

Progress Report
Wireless Networking

Airplane Tracking Using ADS-B Signals

Lazaros Lazaridis
Victoria Mavrikopoulou
Nikolaos Skartsilas

University of TU Delft

Supervisors:

Dr. Przemyslaw (Przemek) Pawelczak
Amjad Yousef Majid

08/03/2017

1 Introduction

Wireless networking constitutes the key enabler of modern communications, given the myriad different use cases and applications. The wireless networking revolution brought fundamental changes to the way communications are set and implemented. Aim of this project is to offer us the opportunity to get acquainted with the reception of real-time packets. Thanks to a RTL-SDR dongle, the transmission and reception of wireless signals in real time is accomplished and the analysis and measurements of those are enabled across a broad frequency range.

The project focuses on airplane surveillance signals (ADB-S) and aims to discover a variety of aspects referred to air-traffic tracking. Automatic dependent surveillance-broadcast (ADS-B) is a new found technology in which aircrafts determine their position and periodically broadcast it, and it constitutes the primary method of air traffic control and surveillance. Modern airplanes use an ADS-B Mode-S transponder, in order to send to the air-traffic controllers their location, with improved precision and timing, enhancing aviation infrastructure and operations.

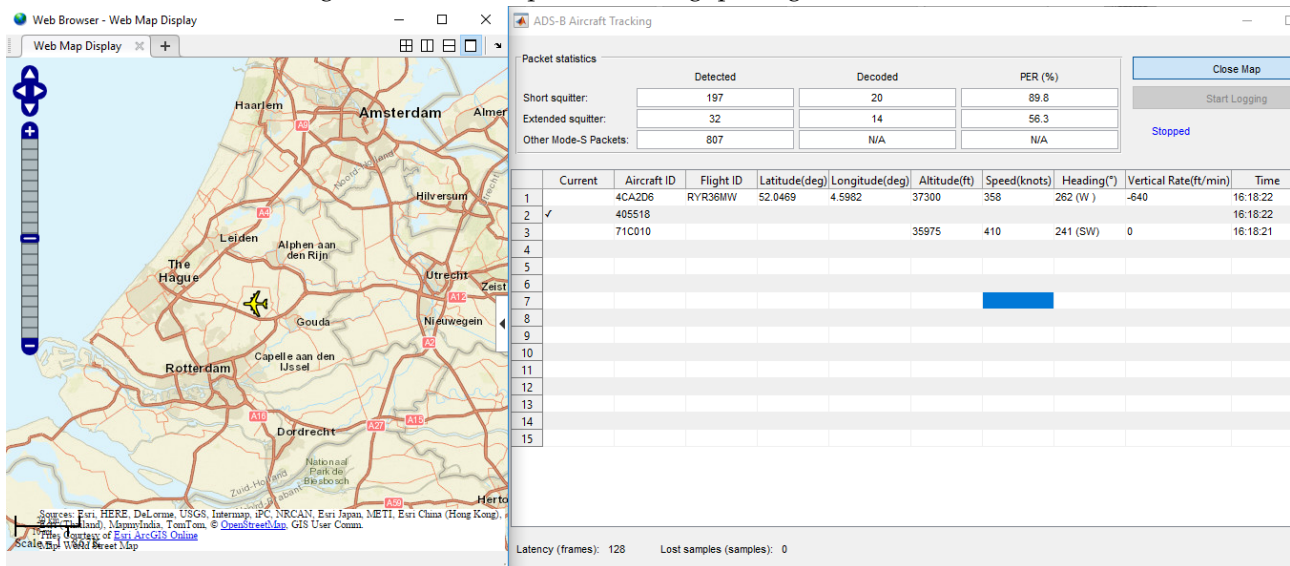
The signal to be analyzed is that of aircrafts sent out in order to be received by other aircrafts, vehicles or ground stations equipped to receive ADS-B. This broadcasting, is usually referred to as "ADS-B Out". ADS-B out periodically broadcasts information about each aircraft, such as identification, current position, altitude, and velocity, through an on-board transmitter. These unencrypted signals provide anyone with the chance to receive and decode them.

Main focus of this assignment is the code analysis and improvement in the way the signals are received and decoded. Furthermore, the conditions under which our receiver works best will be tested. To be more specific, distance from the source, environmental conditions like weather, temperature conditions are some of the features that are going to be examined. The purpose of these tests, is to check the influence of multi-path propagation and attenuation to the signals. Moreover, as it has been reported, improved reception can be achieved after applying a 1090 MHz band pass filter. For that reason a band pass filter will be in our priorities to be applied in the setup.

2 Tools

Using Simulink and Communication System Toolbox we familiarized ourselves with tracking planes, by processing ADB-S signals. The above mentioned in combination with a RTL-SDR dongle and 'Airplane Tracking Using ADS-B Signals' package fulfilled the reception of decoded signals. A former installation and configuration of the required drivers took place. The proper operation of signal detection was tested by the included examples of the ADS-B package, resulting in the detection of the available aircraft and the successful real-time display of their location data.

Figure 2.1: The 'Airplane Tracking' package GUI in Matlab.



Code modifications and tests were the following step. To do so, code had to be revisited and examined in depth as it can be very difficult to intervene into someone's code if its functionality has not been fully understood. The first step towards that direction was the full understatement of the set up of this communication system and the inside implementation of the source files.

3 ADB-S Decoding

ADB-S is a satellite based surveillance system that transmits information through MODE-S Extended Squitter at 1090MHz.

Every ADB-S message is 112 bits long and consists of 5 parts that are explained in the Figure below.

Figure 3.1: ADB-S Messages.



This table lists the key bits of a message:

nBits	Bits	Abbr.	Name
5	1 - 5	DF	Downlink Format (17)
3	6 - 8	CA	Capability (additional identifier)
24	9- 32	ICAO	ICAO aircraft address
56	33 - 88	DATA	Data
	[33 - 37]	[TC]	Type code
24	89 - 112	PI	Parity/Interrogator ID

The process of decoding ADB-s Signals is explained in depth in 'ADS-B Decoding Guide' which is open-source.

4 Trials

In this chapter the tests that were performed using the equipment mentioned above are displayed. The equipment includes two stations with exactly the same characteristics, same Matlab configuration and installations and versions of ADS-B air signal packages. The only difference is that one antenna has been used for a year and the other is a brand new.

The first experiment was taken to determine the difference in signal reception of the two antennas. The two stations were put next to each other and they were receiving packets for 3 minutes at the same time. The outputs of the new antenna will always be presented at the left side.

ADS-B Aircraft Tracking

Packet statistics

	Detected	Decoded	PER (%)
Short squitter:	3682	486	86.8
Extended squitter:	1235	405	67.2
Other Mode-S Packets:	24807	N/A	N/A

Launch Map
Start Logging
Stopped

	Current	Aircraft ID	Flight ID	Latitude(deg)	Longitude(deg)	Altitude(ft)	Speed(knots)	Heading(°)	Vertical Rate(ft/min)	Time
1		484F80								19:31:33
2		3C5EF2	GW0370	51.9349	3.2632	28000	311	260 (W)	64	19:32:42
3		406D98								19:31:58
4		4CA8E4					356	258 (W)	64	19:32:01
5		3C66A2	DLH957	52.0452	4.8708	35000	549	118 (SE)	0	19:32:45
6		484A92								19:32:45
7	✓	478079				31075	418	23 (NE)	1344	19:32:46
8		406A02	BAW884	52.0311	4.8464	36975	543	98 (E)	0	19:32:46
9		484C25								19:32:30
10		4CA912	RYR79MC			38000	400	231 (SW)	-64	19:32:41
11		47340B				28000	317	269 (W)	0	19:32:00
12		406D98								19:31:56
13		405DEA								19:32:45
14		4CA589	RYR52HF	52.1373	4.4585	35000	524	87 (E)	0	19:32:46
15		485207		52.1656	4.3513	7000	267	148 (SE)	0	19:32:45

Figure 4.1: New Antenna.

ADS-B Aircraft Tracking

Packet statistics

	Detected	Decoded	PER (%)
Short squitter:	4633	688	85.2
Extended squitter:	1412	683	51.6
Other Mode-S Packets:	21894	N/A	N/A

Launch Map
Start Logging
Stopped

	Current	Aircraft ID	Flight ID	Latitude(deg)	Longitude(deg)	Altitude(ft)	Speed(knots)	Heading(°)	Vertical Rate(ft/min)	Time
1		484C25								19:32:40
2		484F80								19:32:09
3		406D98								19:32:21
4		405D50								19:32:04
5		4CA912		52.6192	4.5319	38000	400	231 (SW)	-64	19:32:43
6		484A92								19:32:34
7		3C5EF2	GW0370	51.9300	3.2202	28000	312	260 (W)	0	19:32:40
8		3C66A2	DLH957	52.0367	4.8967	35000	548	118 (SE)	0	19:32:44
9		478079	SAS4746	51.6177	4.3613	31225	421	23 (NE)	1008	19:32:43
10	✓	3C6744								19:32:44
11		47340B	VIZZ100	51.8652	3.0855	27875	316	270 (W)	-832	19:32:23
12		406A02	BAW884	52.0296	4.8616	36975	543	98 (E)	0	19:32:43
13		405DEA								19:32:42
14		485207		52.1656	4.3513	7000	267	148 (SE)	0	19:32:38
15		4CA589	RYR52HF	52.1379	4.4781	35000	524	87 (E)	64	19:32:43

Latency (frames): 128 Lost samples (samples): 0

Figure 4.2: Old Antenna.

As it can be observed, while the new antenna receives more S-Mode packets, the old one is able to receive more Squitter packets. The difference lies to the fact that the first antenna is able to fully decode 5 airplane flight details while the second one 6 of them.

The second experiment that was carried out presents the difference in the signal reception in different positions regarding the height that the antenna was positioned. The first image shows the results exported on the base floor of the EWI building while the second one concerns the results on the 20th floor. The signal reception once again took place simultaneously.

Packet statistics

	Detected	Decoded	PER (%)
Short squitter:	3782	1163	68.6
Extended squitter:	2230	862	61.3
Other Mode-S Packets:	30182	N/A	N/A

Launch Map
Start Logging
Stopped

	Current	Aircraft ID	Flight ID	Latitude(deg)	Longitude(deg)	Altitude(ft)	Speed(knots)	Heading(°)	Vertical Rate(ft/min)	Time
1		484C24								19:48:04
2		485206	KLM994	52.1444	4.7229	3235	190	3 (N)	-1152	19:48:05
3		484556				3975				19:47:52
4		4841C3								19:47:42
5		3944C8								19:48:03
6		485084								19:47:59
7		484A92								19:48:05
8		4B1617	SVWR734	52.2129	4.7293	1950	162	4 (N)	-448	19:48:00
9		400E51	BAW9442	52.1541	4.9094	4500	279	177 (S)	-768	19:48:05
10		484132	KLM40E	52.0872	4.7595	3000	179	4 (N)	0	19:48:02
11		48418D								19:48:02
12		3C6670	DLH9WV	52.1133	4.7959	36975	562	119 (SE)	0	19:48:04
13		484C50								19:47:48
14		4007DC								19:48:05
15		48455B	KLM52R	52.0407	4.6187	5425	229	102 (E)	-576	19:48:04

Latency (frames): 1 Lost samples (samples): 0

Figure 4.3: New Antenna on 20th floor.

Packet statistics

	Detected	Decoded	PER (%)
Short squitter:	4253	750	82.4
Extended squitter:	1622	759	63.2
Other Mode-S Packets:	25934	N/A	N/A

Launch Map
Start Logging
Stopped

	Current	Aircraft ID	Flight ID	Latitude(deg)	Longitude(deg)	Altitude(ft)	Speed(knots)	Heading(°)	Vertical Rate(ft/min)	Time
1		48455B	KLM52R	52.0408	4.5600	5775	229	102 (E)	-576	19:47:41
2		484A92								19:48:03
3		4C49BC		52.2024	4.2764	35000	538	92 (E)	0	19:48:02
4		491248								19:47:49
5		7810C7	QCR7965	52.1207	3.4676	32250	380	238 (SW)	-2368	19:48:00
6		3824F2	AFR202V	51.8238	4.5874	20575	387	198 (S)	2496	19:47:25
7		3C6670	DLH9WV	52.1126	4.7978	37000	563	119 (SE)	0	19:48:02
8		4492E2								19:47:49
9		3944C8								19:48:02
10		78023E		52.4279	4.3626	33000	593	100 (E)	64	19:48:02
11		471EA9		51.8933	3.3641	28375	293	285 (W)	-1472	19:47:56
12		4C0265								19:47:32
13		4C4AE7								19:48:00
14		4D02A2								19:47:57
15		400AA0				16000	337	243 (SW)	64	19:48:00

Latency (frames): 128 Lost samples (samples): 0

Figure 4.4: Old Antenna on base floor.

As it can be conceived from the above images, the difference between the signals received is now more significant than before. On the 20th floor, the S-Mode packets received are way more and the flight IDs are now 6 in comparison with those on the base floor, which were only 4.

According to the quick start guide of the rtl-sdr dongle, the best results can be obtained if the dongle is placed on a metallic surface. Our antennas exhibited the following results.

Packet statistics

	Detected	Decoded	PER (%)
Short squitter:	1073	5	99.5
Extended squitter:	75	0	100.0
Other Mode-S Packets:	25547	N/A	N/A

Launch Map
Start Logging
Stopped

	Current	Aircraft ID	Flight ID	Latitude(deg)	Longitude(deg)	Altitude(ft)	Speed(knots)	Heading(°)	Vertical Rate(ft/min)	Time
1		4492E2								19:52:09

Latency (frames): 1 Lost samples (samples): 0

Figure 4.5: New Antenna on 20th floor.

Packet statistics

	Detected	Decoded	PER (%)
Short squitter:	3609	436	87.9
Extended squitter:	1496	564	62.3
Other Mode-S Packets:	23071	N/A	N/A

Launch Map
Start Logging
Stopped

	Current	Aircraft ID	Flight ID	Latitude(deg)	Longitude(deg)	Altitude(ft)	Speed(knots)	Heading(°)	Vertical Rate(ft/min)	Time
1		4492E2	BELZYB	52.1986	4.7820	26275	373	42 (NE)	960	19:53:55
2		40097F								19:53:44
3		40090B	BAW798H	52.6443	4.6376	33050	534	75 (E)	-64	19:52:44
4		400629	EXS348	52.5522	4.4931	34000	368	296 (NW)	64	19:53:55
5		4059FA								19:52:46
6		4063DE					320	283 (W)	-64	19:53:28
7		491248								19:52:13
8		484F5A	TFI555	52.0447	3.2016	25775	378	260 (W)	1408	19:51:40
9		471EA9	VZZ254	51.9100	2.8157	26600	289	288 (W)	-1208	19:53:31
10		484A92								19:53:41
11		484CB5	KLM1030	52.1244	4.5243	4000	228	139 (SE)	64	19:53:43
12		7810C7								19:51:30
13		40621F	EZY81XZ	52.1689	4.3920	4950	292	139 (SE)	-1024	19:53:55
14		436991	MUQIC	52.5504	4.3636	43925	512	68 (E)	768	19:53:49
15		780227		52.6884	4.8775	36000	407	235 (SW)	0	19:53:53

Latency (frames): 128 Lost samples (samples): 0

Figure 4.6: Old Antenna on base floor.

Although the packets on the left hand side image are received, they do not seem to be decoded for some reason. This result will become a subject for further investigation, as it seems an interesting fact.

A third experiment was carried out in order to examine the influence of gain in terms of signal strength throughout the frequency spectrum. Increasing the gain slider with respect to noise restrictions, the signal strength may be amplified considerably.

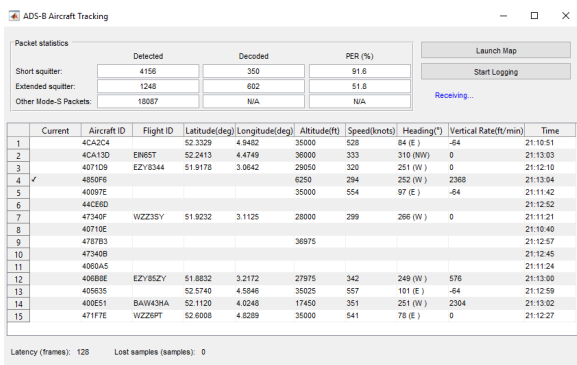


Figure 4.7: Tuner Gain 90db

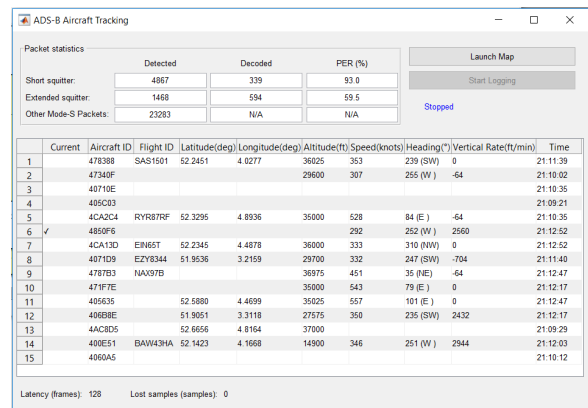


Figure 4.8: Tuner gain 60db

During the execution of the experiment though, no such improvement was noticed, as the tuner gain was increased up to 90 db. Further trials will be carried out in order the optimal gain to be discovered.

Tuning the radio on an RTL SDR receiver, it's very common to find the frequency read-out to be wildly inaccurate. Frequency correction parameters used as an error correction in ppm (parts per million) in order to adjust and correct the device at the software side of operation. We search for this unique PPM value for our RTL USB dongle. We executed one experiment with an increased frequency correction value at 20ppm. We collected the results by using simultaneously a dongle with frequency correction oppm and another with 20 ppm and they are presented in the above images.

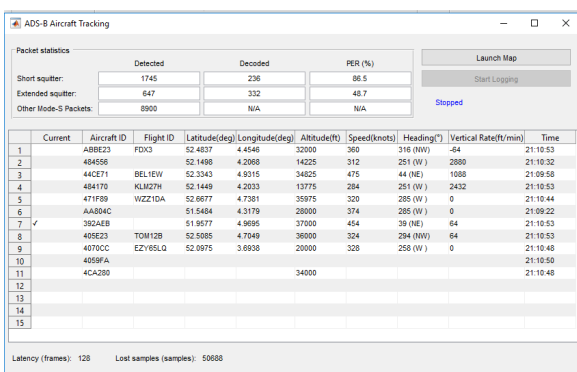


Figure 4.9: Frequency correction 20ppm

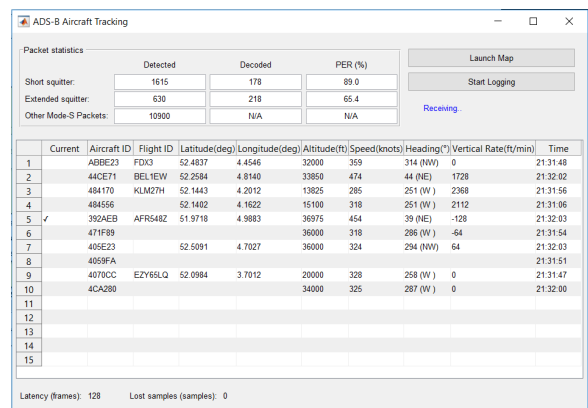


Figure 4.10: Frequency correction oppm

The differences are not significant, a fact that means that we should try to find the ideal frequency correction with the use of the SDRSharp tool.

5 Objectives and Strategies

The assignment aims to the implementation of our own analysis methodology in an already existing system, based on mathematical tools and simulations. The system that was selected receives packages real-time and decodes them providing the desired information.

Our aim is, by changing some parameters that affect the way of packet reception, to improve the acquired output. In later stages, changes may be applied to the code itself, in order to test if these changes enhance the way code operates.

Also, tests will be conducted with respect to determine under which circumstances the reception of the real-time packets performs best. These tests will include reception from different places, closer to the source of the desired signals which are provided by the airplanes, changes in the temperature of the antenna and reception from various heights.

Last but not least, to improve the accuracy of the current setup we would like to check if the Triangular technique would be applicable in this case.