

# [EN-113] Development of TIS-B system for situation awareness enhancement

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**Abstract:** Air traffic situational awareness is an essential factor for flight safety and efficiency. Today, pilots have only two methods for situational awareness with, through visual acquisition or with traffic information via voice messages from Air Traffic Controllers. These methods have limitations in reducing aircraft separation because of their delay in acquiring traffic. To improve the acquisition of traffic information, airborne surveillance with a ADS-B/TIS-B has been proposed. This paper reports on the prototype TIS-B system developed by ENRI and on the results of evaluations with flight testing.

**Keywords:** ADS-B, TIS-B, Situational awareness

## 1. INTRODUCTION

Situational awareness is an essential factor for flight safety and efficiency. Aircraft encounter various situations like significant weather and obstacles that threaten safety services. Today, pilots have only two inefficient methods for air traffic situational awareness, through visual acquisition or traffic information via voice messages from Air Traffic Controllers (ATC). Therefore, these methods have limitations in reducing aircraft separation due to the delay in acquiring traffic conditions.

Recently, a lot of applications to reduce airborne separation have proposed for more efficient operation. However, it is impossible to operate these applications with current airborne surveillance capabilities. To improve the acquisition of traffic information, airborne surveillance with ADS-B/TIS-B has proposed. ADS-B (Automatic Dependent Surveillance - Broadcast) and TIS-B (Traffic Information Service - Broadcast) are concepts of traffic information services and not signals. These are implemented with various media including a 1090MHz extended squitter, a UAT (Universal Access Transceiver), a VDL mode 4 (VHF Digital Link mode-4) and so on. ENRI has developed a prototype TIS-B system using a 1090MHz extended squitter. This paper reports on this system and on the results of evaluations with flight tests.

## 2. 1090MHZ EXTENDED SQUITTER ADS-B AND TIS-B

### 2.1 Airborne Surveillance Application (ASA)

Aircraft pilots are always monitoring their surrounding for flight safety. Today, visual acquisition is the only method for situational awareness around themselves. For the management of air space, ATC coordinate airborne separation using a ground surveillance system such as radar and voice messages via radio communication. Some ACAS (Airborne collision avoidance system) can indicate the rough surrounding conditions. But because ACAS is designed for the purpose of traffic conflict avoidance, directions are inaccurate, even though the distance and aircraft altitude are obtained precisely. ACAS is not sufficient as equipment for airborne surveillance applications. Airborne surveillance with ADS-B satisfies such a demand.

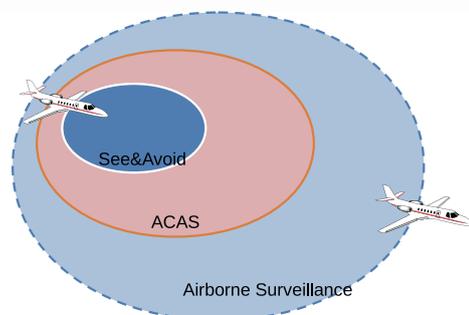


Fig. 1. Range of airborne surveillance

### 2.2 System Overview

ADS-B is a function for airborne or surface aircraft, or other surface vehicles operating within the airport surface movement area, that periodically transmits its state vectors (horizontal and vertical position, horizontal and vertical velocity) and other information. ADS-B relies on on-board navigation sources and on-board transmitting subsystems to provide surveillance information to other users. The aircraft or vehicle originating the broadcast may or may not have knowledge of which users are receiving its broadcast; any user, either aircraft or ground-based, within range of the broadcast, may choose to receive and process the ADS-B surveillance information. ADS-B supports the improved use of airspace, reduced ceiling/visibility restrictions, improved surface surveillance, and enhanced safety such as through conflict management.

TIS-B is a function in which transmitters on the ground provide aircraft with information about nearby aircraft. The TIS-B information is likely to come from ground-based surveillance sensors such as air traffic control radars or multilateration systems. However, TIS-B information broadcast on a particular radio data link might also be derived from the reception on the ground of ADS-B Messages that were transmitted on a different data link. For example, 1090MHz TIS-B transmitters might broadcast information about a nearby aircraft based on the ground reception of ADS-B Messages on other data links.

The 1090MHz ADS-B/TIS-B system uses a Mode S Extended Squitter, as defined in the ICAO (International Civil Aviation Organization) Annex 10, Volumes III and IV, to broadcast the Aircraft/Vehicle position, intent and other relevant information over a RF (radio frequency) medium. For ADS-B Messages, ICAO Annex 10, Volume III provides the Mode S transponder register definitions as well as the 56-bit data formats required for ADS-B Messages. The transmission rate for each of the defined broadcast messages is defined in the MOPS (Minimum Operational Performance Standards) for Air Traffic Control Radar Beacon System/Mode Select (ATCRBS/Mode-S) Airborne

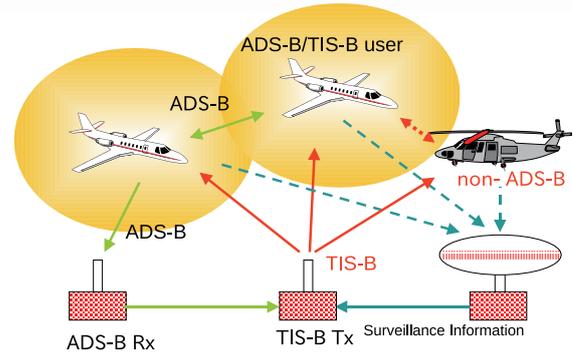


Fig. 3. ADS-B and TIS-B system

Equipment. TIS-B Messages have not yet been incorporated into the ICAO Annex 10 SARPS (Standards and Recommended Practices), nor into the Mode S Transponder MOPS.

### 2.3 Message Characteristics

The ADS-B/TIS-B Message is formed by the Pulse Position Modulation (PPM) encoding of message data. A pulse transmitted in the first half of the interval represents a ONE, while a pulse transmitted in the second half represents a ZERO. This message consists of a preamble and a data block. The preamble is 4-pulse sequence and the data block is binary pulse-position modulated at a 1 megabit per second data rate. Figure 4 shows the 1090MHz extended squitter signal format.

The preamble consist of 4 pulses, each having a duration of 0.5us. The second, third and fourth pulses are spaced 1.0, 3.5 and 4.5us, respectively, from the first transmitted pulse. The block of the message data pulse begins 8.0us after the first transmitted pulse. 1us intervals are assigned to each message transmission. A pulse with a width of 0.5us is transmitted either in the first or the second half of each interval. If a pulse transmitted in the second half of one interval is followed by another pulse transmitted in the first half of the next interval, the two pulses merge and a 1.0us pulse is transmitted.

The ADS-B extended squitter sent from a Mode S transponder uses DF (Downlink Format) 17. Each squitter contains 112 bits, of which 56 bits contain various

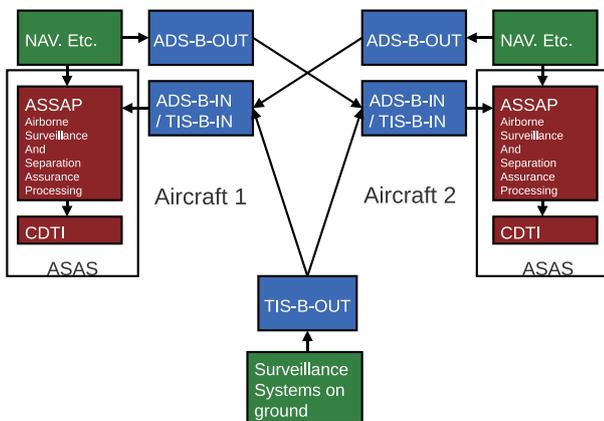


Fig. 2. Diagram of ASAS

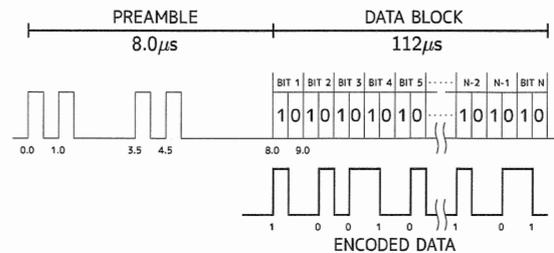


Fig. 4. 1090MHz extended squitter format

Bit #	1 ... 5	6 ... 8	9 ... 32	33 ... 88	89 ... 112
DF=17 Field Name	DF=17	CA	AA ICAO Address	ADS-B Message ME Field	PI
DF=18 Field Name	DF=18	CF=0	AA ICAO Address	ADS-B Message ME Field	
		CF=1	AA non-ICAO Address	TIS-B Message ME Field	
		CF=2,3	AA ICAO Address	TIS-B Message ME Field	
		CF=4	Reserved for TIS-B Management Message		
		CF=5	AA non-ICAO Address	TIS-B Message ME Field	
CF=6,7	Reserved				
DF=19 Field Name	DF=19	AF=0	AA ICAO Address	ADS-B Message ME Field	
		AF=1to7	Reserved for Military Applications		

Fig. 5. ADS-B and TIS-B message baseline format structure. DF means downlink format, CA means capability, CF means code format, AF means application field, AA means announced address field, and PI means Parity/interrogator ID.

navigation information, intent, and other data comprising the ADS-B information. The other 56 bits include the 5-bit DF field, the 3-bit CA (Capability) field, the 24-bit AA (Announced Address) field, and the 24-bit PI (Parity/Interrogator ID) field.

TIS-B and non-transponder-based ADS-B use DF=18. By using this format instead of DF=17, and the ADS-B/TIS-B receiving subsystem will know that the message comes from equipment that cannot be interrogated. Figure 5. shows these message format structures.

### 3. ENRI PROTOTYPE TIS-B SYSTEM

In this section, we describe our prototype TIS-B system using an extended squitter. Figure 6 illustrates the ENRI prototype TIS-B system. This system consists of a three block TIS-B system, surveillance information block and airborne system. Now, we only use the ENRI-SSR for surveillance information because the simple WAM server for TIS-B system evaluation is under development. Therefore, surveillance information updates every 10 seconds. The TIS-B system consists of three components: the information processing subsystem (TIS-B Server), the RF subsystem and the interference reduction system.

The information processing subsystem receives surveillance data from SSR mode S (Secondary Surveillance Radar mode S), the multilateration system and ADS-B ground receivers. The input format of this surveillance data uses ASTERIX-compliant messages. Now, we are still developing our own system of multilateration and the surveillance data source for the TIS-B system is only SSR output. ADS-B information is used to reject information on aircraft that transmit valid ADS-B messages, because it is not necessary to retransmit ADS-B messages using the same data links. The information processing subsystem produces

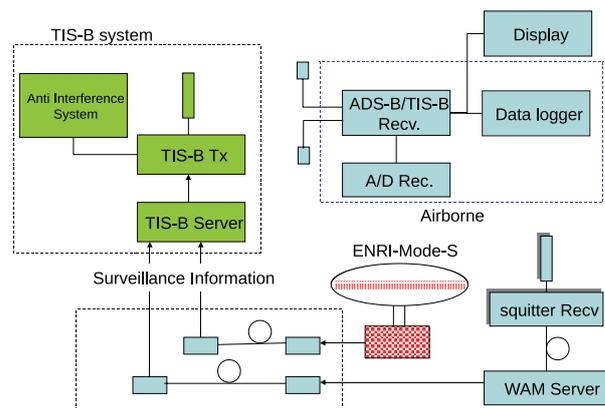


Fig. 6. The diagram of ENRI prototype TIS-B system.

TIS-B messages using this corrected surveillance information and sends messages to the extended squitter generation subsystem.

The TIS-B message is modulated into a pulse based on the ICAO Annex 10 format, and the message passing the RF subsystem is transmitted from an omni-directional antenna.

We assumed that the TIS-B information was provided within a 40NM in radius. Therefore, the maximum transmission power of the extended squitter RF subsystem is 200W. And the maximum transmission rate is 1000 times per second. This rate was decided for the following reason. The aircraft ADS-B message is transmitted 3.1 times per second on average. The SSR mode S which uses one of our surveillance data sources can process 250 aircraft per second. Therefore, the necessary processing performance is assumed to be 775 times per second, and we decided to allow a 1000 transmitted messages system margin.

The interference reduction system is one of most important equipment in the TIS-B system. This equipment receives 1030MHz from another antenna near the TIS-B transmission antenna. When the system receives an interrogation signal from SSR, a suspend signal is sent to the RF subsystem and the transmission of the TIS-B message is interrupted for a few micro-seconds.

Figure 7 shows our prototype TIS-B system. The picture on the left is of the ground system, the anti interference system, the RF subsystem, and the TIS-B server from above. In the center is the ADS-B/TIS-B receiver on the aircraft. This receives and decodes 1090MHz signals, and the decoded squitter message is broadcast to the on-board display via Ethernet (LAN). The receiver does neither a parity check nor error correction, and records raw squitter messages. The on-board display is shown in the right hand picture. The display system decodes ADS-B/TIS-B messages from broadcast raw squitter messages on the LAN and illustrates neighboring aircraft information at their position and the speed, etc. with their call signs.



Fig. 7. ENRI prototype TIS-B system. The left is the ground station, the center is the ADS-B/TIS-B receiver on the aircraft, and the right is the PC-based data display.

#### 4. EVALUATION BY FLIGHT TESTS

##### 4.1 Flight Experiments Overview

In 2010, we obtained a radio station license, a requirement for evaluating the TIS-B system. We installed a receiver and display systems on our Beechcraft B99 and recorded ADS-B/TIS-B messages while in flight. A ground TIS-B station was installed on the roof of the building at ENRI, Chofu. The surveillance information for TIS-B evaluation used ENRI SSR at Chofu. The TIS-B server acquired information from the SSR system at every update. We planned two routes for the flight tests. One route, which we called "direct Oshima" was a round trip between Sendai airport and Oshima VORTAC via the Daigo, Nikko, Omiya, Eda and Yokosuka beacon stations. The other route, which we called "Kanto route", flew around the Kanto region. These routes had different purposes for data acquisition. The direct Oshima aimed at measurement of the TIS-B transmitter coverage, and thus we flew in both directions over the ENRI. The Kanto route aimed at recording ADS-B messages, because Narita International Airport has many international airlines which have installed ADS-B-OUT. This route passed through the Narita departure and arrival area. As a results, we received many ADS-B messages and learned the situation around our aircraft without the TIS-B system. Figure 8 shows the flight track and beacon stations. Each route passed over the ENRI at Chofu. We planned six flights for TIS-B system evaluation. During these experiments, we acquired a lot of squitter data include ADS-B and TIS-B.

##### 4.2 Sample of Recorded Data

Figure 9. illustrates the aircraft position produced by recorded ADS-B/TIS-B messages on the aircraft during flight experiments. The green triangle at the center is the aircraft position measured by GPS. This figure indicates the

position of aircraft using colored points. Red means it was obtained by TIS-B and orange means from ADS-B installed aircrafts. TIS-B aircraft only indicate the Mode S address and their position, because the current TIS-B system can not transmit aircraft call signs and the TIS-B server did not generate tracking data as surveillance information. ADS-B aircrafts indicate their position with call signs, altitude, ground speed and direction. This information can be obtained from the received data.

The green point near the center triangle is the location of our aircraft "JA8801" as broadcast by TIS-B. This difference is due to system delays. System delays are generated in some blocks. One of the delays is in the surveillance block because there is processing time of a few hundred milliseconds from receiving the reply signal at the SSR antenna to inputting the surveillance information onto the TIS-B server. And TIS-B servers also have system delays. The obtained aircraft positions from TIS-B message

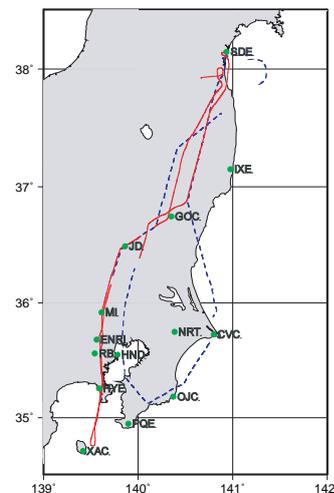


Fig. 8. The flight route and beacon stations. Red line indicates round trip route between Sendai and Oshima. Blue line indicates Kanto route.



Fig. 9. Simplified data plot from received ADS-B/TIS-B messages while airborne. The green triangle at the center indicates the airborne position measured by GPS. Red points indicate TIS-B aircraft, Orange indicate ADS-B transmitting aircraft.

are displayed at slightly difference positions from the actual aircraft positions. Therefore, it is necessary to be careful when applying the area of the airborne surveillance application when using TIS-B information.

### 5. SUMMARY AND CONCLUSIONS

In this paper, we described our prototype TIS-B system using an 1090MHz extended squitter, and the results of evaluation through flight tests. From the results of the flight testing, we have determined the ability of the prototype TIS-B system. It is clear that our system has an enough ability as a TIS-B transfer system for simple applications such as aiding visual acquisition. We are currently developing a new TIS-B server which generates free text type squitter messages instead of RTCA standard. Using the new server, we will try to transmit more useful messages for flight safety with an extended squitter.

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