THE POSITION OF AUTOMATIC DEPENDENT SURVEILLANCE AIRCRAFT – ADS-B

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The article deal with a new system Automatic dependent surveillance – broadcast (ADS-B), which is currently implemented in real practice air traffic control. Description of the system is in terms of principle of action, application mode S and current status of its use in practice. The aspect of perspective of development regards about the third generation system, which allows tracking and recording the flight path of the aircrafts. Available information at websites was analysed in the work. The described new technology of monitoring aircraft positions can greatly increase the capacity of airspace management. Simultaneously it’s using manifold increase safety of aircraft transport and in the co-operation with multilateration systems forms the basis of a compatible globally network of monitoring air traffic.

K e y w o r d s: ADS-B, ADS-B OUT, ADS-B IN, extended squitter, Mode S, ASTERIX.

1 INTRODUCTION

Radio technical systems which are used today, such as primary and secondary surveillance radars are not able to use globally, because air traffic systems (PSR, SSR) over the oceans are not available. In these areas, the aircraft position is reported by flight crew. The potential solution for this problem is the ADS.

The first part of this article describes the historical development and usage of systems for air traffic management. In the main part of the article is presented the system ADS-B in terms of principles, application mode S and current state of implementation into the operation. Information used in this article was found at English websites.

2 HISTORICAL DEVELOPMENT AND USAGE OF SYSTEMS FOR AIR TRAFFIC MANAGEMENT

With the development of aircrafts, which are capable of performing useful work such as transportation goods and passengers and the growing number of these aircraft was a requirement of the organization activities of air traffic control at the airport, near to the airport and of the individual routes between airports. In the past an operation was managed only trough voice communication between pilots and air traffic controllers. This principle was used mainly during the Second World War, where the first rules for the organization of air traffic control were created.

With the development of radar techniques the air traffic controllers got a very strong help, primary radar, which could be specify the position of the aircraft in the air, without the active cooperation between the pilot and air traffic controller. During these days when the Cold War starts, between the East and the West was problem to recognise internal and external resolution of the aircrafts. In this time were developed transponders to identification friend or foe IFF, which through an active replay from the deck of the aircraft send important information to maintain national security eastern and western sides. Using these systems began to show some of their properties for example increase range.

In addition to this feature the signal of response also contain some other information.

On the basis of the idea, that the secondary radiolocation responses from the aircraft may contain a variety of information, so to the secondary response is added information about position from the aircraft navigation on-board computer. This idea introduces a simple sight of the ADS, which is currently transformed from the theoretical plans to the practical implementation. The main objective of the application ADS are providing automatic information about the aircraft position for the ATC. System ADS has several types. Between the basic types belong ADS-B and ADS-C.

3 AUTOMATIC DEPENDENT SURVEILLANCE BROADCAST ADS-B

ADS-B is a data link system in which the aircraft avionics broadcast information about position and other information from the aircraft for ground-based receivers and other aircraft with receivers. This data link allows various options in the aircrafts and as well as providing ATC services. Aircraft or another ground vehicles to determine their own position in the ADS-B system, use data from global navigation satellite systems, respectively from another navigation source. This information with other data from board instrumentation regularly broadcast without the intervention of ground functions.

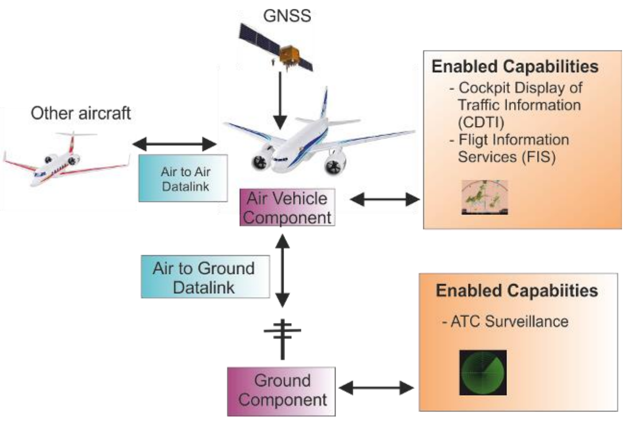

Figure 1. ADS-B components and links showing the enabled capabilities for both air to air and air to ground links [1]

Transmitted information can be received and decoded by any aircraft, vehicles or ground equipment,

which are in the range of broadcasting and aircrafts are equipped with ADS-B compatible receiver. ADS-B provides air to air or air to ground datalink.
The great benefit of this system is that by using the received position reports surrounding aircrafts, pilots on their cockpit displays of traffic information can see similar images as an air traffic controller on the ground. This potentially allows new applications or performing new manoeuvres by pilot. Another advantage of ADS-B is capable of operating at low altitudes or on the ground. Another success is the ability of monitoring the traffic on the taxiway and runways at the airport and the opportunity to work even in areas without radar coverage or in areas where radar coverage is limited – e.g. in the mountains. [1]

3.1 ADS-B Data link technologies

The ADS-B signal transmission can be realised in these ways:

- 1090 MHz Extended Squitter (ES)
- VLD Mode 4 (Very high Data Link)
- UAT (Universal Access Transceiver)

Both Mode S Extended Squitter and UAT systems work on single channels (1090 MHz for Extended Squitter and 978 MHz for UAT). The VDL Mode 4 is used as a multiple channel system operating in the frequency band of 118-137MHz. [2]

3.2 Airborne subsystem

The airborne subsystem consists of ADS-B OUT and possibly of ADS- IN system.
Aircraft using ADS-B OUT periodically broadcasts its own position and other information as shown in figure 2 through an on-board transceiver. ADS-B transceiver the position information obtains from the GNSS receiver, respectively from another navigation source which is currently used, and the other information from other on-board systems or from the pilot (manually entered data). The ADS-B signal can receive with the ground based receivers or with other aircraft, which is equipped with ADS-B IN. [1][3]

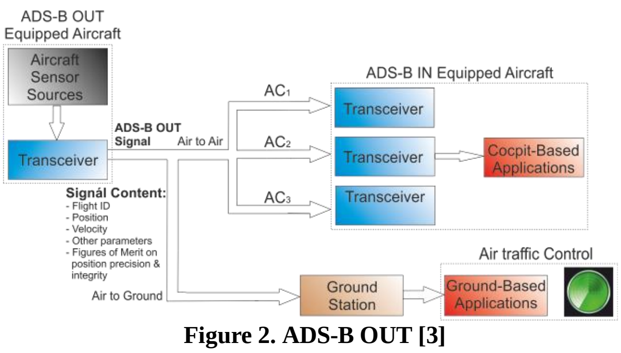

Figure 2. ADS-B OUT [3]

The ability to receive ADS-B signals from the ground and other aircraft, process those signals and display traffic information for flight crews is realised by ADS-B IN, as it is shown in figure 3. Achieving benefits from ADS-B IN requires on-board processing of the ADS-B signal and integration with aircraft displays. The ADS-B signal can be used as logic platform to generate warnings or provide guidance for numerous air to air applications, and may be presented on a variety of display platforms. ADS-B IN complements with ADS-B OUT provides for pilots and aircraft navigation systems with highly accurate position and direction information about other aircraft which are operating nearby.

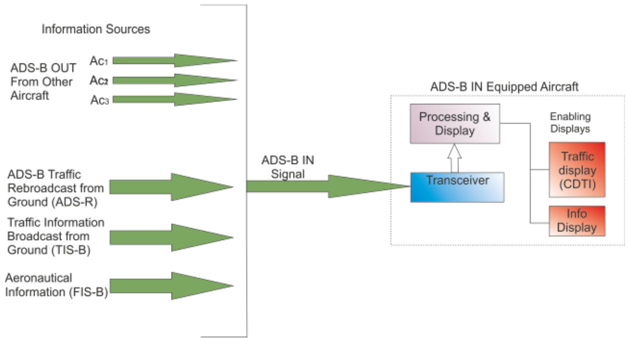

Figure 3: ADS-B IN [3]

ADS-B IN at the lowest level increases situational awareness of the flight crew of aircraft operating in the vicinity. The next step is to enable the flight crew to keep visual separation in the border conditions and later in instrument flight conditions, thus addressing a higher capacity during visibility conditions worse than optimal. Next applications include overtaking manoeuvre in the NRA and manoeuver area to improve the predictability of aircraft arrivals.
Ability of ADS-B IN can be divided as follows:

- Ability provided with ground surveillance component (TIS-B, FIS-B and ADS-R).
    - FIS-B - Flight Information Service – Broadcasting
    - ADS-R – Automatic Dependent Surveillance - Rebroadcast.
    - TIS- B – Traffic information service – Broadcast
- Possibility for adding air to air ADS-B adoption by other aircraft. [1][3]

3.3 Ground Segment

ATS surveillance system must include ADS-B ground stations which receive ADS-B reports from aircraft or ground vehicle. ADS-B ground segment includes ADS-B receiving antennas, ADS-B receiver device that is used to integrate this message into existing ATS surveillance system via the communication protocol (ASTERIX CAT 21), system surveillance data processing and display unit. The combined ATS surveillance systems use ADS-B surveillance information as well as radar information.

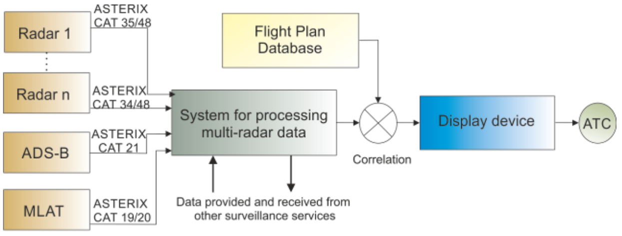

Figure 4: ADS-B Ground segment

The received messages are routed through the network to the processing of surveillance data. There are verified, mixed with existing multilateration and radar data in case when exists radar coverage and if is used MLAT than forwarded to the ATC, where these data are shown in ATC display's. Another purpose of ground stations is broadcast TIS-B, FIS-B and ADS-R messages that can be received by aircraft, which is equipped with ADS-B IN. [4]

3.3.1 FIS-B

The Flight Information Service – Broadcast (FIS-B) is a ground broadcasting service (ground – air) by ADS-B for UAt in the frequency 978MHz. This service provides for pilots and flight crew weather and flight information. Receiving FIS-B messages requires the direct line of sight and can be expected range about 200nm for each UAT GBT. [5]

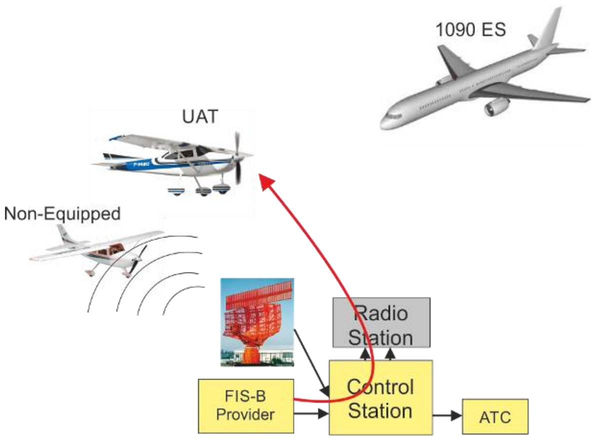

Figure 5: FIS-B [5]

3.3.2 TIS-B

Traffic Information Service – Broadcast (TIS-B) is a service provided by ground. TIS-B sends messages in frequency 1090 MHz. This report contains information specified for aircraft about position of other aircraft in the vicinity. Data are collected from ground surveillance systems, such as radar, MLAT or ADS-B messages from other aircraft. [5]

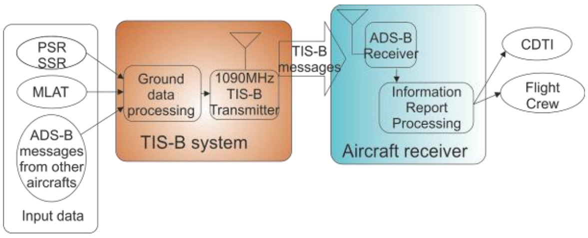

Figure 6: TIS-B [5]

3.3.1 ADS-R

Automatic Dependent Surveillance –Rebroadcast (ADS-R) is a service that transmits ADS-B information transmitted by an aircraft using one link technology to aircraft within the proximity of active users of an incompatible link technology, so the ADS-R receive messages transmitted in frequencies (978 MHz or 1090 MHz) and remakes and reformat the data for next transmission and use on a different frequency. The control station monitor aircrafts which are within range, so ADS-B and UAT broadcast equipment and incompatibility of these aircrafts. If incompatibility is detected, then ground station in range remakes and formulates information for both aircraft. [5]

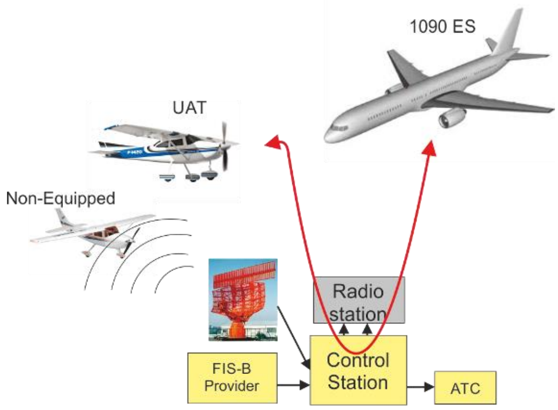

Figure 7: FIS-B [5]

4 METHODES OF POSITION DETERMINATION

During obtaining the position of aircraft using ADS-B system will use primary source of navigation data from GNNS mostly from GPS. Reliability and performance of GNSS system is currently very high, especially with developed variations. For most of ADS-B applications is needed to use upgraded ADS-B receiver on modification of space segment satellite systems- SBAS-WAAS, applied to a large area. In Europe for example the EGNOS system, or GPS receiver that meet the parameters receivers WAAS. The first most important benefit of these systems is to improve data integrity, which is an important condition in aircraft navigation systems. These systems are intended to improve the accuracy of GNSS navigation signals by using pseudo-range corrections. GNSS signal receiver which works for ADS-B, must be fully integrated into the FMS or NMS. [6]

5 EXTENDED SQUITTER

Actually, there is no official dictionary definition of the term "squitter". NASA defines the squitter as random, automatic transmission, intentional or in other way told- it is a transponder transmitter in the absence of interrogation. Therefore the squitter is a not required spontaneous transmission, which can be used to support the acquisition of passive reporting of mod S target by the ground or by aircraft.
Mode S alone sends two types of messages either "Acquisition Squitter" or "Extended Squitter".

Acquisition Squitter: the only message format is DF 11, which contains a unique 24 bit aircraft address. Two methods are to acquire the DF 11. Firstly, it is possible to ask for this report through the UF11 and radar transponder then sends the address of the aircraft (report DF 11). Secondary, this report can be automatically consigned from the aircraft at specific intervals (used for the purpose of TCAS or MLAT systems).

Extended Squitter: the Extended Squitter have three versions (Extended Squitter 0/1/2). This type of message is sent from the desk automatically. With this format works the system ADS-B. Although always sends the same format, the report can contain always a different type of information. This means, once transponder sends DF17, containing register BDS 0,5, which contain information about position of the aircraft, and the next time sends DF17 with the register BDS 0,9, which contains information about the Airborne velocity. Types of the registers and interval which the aircraft must broadcast the information is defined in documents DO-260, DO-260A and as the latest document is DO-260B. Nowadays aircrafts flying under all three types depending on the types of the document was certified under. [7]

5.1 1090 MHz ADS-B message format

It is a set of information that includes a defined number of parameters relating to aircraft. ADS-B message besides normal parameters may generally include information to verify the correctness of data, reducing the number of errors that were not detected at decoding message with receiving system.

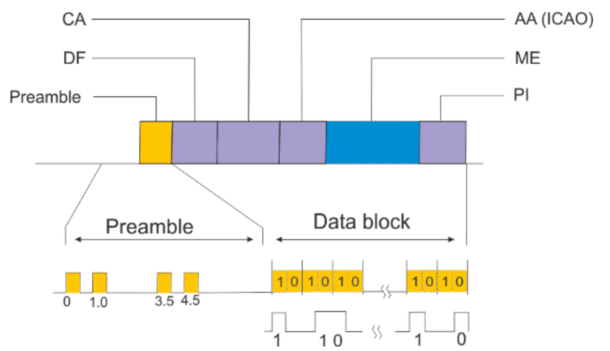

Figure 8: 1090 MHz ADS-B message format [8]

The ADS-B message is transmitted by "Pulse Position Modulation" so-called PPM. That means that the pulse transmitted in the first half period represents the 1, and in the second half of period represents 0. The ES is 112 bits long and contains 56 bits of ADS-B information. The added message information is a 56 bit field inserted between the 24 bit Aircraft address and the Parity information.

- Preamble: this is a special bit sequence to allow the receiver to identify and synchronise with a received message.
- Data block (DA): the data block start with 8.0µs after the first broadcast of pulse. The 112µs interval must be assigned to each transmission message of ADS-B. 112 bits encoded of 112µs contains the ADS-B position reports.
- Downlink format (DF field): the DF field is used to indicate the type of message being transmitted. It is set to 17 for Extended Squitter messages and 18 for TIS-B messages.
- Capability (CA field): this 3-bit field indicates the capability of the Mode S transponder.
- Aircraft (ICAO) address: this is the 24 bit address of aircraft.
- ADS-B data (ME field): this field is 56 bits long and contains the ADS-B data. Its content depends on which ES is being transmitted.
- Parity check (PI field): this 24 bit field is an error detection code to help a receiver identify errors in received messages. [8]

5.2 Extended squitter DF 17

The Extended squitter is a Mode S for ADS-B. The Extended Squitter support regular and frequent monitoring of transmission information (position, identity, etc.). All these transfers are realised at a frequency 1090MHz. Extended Squitter messages contain 56 bit data field, which is encoded in the ME field. Header of each message contains a 56 bit identifier for each message types. Content of ME field can be one of the seven types.

5	3	24	56	24
17	CA	AA	ME	PI

Figure 9: Extended Squitter DF 17

These messages are as follows:

- Airborne position BDS 0,5, it is transmitted when airborne
- Surface position BDS 0,6, this message is transmitted when on airport surface
- Extended Squitter status BDS 0,7
- Type and Aircraft identification BDS 0,8
- Airborne velocity 0,9, this contain 4 subtypes (two for subsonic and two for supersonic)
- Target State and Status Information BDS 6,2
- Aircraft Operational Status BDS 6,5[8]

6 QVALITY ACCURACY INDICATORS FOR POSITION

Quality accuracy indicators are used for ATC system to determine that the ADS-B surveillance reports (position reports) are precise enough to support a variety of functions for air traffic services, especially if it supports ATC separation standards.

These indicators are as follows:

- NUC Navigation Uncertainty Category
- NAC Navigation Accuracy Category
- NIC Navigation Integrity Category
- SIL Surveillance Integrity Limit

NUC indication is used in the ES version 0. Other versions of the ES version 1, 2 reporting about accuracy and integrity report alone using indicators NAC, NIC and SIL. [7]

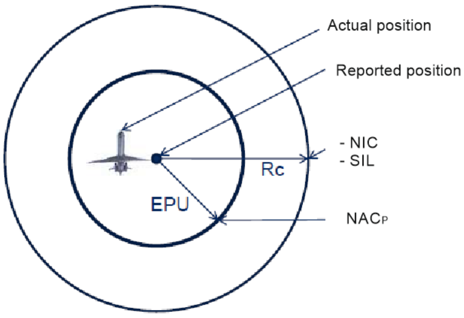

Figure 10: Displaying precision quality information

7 TRANSMISSION PROTOCOLS

ASTERIX, defined by EUROCONTROL is a format used for exchange messages in ATM systems. ASTERIX can be used to transmit messages through various communication models like WAN, LAN and another internet protocols (IP).

There are different categories for ASTERIX, which are referred as CAT000 – CAT 127 for civilian and military use. For the system ADS-B is destined Category 21, which was firstly created in year 1999. The development of these categories continued to this day and there are several versions. [9]

7.1 **The structure of massages**

The data item is the smallest unit of information, which is defined and standardized. Symbolic data reference item will consist of eight characters, which have format: Innn/AAA, where:

- I shows that it contains the data item
- Nnn it is a three digit decimal number, that indicates the data category
- AAA it is three digit decimal number indicating the data item [9]

CAT = 021	LEN	FSPEC	Items of the first record		FSPEC	Items of the last record

Obr. 11 ASTERIX CAT 021 format of data block [9]

Where:

- Data Category (CAT) = 021is a one-octet field indicating that the Data Block contains ADS-B messages
- Length Indicator (LEN) are a two-octet field indicating the total length in octets of the Data Block, including the CAT and LEN fields
- FSPEC is the Field Specification [9]

8 PEROSPECT OF DEVELOPMENT AND INTRODUCTION TO THE PRACTICE

When system is introduced into practice must be satisfied many of the requirements that the navigation service providers, operators and also aircraft manufacturers imposed of the European Commission (under the auspices of) one of them is the “COMISSION IMPLEMENTING REGULATION (EU) No. 1207/2011 of 22 November 2011” that provides requirements for performance and interoperability of surveillance for the single European sky.

Operators must ensure that the Mode S transponder on the aircraft operates with 24-bit ICAO address. All aircraft in 1 January 2020 must be equipped with Mode S transponder.

Category of surveillance systems generally can be divided into cooperative and non-cooperative.

The cooperative surveillance system requires cooperation with the deck of the aircraft. Such a system can provide surveillance data related to the aircraft, including information such as the identity of the aircraft and the aircraft barometric altitude. Between cooperative systems can include system ADS-B, MLAT and SSR.
Non-cooperative surveillance systems not require next equipment, with regard to airborne equipment, but cannot provide information coming from the aircraft. Non-cooperative system is primary surveillance radar.

System ADS-B gives us a lot of information about the target, but in the case of surveillance techniques the final positioning accuracy depends on the accuracy of the airborne navigation system. Their credibility is not fool proof, because we can get an indication of the position of the aircraft, but it can get with very low of quality indicators (NIC, NAC and NUC) and this position cannot be considered credible. MLAT transfers the responsibility of identifying aircraft position back to the “ground”. With the combination of these two systems (ADS-B and MLAT) is possible to use all these advantages of modern surveillance techniques. [10]

9 CONCLUSIONS

This article examines the system Automatic Dependent Surveillance – Broadcast ADS-B, which can be regarded as a third generation of surveillance and recording the flight path of the aircraft. Article focused on the ADS-B in terms of principles, application Mode S and the current state of its implementation into the operation.

This system is the latest essential technology for future generations of air traffic management systems.

In this article was discussed various subsystems such as airborne and ground subsystem, were created basic block diagrams, which brings us the principle of operation of the system.

I believe that the presented article will provide to the reader such a brief description of the ADS-B which will satisfy him.

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