International Civil Aviation Organization

Fourth Meeting of the AFI CNS/ATM Implementation Co-ordination Sub-group (CNS/ATM/IC/4) (Dakar, 10 - 14 March 2003)

Agenda Item 6: **Review and update if required of the Surveillance Plan for the AFI Region**

Automatic Dependent Surveillance Broadcast

(Presented by the Secretariat)

1. Introduction

1.1 Automatic Dependent Surveillance Broadcast (ADS-B) has fast developed into a promising cost-effective and operationally beneficial surveillance technology. It is actively being pursued for implementation in several States and ICAO regions.

1.2 The purpose of this paper is to provide information on this technology and the operational benefits it may hold with the view to taking account ADS-B in the AFI CNS/ATM and Surveillance Plans.

2. Discussion

3.1 ADS-B is a surveillance technology for ATC. It also supports the provision of additional information direct to the pilot such as Cockpit Display of Traffic Information (CDTI). Thus it enhances situation awareness for both ATC controller and pilots.

3.2 At the APANPIRG/13 Meeting, Australia provided an information paper which described the potential ADS-B would offer to the Asia Pacific region to significantly increase ATC surveillance capabilities at a low cost. It was informed that ATC coverage in excess of 250 nautical miles has already been demonstrated at an Australia's ADS-B ground station. It is estimated that an ADS-B ground station could be deployed for less than 15% of the cost of radar. An indicative cost for deployment of a high quality duplicated ADS-B ground station is between US$300,000 USD and $600,000.- each including project management and data communications feeding back to an ATC centre. Lower cost alternatives also exist.

3.3 It was estimated that 33 new ADS-B ground stations with estimated cost less than US$20 M would be required for ATC coverage for South East Asia and 21 new ADS-B ground stations at cost less than US$13 M would be required for the South Pacific area. Data feeds from ADS-B could use the Eurocontrol Category 21 ASTERIX data exchange format.

Operational benefits

3.4 The benefits that could be obtained for equipped aircraft in areas of ADS-B coverage include:

a) Improvements in safety
- Short term conflict alert;
- Danger area infringement warning;
- Cleared level adherence monitoring;
- Route adherence monitoring;
- Minimum safe altitude monitoring.

b) Improvements in FIR crossing coordination
- Improved situational awareness;
- Ability to detect coordination failures eg: mismatches between actual aircraft level and coordination level.

c) Improvements in efficiency
- Potentially the ability to use ADS-B radar like separation standards in lieu of existing procedural standards;
- Ability to detect that aircraft have “passed” and hence issuance of preferred cleared levels;
- Increase probability of states being able to offer user preferred routes.

Data link standards for ADS-B

3.5 ICAO has formalized two ADS-B data links with SARPs in Annex 10 (Mode S Extended Squitter and VDL mode 4), and there is also a proposal to standardize a third data link, known as the Universal Access Transceiver (UAT). The three data links were not inter-operable. Mode S Extended Squitter and VDL Mode 4 are ATN-compatible.

3.6 Mode S Extended Squitter operates on the 1090 MHz reply frequency of the secondary surveillance radar (SSR) Mode S (ES 1090). The 1 090 ES has been developed as an extension of the SSR Mode S technology. Appendix A provides more information on Mode S Extended Squitter.

3.7 The universal access transceiver(UAT) is a transceiver system designed specifically to support the function of ADS-B. It is intended to operate on 978 MHz in the DME band.

3.8 The VHF data link (VDL) Mode 4 provides a range of communication services including broadcast and point-to-point, air/ground and air/air. The services include ADS-B. It is intended to operate the surveillance function in the 108-117.975 MHz band, if the ITU WRC-2003 agrees to it.

Implementing ADS-B

3.9 In order to realize the benefits of ADS-B, aircraft avionics need to be deployed and ground system provided. The upgrading of existing Mode S transponders required the implementation of a link between the navigation system and the transponder. Due to the technical simplicity, the provision of Extended Squitter from most aircraft already equipped with TCAS is expected to be inexpensive. This is totally consistent with the existing ICAO Annex 10 provisions and the development path of Mode S and TCAS.

Selection of ADS-B technology

3.10 The following ADS-B activities, decisions and meetings, have contributed towards the deployment of ADS-B as a surveillance tool.

- The United States of America has formally announced that it will use 1090MHz extended squitter as the ADS-B link technology for Air Transport category aircraft.

- The USA had also selected UAT ADS-B link for the general aviation users.

- ICAO's Separation and Airspace Safety Panel (SASP), First Meeting of the Working Group of the Whole, agreed that an ICAO separation standard be developed for ADS-B using radar surveillance characteristics as a reference system.

- The June 2002 Joint User Requirement Group (JURG) of Association of European Airlines and IATA concluded that 1090 MHz extended squitter ADS-B was the interoperable link.

- Airbus has indicated that it will make ADS-B out capability; using 1090 MHz extended squitter, available on all aircraft produced after early 2003. Airbus also States that retrofit kits will also be made available at that time.

- Some Boeing aircraft are already equipped with ADS-B (e.g. some British Airways B747 and B757). Boeing is expected to consider ADS-B 1090 MHz squitter implementation together with other transponder changes required for Europe's enhanced surveillance and the FAA's anticipated transponder rules regarding security enhancements.

3. Action by the meeting

3.1 The meeting is invited to:

a) Note the information provided herein;
b) Recognize the benefits of ADS-B for the AFI region; and
c) Include planning for ADS-B in its work programme.

Mode S Extended Squitter
(Extract from ICAO Doc.9684-AN/951)

10.1 Introduction

10.1.1 Extended squitter is a technique that combines the capabilities of the SSR Mode S system with those of the automatic dependent surveillance (ADS). This is accomplished by using an extended squitter as the broadcast data link for transferring the aircraft-derived ADS report from the aircraft to airborne or ground users. This type of operation is known as ADS-broadcast (ADS-B). The result is an integrated surveillance concept that permits equipped aircraft to participate in ADS-B or SSR ground environments. The extended squitter concept is illustrated in Figure 10-1.

10.2 **SYSTEM CONCEPT**

SURVEILLANCE

10.2.1 In the current Mode S design, each Mode S transponder pseudo-randomly radiates (squitters) its unique Mode S address in an azimuth-omnidirectional pattern once per second. This squitter is a 56-bit transponder reply frequency (1 090 MHz). Figure 10-2 illustrates the current Mode S squitter. The squitter is used by the airborne collision avoidance system (ACAS) to detect the presence of Mode S-equipped aircraft. In operation, an ACAS listens for squitters, extracts the 24-bit aircraft address contained in the squitter data and uses this address as the basis for discrete interrogation, as required, to perform surveillance on Mode S-equipped aircraft.

10.2.2 This form of squitter is currently in operational use with ACAS. Its performance is well understood from the design and validation of ACAS as well as the substantial experience with ACAS as an operational system.

10.2.3 The Mode S message protocol defines both 56-bit and 112-bit reply formats. The extended squitter approach uses a 112-bit format for squitters, as shown in Figure 10-3. This creates a 56-bit message field for ADS data. All other fields remain the same as in the original short squitter.

10.2.4 In operation, aircraft equipped with a GNSS receiver determine their position and velocity at least once every second. This information is inserted into the 56-bit ADS message field of the long squitter and broadcast twice per second by the Mode S transponder. The current 56-bit short squitter continues to be broadcast for compatibility with ACAS. The short squitter transmission can be omitted if all ACAS equipment is converted to receive the long squitter.

10.2.4 The omnidirectional pattern of extended squitter broadcast makes it possible to support both air-ground and air-air surveillance applications. A key advantage of ADS-B is that the ground station can be relatively simple compared to a current ground SSR.

10.3 DATA LINK

It is intended that extended squitter ground stations be capable of interrogation as well as reception. This capability is needed to support the hybrid surveillance concept (10.5.5) and also for the provision of two-way Mode S data link. This capability can be used to augment the data link service provided by Mode S interrogators, particularly for extending data link coverage down to a low altitude. Another important application is data link service on the airport surface.

10.4 SURVEILLANCE APPLICATIONS

10.4.1 The most important surveillance applications of extended squitter are:

a) air-ground:
   1) en route
   2) terminal ; and
   3) precision runway monitoring (PRM).

b) surface, for runway and taxiways; and

c) air-air;

   1) ACAS hybrid surveillance; and
   2) Cockpit display of traffic information (CDTI).

AIR-GROUND SURVEILLANCE

10.4.2 Mode S extended squitter ground stations will perform both surveillance and data link tasks. Surveillance will be principally through the passive reception of position and aircraft type and identification squitter information. Active surveillance will be used to acquire additional information such as aircraft SSR Mode A code.

10.4.3 The concept for air-ground surveillance for both a terminal area and en route is shown in Figure 10-4. Aircraft determine their position using GNSS and broadcast these positions via the squitter. The squitter is received by terminal and en-route ground stations. The terminal antenna is shown as a single omni, which is capable of squitter reception range of 90 to 180 km (50 to 100 NM).

10.4.4 PRM surveillance can be supported using the same antennas used for terminal surveillance, or may use dedicated antennas to provide the required coverage. The accuracy requirement for PRM imposes the use of differential corrections by the

GNSS navigation equipment. These corrections are determined on the ground and are transmitted to the aircraft.

10.4.5 For en-route operation, a 6-sector high-gain antenna (with six independent low-noise receivers) is necessary in order to obtain a 370 km (200NM) surveillance range. The 6-sector antenna may also be used in high traffic density areas in order to limit the number of aircraft being processed by any one receiver.

SURFACE SURVEILLANCE

10.4.6 Airport surface surveillance is illustrated in Figure 10-5. Aircraft transmit squitters containing their differentially corrected positions while operating on runways and taxiways. These squitters are received by several stations around the periphery of the airport. Two such stations are shown in the figure but the actual number for each airport will be determined by squitter reception performance in the environment of the airport surface. Measurements have indicated that four stations will provide good coverage for most terminals.

AIR-AIR SURVEILLANCE

ACAS hybrid surveillance

10.4.7 Although it does not affect the collision avoidance function, the availability of position and velocity data in the extended squitters will result in significant improvement to ACAS surveillance.

10.4.8 Extended squitter will reduce the effect of ACAS on the SSR environment through reduced interrogation rates. ACAS will be able to monitor intruders at full range rather than the reduced range currently available to ACAS in high traffic density environments due to the action of interference limiting.

10.4.9 The ACAS ability to support active Mode S interrogations makes it possible for ACAS to obtain additional information from a threat aircraft via readout of registers contained in every Mode S transponder. This capability is termed the ACAS cross-link (see Annex 10, Volume IV, 3.1.2.8). Cross-link information can provide for enhanced operation of ACAS through the use of intent information to reduce the rate of unnecessary alerts.

CDTI via extended squitter

10.4.10 CDTI enables situational awareness and is feasible for aircraft which are equipped with a 1 090 MHz receiver. Such aircraft would listen to extended squitters from nearby aircraft and display their positions and identity on a small cockpit display. A range of 26 km (14 NM) can be supported for CDTI using receivers equivalent to those in ACAS. This range can be extended up to 185 km (100 NM) through the addition of a low-noise front end to the receiver. ACAS aircraft already have 1 090 MHz receivers, which would require modifications for increased range, but other aircraft would have to equip in order to realize this benefit. For capacity limitations see 10.8.

OTHER SURVEILLANCE APPLICATIONS

10.4.11 Provided that the independence of navigation and surveillance functions is preserved, extended squitter could be considered as a low-cost means for surveillance:

a) for small terminals which do not qualify for high cost ground SSR equipment; and
b) for en-route gap filing in mountainous or remote areas.

10.5 INDEPENDENCE OF NAVIGATION AND SURVEILLANCE

POTENTIAL FOR LOSS OF INDEPENDENCE

10.5.1 Traditionally, ATC has required the use of separate and independent systems for communications, navigation and surveillance. This is referred to as the principle of independence. The benefit to aviation is that independence makes it unlikely that an aircraft could lose more than one of its capabilities at the same time. This provides for a robust backup in the event of a failure of one of the systems. For example, loss of navigation capability on board an aircraft can be accommodated through the use of ground vectors provided by an air traffic controller based on ground SSR data.

10.5.2 If used as the sole means of surveillance, ADS-B inherently merges the aircraft navigation and surveillance capabilities. As a consequence, loss of navigation capacity would not be able to be accommodated with ADS-B alone, since ATC would lose surveillance and, therefore, be unable to provide vectors.

10.5.3 In addition to a complete failure of navigation, a second aspect of loss of independence is that an undetected failure of the navigation system that resulted (for example) in a slowly increasing error may not be detected. This can happen since both pilot and ground controller would see the aircraft on its intended course, when, in fact, the actual position of the aircraft could be on a very different course.

10.5.4 Due to loss of independence, ADS-B cannot by itself be considered to be a direct replacement for SSR.

HYBRID SURVEILLANCE

10.5.5 The integration of extended squitter into the SSR Mode S system offers a straightforward way to obtain the benefits of ADS-B while still maintaining independence. This is based on the use of hybrid surveillance.

10.5.6 As the name implies, hybrid surveillance makes use of both passive ADS-B and active SSR surveillance. The technique can be applied to both ground ATC and

ACAS surveillance applications. The active surveillance is used to validate the ADS-B reported position, and to take the place of ADS-B if an aircraft loses navigation capability.

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