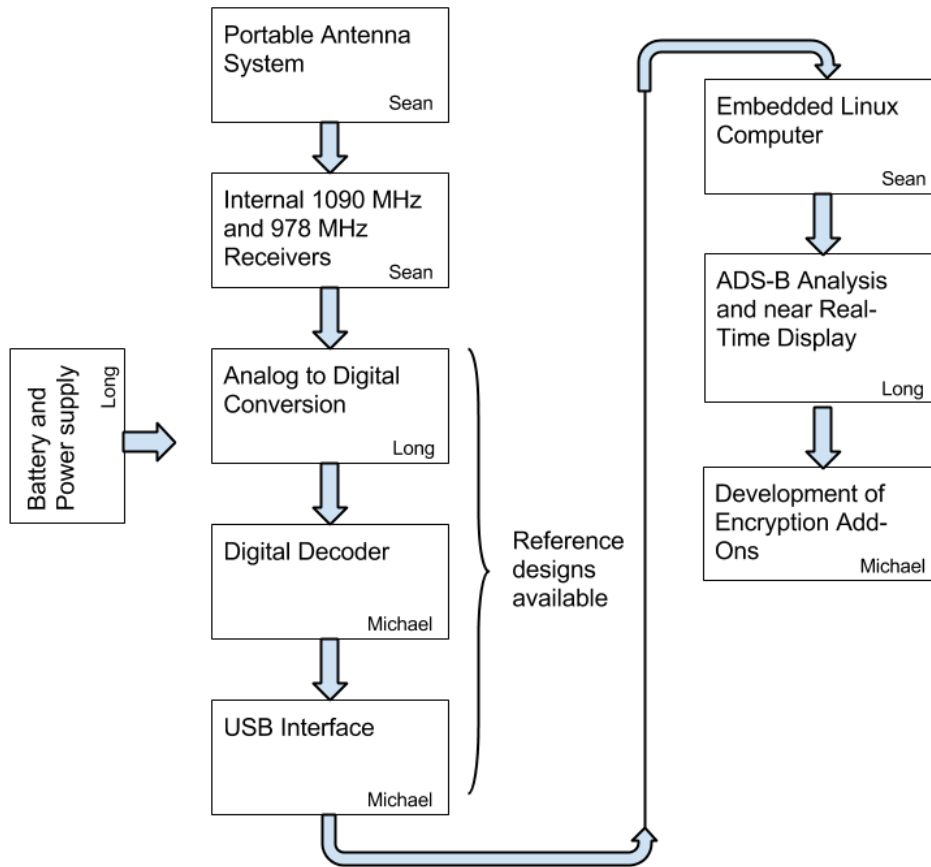
Detail Specifications and Requirements

- Build portable, tuned antennae for reception at 1090 MHz and at 978 MHz.
- Develop bandpass filters for these same frequencies.
- Determine if amplification is needed and if so, integrate optimally.
- Design and build a digital signal decoder, (possibly using a Realtek RTL2832U SDR and R820T tuner or a similar reference design.)
- The receiver will transmit the ADS-B data stream to a small-format embedded computer, (e.g. Beaglebone or similar,) via USB connection.
- Develop software to process the ADS-B data stream and display the result dynamically.

Specifically we will consider message types:

- DF0 (56-bit) Generally referred to as the ACAS message. TCAS is a subset of ACAS.
- DF4 (56-bit) Rollcall reply: Altitude - resolution to 100ft.
- DF17 (112-bit) Extended Squitter: Contains ADS-B data (position, heading, etc.)
- DF18 (112-bit) Extended Squitter: Same as DF17 but from ground traffic.
- DF20 (112-bit) Rollcall reply: Altitude - resolution to 25ft. Uses EHS/BDS registers.
- DF21 (112-bit) Rollcall reply: Identity. Uses EHS/BDS registers.
- Build a working prototype without encryption capability for proof of concept and initial testing.
- Develop software to simulate an encrypted ADS-B data stream, specifically for the same message types identified previously. The specifics of the encryption scheme are yet to be determined. For example, will the encryption occur within each ADS-B message frame or can less complex methods be implemented.
- Enhance the previously developed software to process the encrypted ADS-B data stream.
- An encryption-enhanced version of the device is the final working product for the project.

Block Diagram



Project Budget

Component	Estimated Costs
Battery	\$ 32.00
Power Supply Circuit	\$ 5.00
Antenna Hardware	\$ 25.00
Unamplified RF Receiver Circuits	\$ 15.00
ADC and Decoder FPGA	\$ 90.00
USB Interface	\$ 5.00
Custom Printed Circuit Board	\$ 100.00
Embedded Linux Board	\$ 90.00
Small-Format Display Screen	\$ 125.00
Total	\$ 487.00

ID		Task Name	Duration	Start	Finish
1		Group24 Project Scope	6 days	Thu 8/28/14	Mon 9/8/14
2		Research Software Defined Radio	12 hrs	Thu 8/28/14	Fri 8/29/14
3		Research Mode-S Receivers	12 hrs	Fri 8/29/14	Mon 9/1/14
4		Research ADS-B Topics	12 hrs	Tue 9/2/14	Wed 9/3/14
5		Preliminary Costs Estimate	3 hrs	Wed 9/3/14	Wed 9/3/14
6		Develop Initial Project Plan	18 hrs	Wed 9/3/14	Mon 9/8/14
7		Scope complete	0 days	Mon 9/8/14	Mon 9/8/14
8		Detailed Analysis	8 days	Tue 9/9/14	Fri 9/19/14
9		Review specifications/budget with team	3 hrs	Tue 9/9/14	Tue 9/9/14
10		Incorporate feedback on specifications	6 hrs	Tue 9/9/14	Wed 9/10/14
11		Draft detailed hardware specifications	12 hrs	Wed 9/10/14	Fri 9/12/14
12		Draft detailed software specifications	18 hrs	Fri 9/12/14	Thu 9/18/14
13		Improve milestone timeline	3 hrs	Thu 9/18/14	Thu 9/18/14
14		Obtain approvals to proceed (concept, timeline, bu	6 hrs	Fri 9/19/14	Fri 9/19/14
15		Analysis complete	0 days	Fri 9/19/14	Fri 9/19/14
16		Design Signal-to-USB	14.5 days	Tue 9/23/14	Thu 10/16/14
17		Develop Schematics	36 hrs	Tue 9/23/14	Wed 10/1/14
18		Outline Verilog Approach	24 hrs	Thu 10/2/14	Wed 10/8/14
19		Outline Software Classes/Modules	6 hrs	Thu 10/9/14	Thu 10/9/14
20		Review specifications	3 hrs	Fri 10/10/14	Fri 10/10/14
21		Incorporate feedback into specifications	6 hrs	Fri 10/10/14	Tue 10/14/14
22		Revise and expand project documents	12 hrs	Tue 10/14/14	Thu 10/16/14
23		Design Signal-to-USB complete	0 days	Thu 10/16/14	Thu 10/16/14
24		Design USB-to-Display	5.5 days	Tue 9/23/14	Wed 10/1/14
25		Outline Software Classes/Modules	12 hrs	Tue 9/23/14	Wed 9/24/14
26		Review specifications	3 hrs	Thu 9/25/14	Thu 9/25/14
27		Incorporate feedback into specifications	6 hrs	Thu 9/25/14	Fri 9/26/14
28		Revise and expand project documents	12 hrs	Fri 9/26/14	Wed 10/1/14
29		Design USB-to-Display complete	0 days	Wed 10/1/14	Wed 10/1/14
30		Design ADS-B Encryption	6.5 days	Wed 10/1/14	Fri 10/10/14
31		Evaluate streaming vs block modes	12 hrs	Wed 10/1/14	Fri 10/3/14
32		Outline Software Classes/Modules	12 hrs	Fri 10/3/14	Wed 10/8/14
33		Review specifications	3 hrs	Wed 10/8/14	Wed 10/8/14
34		Incorporate feedback into specifications	6 hrs	Thu 10/9/14	Thu 10/9/14
35		Revise and expand project documents	6 hrs	Fri 10/10/14	Fri 10/10/14
36		Design ADS-B Encryption complete	0 days	Fri 10/10/14	Fri 10/10/14
37		Prototype Signal-to-USB	14 days	Thu 10/16/14	Thu 11/13/14
38		Breadboard solution	18 hrs	Thu 10/16/14	Wed 10/22/14
39		Develop Verilog Decoder	30 hrs	Wed 10/22/14	Fri 10/31/14
40		Developer testing (primary debugging)	24 hrs	Fri 10/31/14	Fri 11/7/14
41		Revise and expand project documents	12 hrs	Fri 11/7/14	Thu 11/13/14
42		Development Signal-to-USB complete	0 days	Thu 11/13/14	Thu 11/13/14
43		Testing Signal-to-USB	12 days	Thu 11/13/14	Tue 1/13/15
44		Unit Testing	6 days	Thu 11/13/14	Wed 11/26/14
45		Test component modules to product specifica	6 hrs	Thu 11/13/14	Tue 11/18/14
46		Identify anomalies to product specifications	6 hrs	Tue 11/18/14	Wed 11/19/14
47		Modify Verilog	6 hrs	Wed 11/19/14	Thu 11/20/14
48		Re-test modified code	6 hrs	Thu 11/20/14	Fri 11/21/14
49		Revise and expand project documents	12 hrs	Fri 11/21/14	Wed 11/26/14

ID	Task Name	Duration	Start	Finish
50	Unit testing Signal-to-USB complete	0 days	Wed 11/26/14	Wed 11/26/14
51	Integration Testing	6 days	Wed 11/26/14	Tue 1/13/15
52	Module integration	6 hrs	Wed 11/26/14	Thu 12/4/14
53	Identify anomalies to specifications	6 hrs	Thu 12/4/14	Tue 1/6/15
54	Modify code	6 hrs	Tue 1/6/15	Wed 1/7/15
55	Re-test modified code	6 hrs	Wed 1/7/15	Thu 1/8/15
56	Revise and expand project documents	12 hrs	Thu 1/8/15	Tue 1/13/15
57	Integration testing Signal-to-USB complete	0 days	Tue 1/13/15	Tue 1/13/15
58	Develop USB-to-Display	10 days	Thu 10/16/14	Wed 11/5/14
59	Coding	24 hrs	Thu 10/16/14	Thu 10/23/14
60	Developer testing (primary debugging)	24 hrs	Thu 10/23/14	Fri 10/31/14
61	Revise and expand project documents	12 hrs	Fri 10/31/14	Wed 11/5/14
62	Development USB-to-Display complete	0 days	Wed 11/5/14	Wed 11/5/14
63	Testing USB-to-Display	11 days	Wed 11/5/14	Thu 12/4/14
64	Unit Testing	5 days	Wed 11/5/14	Tue 11/18/14
65	Test component modules to product specifica	6 hrs	Wed 11/5/14	Thu 11/6/14
66	Modify code	6 hrs	Thu 11/6/14	Fri 11/7/14
67	Re-test modified code	6 hrs	Fri 11/7/14	Wed 11/12/14
68	Revise and expand project documents	12 hrs	Wed 11/12/14	Tue 11/18/14
69	Unit testing USB-to-Display complete	0 days	Tue 11/18/14	Tue 11/18/14
70	Integration Testing	6 days	Tue 11/18/14	Thu 12/4/14
71	Module integration	6 hrs	Tue 11/18/14	Wed 11/19/14
72	Identify anomalies to specifications	6 hrs	Wed 11/19/14	Thu 11/20/14
73	Modify code	6 hrs	Thu 11/20/14	Fri 11/21/14
74	Re-test modified code	6 hrs	Fri 11/21/14	Tue 11/25/14
75	Revise and expand project documents	12 hrs	Tue 11/25/14	Thu 12/4/14
76	Integration testing USB-to-Display complete	0 days	Thu 12/4/14	Thu 12/4/14
77	Develop ADS-B Encryption	10 days	Wed 11/5/14	Wed 11/26/14
78	Coding	24 hrs	Wed 11/5/14	Thu 11/13/14
79	Developer testing (primary debugging)	24 hrs	Thu 11/13/14	Fri 11/21/14
80	Revise and expand project documents	12 hrs	Fri 11/21/14	Wed 11/26/14
81	Development ADS-B Encryption complete	0 days	Wed 11/26/14	Wed 11/26/14
82	Testing ADS-B Encryption	11 days	Wed 11/26/14	Wed 1/21/15
83	Unit Testing	5 days	Wed 11/26/14	Fri 1/9/15
84	Test component modules to product specifica	6 hrs	Wed 11/26/14	Thu 12/4/14
85	Modify code	6 hrs	Thu 12/4/14	Tue 1/6/15
86	Re-test modified code	6 hrs	Tue 1/6/15	Wed 1/7/15
87	Revise and expand project documents	12 hrs	Wed 1/7/15	Fri 1/9/15
88	Unit testing ADS-B Encryption complete	0 days	Fri 1/9/15	Fri 1/9/15
89	Integration Testing	6 days	Fri 1/9/15	Wed 1/21/15
90	Module integration	6 hrs	Fri 1/9/15	Tue 1/13/15
91	Identify anomalies to specifications	6 hrs	Tue 1/13/15	Wed 1/14/15
92	Modify code	6 hrs	Wed 1/14/15	Thu 1/15/15
93	Re-test modified code	6 hrs	Thu 1/15/15	Fri 1/16/15
94	Revise and expand project documents	12 hrs	Fri 1/16/15	Wed 1/21/15
95	Integration testing ADS-B Encryption complet	0 days	Wed 1/21/15	Wed 1/21/15