Automatic Location using ADS-B Mode for Ground Vehicle

Marisa Premitasari[1], Uung Ungkawa [2], and Adjie Putra Perdana[3]

[1,2,3] Department of Informatics, Institut Teknologi Nasional (Itenas), Bandung - INDONESIA

[*] Corresponding author e-mail: marisa@itenas.ac.id

Abstract

To increase the ground vehicle safety on landing area, Federation Aviation Administration (FAA) published some regulations for flight operation standard to implement transponder technology on aircraft by January 1st, 2020. These transponder technologies, which implemented on aircraft transmitter, aimed to transmit the aircraft position (longitude and latitude) data using Automatic Dependent Surveillance-Broadcast (ADS-B) mode as its automatic location. The aircraft will then communicate with the ground vehicle through an Air Traffic Controller (ATC) to avoid collision around landing areas.This paper presents the test results of a transmission system that simulates the ADS-B data sending through a transponder from a ground vehicle on both static and dynamic environment. The data transmission system designed by implementing HackRF, as decrypts hardware for radio data and a transmitter as the hardware for decrypting the ADS-B data . Moreover, these systems used a mini-computer called raspberry to process the ADS-B data and send the GPS data to the ground vehicle at a real-time condition. Furthermore, Pulse Position Modulation (PPM) utilised to change the digital format data-to-data radio signal. Then, the hackRF transmitter which sends ADS-B data is captured by the receiver so ground vehicle coordinate will enable to detect by a receiver or radar. Results show time delays of 1-5 second for static test and 1-20 second for the dynamic test. .

Keywords: ADS-B,longitude,latitude,ground vehicle, transmission

1. Introduction

The development of radar technology, especially in data transmission, has undergone sophisticated changes. For example, Primary Surveillance Radar (PSR) and Secondary Surveillance Radar (SSR), a technology that commonly used all around the world, will no longer exist and soon replaced by ADS-B. ADS-B, abbreviated from Automatic Dependent Surveillance-Broadcast is one of flight mode as navigation tools to communicate with ATC (Air Traffic Controller) or another aircraft. ADS-B mode launched as the development from the existing data transmission system, which is PSR and SSR (Devolski et Al,2014). The previous transmission mode can only detect the location of a small object, such as military aircraft, but not its identity. SSR data transmission system operated by using 1030 MHz carrier frequency, which also requires a request to respond while transmitting the data, afterwhile the transponder answer and giving the feedback signal at 1090 MHz carrier frequency. ADS-B signal has the advantage that does not only respond to SSR interrogation but also detect aircraft distance and its location. Moreover, ADS-B also communicates with another ADS-B mode to prevent the collisions between aircraft. This ADS-B regulation will be published by January 1st, 2020 (ICAO,2017). ADS-B mode works by using satellite technology to monitor aircraft position while it is moving and periodically it will broadcast pieces of information to navigation tools on the plane, the pilot and ATC. The information received by pilots and ATC as the replacement mode for SSR will give situation awareness and is capable of getting the data at any time (Airnav Indonesia,2017). At this project, the authors are building a data transmission system with ADS-B mode and testing it on a ground vehicle which Pulse Position Modulation (PPM) as the modulation technique.

2. Methods

These research project measured how long-time delays coming from ADS-B data signals transmission which are transmitted to a receiver. Time delays measured based on latitude and longitude comparation result and its measurement obtained from each time span on the transmitter .ADS-B signals will sent through 1090 MHz antenna . There are five step sytem development that has been used as a method reference, namely waterfall method. First step is system requirement while this system need to analyze and design specific hardwares and softwares. For hardware devices, there were six tools implemented on these project which are Laptop Asus A43E, Smartphone One Plus X, Raspberry Pi 3 B, Rtl SDR, HackRF and GPS Module. For software devices, Phyton IDLE, Modul Phyton and Avare ADS-B has been implemented. Second Step of this methods reference is system design, illustrated on figure 1 as above

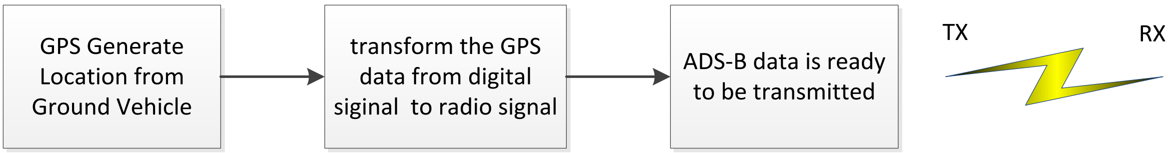

Fig. 1: System Design

Input coming from GPS module determine ground vehicle coordinate which generate longitude, latitude and altitude data that is ready to proceed by HackRF transmitter. This transmitter will transform digital signal data to radio signal and the signal captures by the receiver. Implementation process is the third step which illustrated on figure 2 named Diagram Block System.

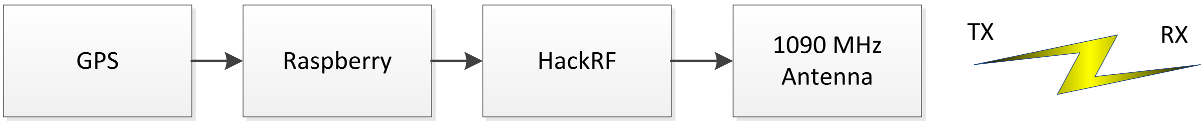

Fig. 2: Diagram Block System

This picture explained data transmission flow whereas the GPS module determine initial data coming from ground vehicle that has been generated three directions vehicle coordinated which updated in every second. The data converted into ADS-B file by Raspberry minicomputer whereas the data changed into DF-17 or S-mode format. Afterwhile the raspberry transformed the signal from digital signal to radio signal. Before forwarding datas to HackRF transmitter, its signal will modulated by PPM. HackRF, thats also functioned as repeater will forwarding ADS-B data which has been transformed into DF-7 or S-mode to the receiver. An antenna is sending a file with raw iq format at 1090 MHz carrier frequency so the data is ready to be received. These method step using comparasion about how long the delay occured and how accurate the transmission while sending ADS-B data format. Final step of this method is testing while the hardware built up is place on a motorcycle as the dummy ground vehicle and the specification is Honda Beat with D1B02N26L2 A/T Type, launched in 2017 with 108 CC capacity and having ABCDEF, BBBBBB, CCCCCC call sign. The motorcycle will be running and receiver will capture its position wheter it was detected or not. This testing step revealed on how accurate data transmission using ADS-B and how the delay gap occured.

3. **Results and Discussions**

The testing results of data transmission system with these automatic location shows tables for GPS testing, Static testing and Dynamic testing as follows

3.1. GPS Testing

This GPS testing was created to test the accuracy coming from GPS module on transmitter compare with GPS module on Google Maps. This testing was carried out at Ujung Berung, one of Bandung City sub-district and table 1 shown Gap results about 0.00007-0.00013 at latitude coordinate and 0.00007-0.0001 at its longitude.

Table 1: The GPS Testing at Ujung Berung Sub-District

GPS Transmitter		GPS Google		Gap Value	
Latitude	**Longitude**	**Latitude**	**Longitude**	**Latitude**	**Longitude**
-6.9100394	107.69827	-6.9101	107.69834	0.00007	0.00007
-6.91004	107.69827	-6.91011	107.69836	0.00007	0.00009

-6.91004	107.69828	-6.91013	107.69836	0.00009	0.00008
-6.910039	107.69827	-6.91014	107.69836	0.00009	0.00009
-6.910038	107.69827	-6.91014	107.69835	0.00009	0.00008
-6.9100366	107.69827	-6.91015	107.69836	0.00012	0.00009
-6.910036	107.69827	-6.91015	107.69836	0.00012	0.00009
-6.9100356	107.69827	-6.91016	107.69837	0.00013	0.0001
-6.910035	107.69827	-6.91016	107.69837	0.00013	0.0001
-6.910035	107.69827	-6.91016	107.69837	0.00013	0.0001
-6.9100347	107.69827	-6.91016	107.69837	0.00013	0.0001

3.2. Static Testing

.Table 2 as seen below shown result of GPS accuracy testing statically.

Table 2: Statically Accuracy Testing

Transmitter		**Receiver**		**Gap Value**	
Latitude	**Longitude**	**Latitude**	**Longitude**	**Latitude**	**Longitude**
6	107	5.999978	107.0002	0.000022	0.00002
6	107	5.999978	107.0002	0.000022	0.00002
6	107	5.999978	107.0002	0.000022	0.00002
6	107	5.999978	107.0002	0.000022	0.00002
6	107	5.999978	107.0002	0.000022	0.00002
6	107	5.999978	107.0002	0.000022	0.00002
6	107	6	107	0	0.00002
6	107	5.999978	107.0002	0.000022	0.00002
6	107	5.999978	107.0002	0.000022	0.00002
6	107	6	107	0	0.00008
8	107	8.000002	107.0002	0.000002	0.00002
8	107	8.000002	107.0002	0.000002	0.00002
8	107	8.000002	107.0002	0.000002	0.00002
8	107	8.000002	107.0002	0.000002	0.00002
8	107	8.000002	107.0002	0.000002	0.00002
8	107	8.000002	107.0002	0.000002	0.00002
8	107	8.000002	107.0002	0.000002	0.00002
8	107	8.000002	107.0002	0.000002	0.00002
6	107	5.999978	107.0002	0.000022	0.00002

Static Testing was created to test the accuracy and delay time coming from ADS-B transmission by transmit the data on ten second each at 6,8 then 4 at latitude coordinate and 107 on its longitude This test aimed to obtained how much the latitude and longitude gap coordinate on receiver and the acuuracy on transmitter while doing the test statically.From table 2 above, we concluded that static testings resulted in latitude gap value both on transmitter and receiver. Meanwhile table 3, 4 and 5 is testing results for three times experiment delay with various time .

Table 3: First Experiment Testing

Time Span	Transmitter		Receiver	
	Latitude	Longitude	Latitude	Longitude
10:38:15	0	0	0	0
10:38:16	0	0	0	0
10:38:17	0	0	0	0
10:38:18	0	0	0	0
10:38:19	0	0	0	0
10:38:20	6	107	0	0
10:38:21	6	107	0	0
10:38:22	6	107	0	0
10:38:23	6	107	5.999978	107
10:38:24	6	107	0	0
10:38:25	6	107	0	0
10:38:26	6	107	0	0
10:38:27	6	107	0	0
10:38:28	6	107	5.999978	107
10:38:29	6	107	5.999978	107
10:38:30	6	107	0	0

Table 4: Second Experiment Testing

Time Span	Tranmitter		Receiver	
	Latitude	Longitude	Latitude	Longitude
10:50:20	0	0	0	0
10:50:21	0	0	0	0
10:50:22	0	0	0	0
10:50:23	0	0	0	0
10:50:24	0	0	0	0
10:50:25	8	107	0	0
10:50:26	8	107	0	0
10:50:27	8	107	0	0
10:50:28	8	107	8.000002	107
10:50:29	8	107	0	0
10:50:30	8	107	0	0
10:50:31	8	107	0	0
10:50:32	8	107	0	0
10:50:33	8	107	8.000002	107
10:50:34	8	107	0	0
10:50:35	8	107	0	0

Table 5: Third Experiment Testing

Time Span	Receiver		Gap Value	
	Latitude	Longitude	Latitude	Longitude
10:53:50	0	0	0	0

10:53:51	0	0	0	0
10:53:52	0	0	0	0
10:53:53	0	0	0	0
10:53:54	4	107	4.000001	107
10:53:55	4	107	0	0
10:53:56	4	107	0	0
10:53:57	4	107	3.999985	107
10:53:58	4	107	0	0
10:53:59	4	107	4.000001	107
10:54:00	4	107	4.000001	107
10:54:01	4	107	0	0
10:54:02	4	107	3.999985	107

ADS-B data with 6 latitude coordinates obtained gap values about Data ADS-B 0.000022 for the latitude dan 0.0000168 for its longitude coordinates, although there are some datas which doesn‘t have gaps on latitude coordinates. ADS-B data with 8 latitude shown some gap value about 0.000002 at latitude coordinates and the longitude shown 0.0000168. Moreover, ADS-B data with 4 latitude shown gap value about 0.000001 at latitude and 0.0000168 at longitude coordinates. Gap results from statically testing shown longitude and latitude coordinates from ADS-B data which was sent from the transmitter and captured by the receiver that is obtained gap value for the latitude around 0-0.000022 and 0.00000072-0.0000168 for the longitude. In table 3, data transmission on first trial proceeds at 6,8,4 latitude coordinates and 107 longitude coordinates which started at 10.38.15. It sent ADS-B data at 10.38.20 whereas the data just red on receiver at 10:38:23, 10:32:28 and 10:32:29. On Second experiment, given by table 4 which start at 10:50:20, ADS-B data sent at 10:50:25 and read by the receiver at10:52:28 dan 10:50:33. Table 5 which performed third experiment just started at 10:53:50 where the data sent at 10:53:54. Receiver reading the ADS-B data at 10:53:54,10:53:57, 10:53:59,10:54:00,10:54:02,10:54:03 and10:54:05. Results from delay testing concluded that delay time occurred from these transmissions on static testing shown around 1-5 second

3.3 Dynamic Testing

Dynamic testing was carried out to measure the accuracy of transmitter and receiver with moving ground vehicle. Dynamic testing showed latitude and longitude result compared by ADS-B data on receiver and transmitter whereas the data is recorded each second. Table 6 shown gap value around 0.00001-0.00034 at latitude coordinates and 0-0.00009 at the longitude

Table 6: Dynamic Accuracy Testing

GPS Transmitter		GPS Google		Gap Value	
Latitude	**Longitude**	**Latitude**	**Longitude**	**Latitude**	**Longitude**
-6.910178	107.69864	-6.91016763	107.6986431	0.00001	0
-6.910171	107.69864	-6.91016763	107.6986431	0	0
-6.9101863	107.69863	-6.91016763	107.6986431	0.00002	0.00001
-6.9102025	107.69858	-6.91021418	107.6985958	0.00001	0.00002
-6.91018	107.69858	-6.91016763	107.6985958	0.00001	0.00002
-6.910176	107.69861	-6.91017151	107.6986022	0.00001	0.00001
-6.9101725	107.698616	-6.91016763	107.6985958	0	0.00001
-6.9101715	107.698616	-6.91016763	107.6985958	0	0.00002
-6.9101477	107.69861	-6.91016763	107.6985958	0.00002	0.00002
-6.9101405	107.698616	-6.91016763	107.6985958	0.00003	0.00001
-6.910144	107.69865	-6.91012108	107.6986431	0.00002	0.00001
-6.910145	107.69863	-6.91012108	107.6986431	0.00003	0.00001

-6.9102225	107.69863	-6.91016763	107.6986431	0.00005	0.00001
-6.9102783	107.69861	-6.91026073	107.6986431	0.00002	0.00003
-6.910508	107.69866	-6.91044694	107.6985958	0.00006	0.00006
-6.9105635	107.69878	-6.91054005	107.6986905	0.00002	0.00009

Meanwhile Figure 3 as shown above mapping ground vehicle footprint for dynamic testing whereas green bullet sign describe detected signal and red cross sign describe undetected signal Figure 3 also describe the path for ground vehicle that route around Ujung Berung Residence with +- 380 meters away and tooks about 2 minutes.

Fig. 3: Ground Vehicle 'footprint' for Dynamic Testing

The results for the dynamic testing shown delay around 1-20 second from transmission whereas these test start at 10:20:35 and ADS-B sytem start to send the data at 10:20:40

4. Conclusion

Automatic location with ADS-B mode on a ground vehicle aims to simplify ADS-B data which transmit from aircraft to communicate. The data sent to ADS-B ground vehicle only contained longitude and latitude coordinates position unlike real data on aircraft such as altitude coordinates,compass for wind directions or speed information. After doing accuracy test on coordinates between GPS transmitter and GPS Google, Gap value occurred around 0.00001-0.000015 for latitude coordinates and 0.00001-0.00011 for the longitude. For accuracy testing between static transmitter and receiver,gap value occurred around 0.000001-0.000022 at latitude coordinates and 0.0000072-0.0000168 at the longitude. On dynamic testing, data transmission accuracy between receiver and transmitter obtained gap value around 0.000001-0.000034 for longitude coordinates and around 0-0.000009 for the latitude. The static and dynamic test concluded, these ADS-B data transmission systems obtained delay time around 1-5 second for static testing and 1-20 second for the dynamic testing. Sugestion to develop this project is data transmission system with ADS-B mode are enable by using decrypt radio as translator on the receiver with more sophisticated specification to reduce delay times because of limited data input which only generate latitude and longitude coodinates . Moreover, such a project by doing an investigation at altitude coordinates on ground vehicle is needed to be developed.

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