EUROPEAN ORGANISATION FOR THE SAFETY OF AIR NAVIGATION

EUROCONTROL

Clarification

Mode S Transponder

in an Airport/A-SMGCS Environment

MODES/SYS/002

Edition	:	1.1
Edition Date	:	3 May 2005
Status	:	Released
Class	:	General Public

EUROPEAN AIR TRAFFIC MANAGEMENT PROGRAMME

DOCUMENT IDENTIFICATION SHEET

DOCUMENT DESCRIPTION

Document Title

Clarification Mode S Transponder in an Airport/A-SMGCS Environment

PROGRAMME REFERENCE INDEX	**EDITION :**	1.1
Surveillance Domain	**EDITION DATE :**	3 May 2005

Abstract

This Document clarifies the behaviour of Aircraft Mode S Transponders on the ground, based on ICAO, EUROCAE and ARINC documents.

The purpose is to contribute to the understanding how to use aircraft transponder signals on the ground.

Keywords

Surveillance	Transponder	Secondary	Mode S
Safety	Airport	TMA	En-Route
Performance	N/A		
Requirements			

CONTACT PERSON : P. Ruault	**TEL :** 3198	**DIVISION :** DAS/CSM/SUR

DOCUMENT STATUS AND TYPE

STATUS			CLASSIFICATION	
Working Draft	☐		General Public	☑
Draft	☐		EATCHIP	☐
Proposed Issue	☐		Restricted	☐
Released Issue	☑			

ELECTRONIC BACKUP

INTERNAL REFERENCE NAME :

HOST SYSTEM	MEDIA	SOFTWARE(S)
Microsoft Windows	Type : Hard disk	
	Media Identification :	

COPYRIGHT NOTICE

DOCUMENT APPROVAL

The following table identifies all management authorities who have successively approved the present issue of this document.

AUTHORITY	NAME AND SIGNATURE	DATE
Surveillance Domain	E. Potier P. Ruault	14/02/2003
Surveillance Domain Manager	J. Berends	14/02/2003

Content:

1 Introduction **1**
2 Transponder Air/Ground Logic **2**
2.1 SUMMARY TRANSPONDER AIR/GROUND LOGIC 2
2.2 ICAO ANNEX 10 VOLUME 4 AMENDMENT 77 2
2.3 EUROCAE MOPS ED73B 3
2.4 ARINC 718-A 4
2.5 ARINC OVERVIEW ON AIR/GROUND LOGIC 5
3 Transponder Standby Status **6**
3.1 SUMMARY TRANSPONDER STANDBY STATUS 6
3.2 ICAO ANNEX 10 VOLUME 4, AMENDMENT 77 6
3.3 EUROCAE ED73B MOPS 6
3.4 ARINC 718-A (MARK 4 MODE S TRANSPONDER) 6
3.5 OVERVIEW ON TRANSPONDER POWER OFF/ON AND STANDBY STATUS 7
3.6 MODE OF OPERATION OF ATC TRANSPONDERS 8
4 Transponder transmissions on the ground **9**
4.1 SUMMARY TRANSPONDER TRANSMISSIONS ON THE GROUND 9
4.2 ICAO DOCUMENT - ANNEX 10 - VOLUME 4, AMENDMENT 77 9
4.3 EUROCAE MOPS ED 73B 9
4.4 ARINC DOCUMENT - 718 - A 10
4.5 OVERVIEW OF THE TRANSPONDER TRANSMISSIONS ON THE GROUND. 11
5 Transponder Antenna Selection **12**
5.1 SUMMARY TRANSPONDER ANTENNA SELECTION 12
5.2 ICAO - ANNEX 10 - VOLUME 4 AMENDMENT 77 12
5.3 EUROCAE ED 73B 13
5.4 ARINC 718-A 13
5.5 OVERVIEW OF ANTENNA CHOICES 14
6 Mode S Transponder Squitter formats **15**
6.1 ACQUISITION SQUITTER: DF 11 - (56 BITS SHORT SQUITTER) 15
6.2 EXTENDED SQUITTER: DF 17 - (112 BITS LONG SQUITTER) 15
6.3 OVERVIEW SQUITTER FORMATS AND TRANSMISSION RATES 16
7 Summary of (M)SSR and Mode S Interrogations and Replies **17**
7.1 MAIN INTERROGATIONS AND REPLIES OF AIR TRAFFIC TRANSPONDERS 17
7.2 SPONTANEOUS MODE S TRANSPONDER TRANSMISSIONS 18
8 Traffic Alert and Collision Avoidance System / Airborne Collision Avoidance System **19**
8.1 THE TCAS / ACAS SYSTEM SET UP OVERVIEW 19
8.2 TCAS / ACAS ON THE GROUND 19
9 Mode S Interrogation by Airport Multi-Lateration systems **20**
9.1 INTRODUCTION 20
9.2 SYSTEM OPERATION 20
9.3 RF ISSUES 20
9.4 IN SUMMARY 21
9.5 AIRPORT MULTI-LATERATION INTERROGATOR RESTRICTION REQUIREMENTS: 22
10 Surveillance Systems terms and definitions. **23**
10.1 DEFINITION EUROCAE ED-87A: CO-OPERATIVE AND NON CO-OPERATIVE TARGET 23
10.1.1 Co-operative Target *23*
10.1.2 Non co-operative Target *23*
10.2 SURVEILLANCE TECHNIQUES AND TECHNOLOGIES 23
10.3 TYPES OF (ATC) SURVEILLANCE SYSTEMS, CURRENT DEFINITIONS: 24
11 List of abbreviations **26**

1 Introduction

To support the understanding of the performance of Mode S transponders in Airport Surveillance Systems and several European Air Traffic Management Programme (EATMP) Projects like the Advanced Surface Movement and Ground Control System (A-SMGCS), this document analyses, describes or clarifies the Mode S transponder performances and characteristics as defined in the different relevant documents, in particular when the aircraft is on the ground.

The analysis has been done essentially on the following documents:

⇒ **ICAO Annex 10 Volume 4, Surveillance Radar and Collision Avoidance System, up to Amendment 77**
The International Civil Aviation Organisation (ICAO) aims to achieve the highest practicable degree of uniformity world-wide whenever this will facilitate and improve air safety, efficiency and regularity, the ICAO Council adopts International Standards and Recommended Practices (SARPs), and approves Procedures for Air Navigation Services (PANS). The necessary international standardisation has been achieved by the Organisation primarily through the creation of Annexes to the Convention on International Civil Aviation. The main parts of each Annex are International Standards and Recommended Practices (SARPs).

⇒ **EUROCAE MOPS ED73B and**
The European Organisation for Civil Aviation Equipment (EUROCAE) prepares the Minimum Operational Performance Specifications (MOPS) for airborne electronic equipment. The European Civil Aviation Conference (ECAC) has proposed to European National Airworthiness Authorities to take EUROCAE specifications as the basis of their national regulations
EUROCAE document are considered by Joint Aviation Authorities (JAA) to be referenced by the JAA Joint Technical Standard Orders and other regulatory documents. The main European administrations and the main aircraft and equipment manufacturers are members of EUROCAE and actively participate in the Working Groups which prepare these specification documents.

⇒ **ARINC 718-A**
Aeronautical Radio Incorporated (ARINC - USA) define the form, fit, function, and interfaces of avionics equipment. The ARINC 700 series defines digital avionics like the ARINC 718 : ATC Transponder

Based on the information in the above documents, this document clarifies the situation of Mode S transponders in an Airport/A-SMGCS environment regarding the following points:

- Air/ground logic — chapter 2
- Standby status — chapter 3
- Transponder replies on the ground — chapter 4
- Antenna Selection — chapter 5
- Squitter formats — chapter 6
- Summary of interrogations and replies — chapter 7

Further this document provides a Traffic Alert and Collision Avoidance System/Airborne Collision Avoidance System (TCAS/ACAS) system overview in chapter 8 and, having in mind that these systems are making use of the 1030/1090 MHz SSR frequencies, sets the requirements for possible interrogations by multi-lateration systems in chapter 9.

Chapter 10 clarifies some "surveillance" phraseology and definitions, and finally chapter 11 tables the abbreviations used.

2

Transponder Air/Ground Logic

2.1 Summary Transponder Air/Ground Logic

Aircraft should provide means to determine the on-the-ground state automatically and provide that information to the transponder, e.g. by a "nose wheel switch". If there is no on-the-ground status indication provided to the Transponder, by default the status is airborne.

Based on the identified status (airborne or on-the-ground) the Mode S transponder will react different, see chapter 4, and with different squitter rates.

The following documents support in detail the Air/Ground logic of Mode S transponders. Subparagraph numbers are kept for reference in case more analysis have to be done.

2.2 ICAO Annex 10 Volume 4 Amendment 77

§3.1.2.6.10.1.2 ***Ground report.***

The on-the-ground status of the aircraft shall be reported in the FS field and the VS field (3.1.2.8.2.1) and the CA field (3.1.2.8.1.1). If a means for automatically indicating the on-the-ground condition (e.g. a weight on wheels or strut switch) is available at the transponder data interface, it shall be used as the basis for the reporting of vertical status.

If a means for automatically indicating the on-the-ground condition is not available at the transponder data interface (3.1.2.10.5.1.3), the FS and VS codes shall indicate that the aircraft is airborne and the CA field shall indicate that the aircraft is either airborne or on the ground (CA = 6).

§3.1.2.6.10.3 ***Validation of declared on-the-ground status***

Note.— For aircraft with an automatic means of determining vertical status, the CA field reports whether the aircraft is airborne or on the ground. ACAS II acquires aircraft using the short or extended squitter, both of which contain the CA field. If an aircraft reports on-the-ground status, that aircraft will not be interrogated by ACAS II in order to reduce unnecessary interrogation activity. If the aircraft is equipped to report extended squitter messages, the function that formats these messages may have information available to validate that an aircraft reporting "on-the-ground" is actually airborne.

§3.1.2.6.10.3.1 Aircraft with an automatic means for determining the on-the-ground condition that are equipped to format extended squitter messages shall perform the following validation check:

If the automatically determined air/ground status is not available or is "airborne", no validation shall be performed. If the automatically determined air/ground status is available and "on-the-ground" condition is being reported, the air/ground status shall be overridden and changed to "airborne" if the conditions given for the vehicle category in Table 3-6 are satisfied.

Note.— While this test is only required for aircraft that are equipped to format extended squitter messages, this feature is desirable for all aircraft.

§ 3.1.2.8.6.7- Airborne / surface state determination:

Aircraft with an automatic means of determining on the ground conditions shall use this input to select whether to report the airborne or surface message types [1]. Aircraft without such means shall report the airborne type messages. Aircraft with or without such automatic on the ground determination shall use position message types as commanded by control codes in TCS. After time out of the TCS commands, control of airborne/surface determination shall revert to the means described above.

Note: Extended squitter ground stations determine aircraft airborne or surface status by monitoring aircraft position, altitude and ground speed. Aircraft determined to be on the ground that are not reporting the surface position message type will be commanded to report the surface format via TCS. The normal return to the airborne position message type is via a ground command to report the airborne message type. To guard against loss of communications after take off, commands to report the surface position message type automatically time out.

[1] The surface message type gives more accurate position information.

§3.1.2.8.7.7 *Airborne/surface state determination.*

Aircraft with an automatic means of determining on-the-ground condition shall use this input to select whether to report the airborne or surface message types. Aircraft without such means shall report the airborne type messages.

§3.1.2.10.3.10.1 Recommendation.— *Aircraft should provide means to determine the on-the-ground state automatically and provide that information to the transponder.*

2.3 EUROCAE MOPS ED73B

§ *3.18.4.12 - Flight Status (FS) :*

This 3 bit downlink field reports the flight status of the aircraft and is used in format DF=4,5,20 and 21.

§ 3.18.4.38 Vertical Status VS This 1 bit downlink field in DF=0, 16 indicates, when ZERO, that the aircraft is airborne and, when ONE, that the aircraft is on the ground.

§ *3.20.2.7 b - On the ground Report:*

The transponder shall have a means of reporting that the aircraft is on the ground. This information shall be coded in the FS and VS fields. If a means for indicating the on the ground condition is not available at the transponder, the FS and VS codes shall indicate that the aircraft is airborne.

§3.21.2.6.5 Airborne/Surface State Determination

Aircraft with an automatic means of determining on-the-ground condition shall use this input to select whether to report the airborne or surface message types. Aircraft without such means shall report the airborne type messages. Aircraft with or without such automatic on-the-ground determination shall use position message types as commanded by control codes in the TCS subfield (Paragraph 3.21.2.6.7). After timeout of the TCS commands, control of airborne/surface determination shall revert to the means described above.

NOTE: Extended squitter ground stations determine aircraft airborne or surface status by monitoring aircraft position, altitude and ground speed. Aircraft determined to be on the ground that are not reporting the surface position message type will be commanded to report the surface format via the TCS subfield. The normal return to the airborne position message type is via a ground command to report the airborne message type. To guard against loss of communications after takeoff, commands to report the surface position message type automatically timeout.

§5.2.2 Mode A/C, Mode A/C/S All-Call and Mode A/C-Only All-Call Interrogations

The nominal characteristics shall be as specified in paragraph 1.6. In addition, in order to prohibit any reply inhibition, the "on-the-ground" report (VS or FS field) shall not indicate the on-the-ground condition but the airborne condition unless otherwise noted in the test procedure.

§6.2.3 Validation of declared on-the-ground status

Note: While this is only a requirement for aircraft that are equipped with extended squitter functionality, this feature is desirable for all aircraft.

Aircraft with an automatic means for determining the on-the-ground condition that are equipped to format extended squitter messages shall perform the following validation check:

If the automatically determined air/ground status is not available or is “airborne”, no validation shall be performed. If the automatically determined air/ground status is available and “on-the-ground” condition is being reported, the air/ground status shall be overridden and changed to “airborne” if the conditions given for the vehicle category in the table below are satisfied,

§6.4.3.11 On-the-Ground Condition

If a means for automatically indicating the on-the-ground condition (e.g. a weight on wheels or strut switch) is available

a) Verify that the equipment correctly reports the "on-the-ground" condition in the CA, FS and VS fields.

b) Verify that the equipment correctly reports the "airborne" condition in the CA, FS, and VS fields.

If a means for automatically indicating the on-the-ground condition (e.g. a weight on wheels or strut switch) is not available

a) Verify that the FS and VS fields indicate that the aircraft is airborne and that the CA field indicates that the aircraft is either airborne or on the ground (CA=6)

2.4 ARINC 718-A

[14] Air / Ground Logic input

Pin TP-5J is assigned to Air/Ground Discrete Input #2. TP-5K is assigned to Air/Ground Discrete Input #1. The Mark 4 transponder should interpret a “ground” at the Air/Ground discrete as an indication that the aircraft is on the ground. An “open” should indicate to the Mark 4 transponder that the aircraft is airborne. This information may be used to activate other functions such as identifying the flight phase for BITE.

NOTE: The Mark 4 transponder may also be supplied other aircraft information, which may provide this determination in a more reliable manner. Air/Ground Discrete Input #2 is to be used when it is desired that the Mark 4 transponder automatically inhibit replies per ICAO Annex 10 when the aircraft is on the ground. Air/Ground Discrete Input #1 is to be used when replies are not to be inhibited when the aircraft is on the ground. Airframe and equipment manufacturers are cautioned to provide “sneak circuit” protection for these inputs so that malfunctions of other equipment connected to the same logic source do not affect operation. The system should be designed such that the normal failure mode should be to the “airborne” condition.

§4.2.19.2.8 Surface/Airborne Determination

The determination whether the aircraft is airborne or on the ground is historically determined by logic inputs on the Mark 4 transponder rear connector. A more reliable means of determining Air/Ground status has been provided in ICAO Annex 10 and RTCA (Radio Technical Commission for Aeronautics) DO-260 as provided in the following subparagraphs:

a. If there is a means to automatically determine the vertical status of the given Aircraft Category (see subparagraph c), then such information should be used to determine whether to report the airborne state or the on-ground state.
b. If there is no means to automatically determine the vertical status of the given Aircraft Category, then the airborne state should be reported except under the condition provided in Figure 4-2 [2]. If the conditions given in Figure 4-2 are met for the given Aircraft Category, then the surface state should be reported for the installation.
c. If the automatically determined Air/Ground status is not available or indicates the airborne state, then the airborne state should be reported in accordance with subparagraph b. If one of the conditions in Figure 4-3 [2] is satisfied, then the airborne state should be reported irrespective of the automatically determined Air/Ground status.
d. The Mark 4 transponder will normally configure the variable squitter rates dependent on the airborne or on-ground state determination.
e. The Mark 4 transponder may also be commanded by interrogation to report the surface or airborne squitter formats independent of the self-determined Air/Ground status. This command has no effect on the vertical status reported in the CA, FS, or VS fields.

[2] Mandatory for extended squitter capability and recommended for all other: depending on category/type/speed/altitude.

2.5 ARINC overview on Air/Ground Logic

Air/ground Discrete Input 1 pin **TP-5J**	Air/ground Discrete Input 2 pin **TP-5K**	Connection of the Air/ground Switch	**Aircraft Situation**	It was decided that the Transponder have to:
0	**0**	TP-5K is connected to the Air/ground Switch	**Airborne**	Reply normally to ATCRBS
0	**1**	TP-5K is connected to the Air/ground Switch	**Ground**	Reply normally to ATCRBS
1	**0**	TP-5J is connected to the Air/ground Switch	**Ground**	Inhibit ATCRBS replies
1	**1**	TP-5J is connected to the Air/ground Switch	**Airborne**	Reply normally to ATCRBS

3

Transponder Standby Status

3.1 Summary Transponder Standby Status

The operational modes of Mode S transponders are mainly described in the ARINC 718-A. The transponder status "Power off" and "Power on" are clear.

The "Standby" status results in no RF transmission in any event.

The following documents support in detail the Standby Status of Mode S transponders. Subparagraph numbers are kept for reference in case more analysis have to be done.

3.2 ICAO Annex 10 Volume 4, Amendment 77

Nothing stated

3.3 EUROCAE ED73B MOPS

Nothing stated

3.4 ARINC 718-A (Mark 4 Mode S Transponder)

§ 2.4.2. Power Control Circuitry:

There should be no master on/off power switching within the mode S transponder. Any user desiring power on/off control for the unit should provide , through the medium of a switching function installed in the airframe, means of interrupting the primary AC power to the equipment. It may be noted that primary power on/off switches will not be needed in most installations and power will be wired directly to the equipment from the circuit breaker panel;

Commentary

Although only one transponder of a dual installation will be operating at a time, users may desire the inoperative unit to be held in a powered-up “standby” condition so that is BITE may detect and enunciate any failures that would render it incapable of providing its service when called upon.

§ 4.5.2. Dual installation

Dual installation of the Mark 4 transponder should be configured such that only one Mark 4 transponder is active at a time, the other remaining in the “standby” condition until the pilot action at the control panel calls for a changeover.

§ 4.8. Operational Modes of the Mark 4 Transponder

The Mark 4 transponder will have three operational modes:

1. “Power off” mode

In this mode the mark 4 transponder does not receive any primary power. This mode is the normal mode when the avionics is switched off or the circuit breaker to the Mark 4 transponder is pulled (The Mark 4 transponder is presented with an open circuit power input)

The Mark 4 transponder should be capable to maintain specific internal states during a “power-off” mode condition for a minimum of 500 milliseconds, and all program or configuration non-volatile settings during a “power off” mode condition for up to 3 years.

2. “standby” Mode

In this mode the Mark 4 transponder receives primary power but **conducts no RF transmission, in any event**. The “Standby” condition may be commanded by the standby/on discrete or by loss of valid Mark 4 transponder control data.

In the “Standby” condition the Mark 4 transponder should be operational but with limited capabilities. In this mode the Mark 4 transponder should not respond to received interrogations. It should continue to provide periodic data on defined ARINC 429 output ports. Mark 4 transponder BITE is to be operational in the “Standby" mode, but may be reduced in functionality due to the inability to transmit. When in standby mode the Mark 4 transponder should respond to bus test commands.

3. <u>"Power on " Mode</u>
In this mode the Mark 4 transponder receives primary power and has been commanded to the "on" condition by the standby/on discrete.
In the "on" condition the Mark 4 transponder should be capable of replying to interrogations and should establish logical connections to the connected applications which require the communication functions.
All functions should be activated in the "on" condition of the Mark 4 transponder.

§ 6.4.1. Stand by /on Switching
Means allowing the crew to select whether the connected transponders should be in the "standby" condition or switched "on" should be provided. Means must be foreseen which ensure that only one unit of a dual installation can be switched on at a time.

[19] Standby/on Control
The Standby /on discrete provides a stand by (no replies) condition for the Mark 4 transponder unit controlled from the control panel. This permits BITE to be running in the inactive Mark 4 transponder of a dual installation, thus enabling the states of both Mark4 transponder units to be monitored continuously. To obtain "Standby " operation, connect pin TP7G to chassis or airframe ground. For "on" operation leave pin TP7G open.

3.5 Type of Control Panel

Two type of control are installed on Aircraft.

- Control panel with Stby/on Mode
- Control Panel with Stby-Auto-On Switch

The indication on these control panels are not always coherent and can be misunderstood by the flight crew

3.5.1 Control panel with Stby/on Mode

It is the classical situation

Stand by : Is defined as the status of transponder in which the transponder can not transmit any RF signals. The transponder is active to follow the BITE activity. This status is defined on the pin TP7G of transponder.
The stand by mode is independent of the situation of the aircraft in air or on the ground.

ON : In this position the transponder is working normally depending of the air/ground position defined only by the pin TP5J.

3.5.2 Control panel with Stby- Auto-On Switch.

Stand By: idem

Auto mode : is referring to the air/ground logic. Defined by the pin TP5J **.** when the aircraft is on the ground replies inhibited as specified by ICAO Annex 10

- Mode A/C should be inhibited
- All Call shall be inhibited
- Roll Call shall not be inhibited
- Extended Squitter not inhibited
- Acquisition Squitter not inhibited

On Mode : Is referring to the air/ground Logic. Defined by the pin TP5K. When the aircraft is on the ground no replies can be inhibited.

Switch	TP5J Input 2	TP5K Input 1	AC situation	Actions

Position				
Auto	**0**	1	Ground	Replies inhibited as defined per ICAO Annex 10
Auto	**1**	1	Air	Reply Normally
On	1	**0**	Ground	NO INHIBITION OF REPLIES
On	1	**1**	Air	Reply Normally
	0	0	Ground	Not defined

In this control panel configuration, care must be taken to ensure that the flight crew do not wrongly use the “ON” mode, in the belief that it is the normal setting, rather than the required Auto mode.

3.6 Overview on Transponder Power Off/On and Standby Status

	ICAO	**MOPS**	**ARINC**
Power OFF	Nothing stated	Nothing stated	- No power supplied - Inactive - No transmission
Standby	Nothing stated	Nothing stated	- Power supplied - No RF transmission - Active with bus activity and limited BITE
Power ON	Nothing stated	Nothing stated	- Power supplied - Active and transmit - Normal operation

3.7 Mode of operation of ATC transponders

Mode	Operation
Off	None
Stand-by	No RF transmission. TCAS and transponder are in the warm up cycle.
On	The transponder replies on interrogations (see chapter 4)
Altitude reporting off	The transponder replies without altitude information. TCAS is in the standby mode.
Xpdr	Transponder on and TCAS is in the warm up cycle
TA only	The transponder is on. The TCAS is on but only the Traffic Advisory function of the TCAS is operational.
TA/RA	The transponder is on and all Traffic Advisory and Resolution Advisory functions of TCAS are operational

4

Transponder transmissions on the ground

4.1 Summary Transponder transmissions on the ground

When the Mode S transponder is switched on and not in the stand-by mode and in the on-the-ground status, only all call transmissions are inhibited.

Squitter messages will continue to be transmitted to be used by other systems like multi-lateration systems and Mode S transponders shall always reply to selective interrogations (24 bits Mode S address) e.g. to acquire the aircraft call sign or Mode 3A.)

Transmission or non-transmission of Mode 3A/C is not defined and dependent on (local) operational procedures and pilot selections, if "Mode 3A/C reply" selection is implemented in the aircraft.

The following documents support in detail the Transponder replies on the ground.
Subparagraph numbers are kept for reference in case more analysis have to be done.

4.2 ICAO Document - Annex 10 - Volume 4, Amendment 77

§ 3.1.2.10.3.10 - Inhibition of replies:
Replies to Mode A/C/S all call and Mode S only all call interrogations shall always be inhibited when the aircraft declares the on the ground state.
It shall not be possible to inhibit replies to discretely addressed Mode S interrogations regardless of whether the aircraft is airborne or on the ground.

***§ 3.1.2.10.3.10.2 - Recommendation*:**
Mode A/C replies should be inhibited when the aircraft is on the ground to prevent interference when in close proximity to an interrogator or other aircraft.

Note.— Mode S discretely addressed interrogations do not give rise to such interference and may be required for data link communications with aircraft on the airport surface. Acquisition squitter transmissions may be used for passive surveillance of aircraft on the airport surface.

§ 3.1.2.10.3.10.3 - Inhibition of squitter transmission:
It shall not be possible to inhibit extended squitter transmissions except as specified in § 3.1.2.8.6 or acquisition squitter transmissions except as specified in § 3.1.2.8.5 regardless of whether the aircraft is airborne or on the ground.

4.3 EUROCAE MOPS ED 73B

§3.16.7.2 Acquisition Squitter

Transponders operating with antenna diversity (paragraph 1.4.2.5) shall transmit acquisition squitters as follows:

b. when on the surface, the transponder shall transmit acquisition squitters under control of the SAS subfield (paragraph 3.21.2.6.7). In the absence of any SAS commands, use of the top antenna only shall be the default condition.

NOTE: *Acquisition squitters shall only be transmitted on the surface if the transponder is not reporting the surface position.*

NOTE: *The surface report type may be selected automatically by the aircraft or by commands from a squitter ground station*

§3.16.7.3 Extended Squitter

Transponders equipped for extended squitter and operating with antenna diversity shall transmit extended squitters as follows:

b. when on the surface, the transponder shall transmit extended squitters under control of the SAS subfield. In the absence of any SAS commands, use of the top antenna only shall be the default condition

§3.21.2.6 Extended Squitter Protocols

This paragraph is only applicable to transponders equipped for extended squitter.

In addition to the acquisition squitters Datalink transponders may be capable of transmitting extended squitters. When a transponder has extended squitter capability it shall not be possible to inhibit acquisition squitters except as specified in this section (3.21.2.6)

The extended (112-bit) squitter contains the same fields as the acquisition squitter plus a 56-bit message field that is used to broadcast Automatic Dependent Surveillance (ADS) data. The extended squitter may be used by ACAS and ground ATC users for passive air and surface surveillance.

Mode S transponders shall transmit extended squitters to support the broadcast of aircraft-derived position, identification and state information.

NOTE: The broadcast of this type of information is a form of Automatic Dependent Surveillance (ADS) known as ADS-broadcast or ADS-B.

In addition to the acquisition squitter, the following shall apply:

a. The scheduled acquisition squitter shall be delayed if an extended squitter is in process.

b. Acquisition squitters shall only be transmitted on the surface if the transponder is not reporting the surface position type of Mode S extended squitter

c. Transponders equipped for extended squitter operation should have a means to disable acquisition squitters when extended squitters are being emitted.

NOTE: This will facilitate the suppression of acquisition squitters when all ACAS units have been converted to receive the extended squitter

***§* 6.4.3.11 On the Ground Condition**

Also verify that when the unit is in the “inhibit replies” condition (on the ground), the transponder continues to generate Mode S squitters and replies to discretely addressed Mode S interrogations (UF=0,4,5,16,20,21,24) but does not reply to Mode A/C/S All Call or Mode S only All Call Interrogations (some installations may inhibit Mode A/C)

If the units is not in the “inhibit replies condition" (Airborne condition) verify that the transponder continues to generate Mode S squitters and also replies to Mode A/C, Mode A/C/S All Call or Mode S Only All Call and discretely – addressed Mode S interrogation (UF=0,4,5,16,20,21,24)

4.4 ARINC Document - 718 - A

§4.2.8.9 Mode S No-Reply

The Mode S transponder should not reply to a Mode S interrogation when one, or a combination of, the following conditions occur (see also ICAO Annex 10):

iii. the aircraft is on the ground condition with Inhibit Replies configuration wired

Attachment 2C

[14] Air / Ground Logic input

Pin TP-5J is assigned to Air/Ground Discrete Input #2. TP-5K is assigned to Air/Ground Discrete Input #1. The Mark 4 transponder should interpret a “ground” at the Air/Ground discrete as an indication that the aircraft is on the ground. An “open” should indicate to the Mark 4 transponder that the aircraft is airborne. This information may be used to activate other functions such as identifying the flight phase for BITE.

NOTE: The Mark 4 transponder may also be supplied other aircraft information, which may provide this determination in a more reliable manner. Air/Ground Discrete Input #2 is to be used when it is desired that the Mark 4 transponder automatically inhibit replies per ICAO Annex 10 when the aircraft is on the ground.

Air/Ground Discrete Input #1 is to be used when replies are not to be inhibited when the aircraft is on the ground. Airframe and equipment manufacturers are cautioned to provide “sneak circuit” protection for these inputs so that malfunctions of other equipment connected to the same logic source do not affect operation. The system should be designed such that the normal failure mode should be to the "airborne" condition.

§4.2.19.2.2 Acquisition Squitter Transmissions
Acquisition squitter transmissions should be emitted once per second at random intervals that are uniformly distributed over the range from 0.8 to 1.2 seconds relative to the previous acquisition squitter emission. The acquisition squitter consists of the Mode S All-call reply (Downlink Format 11).

Commentary:
The acquisition squitter may become obsolete, once all TCAS equipment is converted to accept the extended squitter defined below. The acquisition squitter should then be disabled in order to reduce channel occupancy. Manufacturers should therefore make provisions in their equipment to disable the acquisition squitter at a later stage with a minimum maintenance effort. Note that no discrete inputs have been provided in the Mark 4 Transponder interface for this function: therefore, acquisition squitter may have to be disabled at a later date via internal strap options, software only, or other suitable methods.

§4.2.19.2.5 Extended Squitter Surface Position
When enabled, the surface position squitter is emitted when the aircraft is on the ground. The determination of the airborne/ground status is described in Section 4.2.19.2.8 of this document. The surface position squitter contains position information derived from aircraft navigation aids. The data content is described in the ICAO Annex 10 and RTCA DO-260 register 0,6**.** The extended squitter for airborne position is transmitted as Downlink Format 17.
Once started, the surface position squitter is emitted when in the on-ground state at different repetition rates know as the "high" or "low" rate which has been selected as follows:

[34] Extended Squitter Disable Discrete Input
The Extended_Squitter_Disable Discrete is used to disable all Extended Squitter functions. When the pin is grounded Extended Squitter functions are *disabled* and when it is open the Extended Squitter functions are *enabled*.

4.5 Overview of the transponder Transmissions on the ground.

Type of Interrogations	**ICAO** **Amendment 77**	**EUROCAE** **Mops ED73B**	**ARINC** **718A**
MODE A/C	*Recommendation:* Should be Inhibited	May be inhibited	Refer to ICAO
Mode A/C/S All Call (P1,P3, P4L)	Shall always be Inhibited	Shall always be inhibited	Refer to ICAO
Mode S only all call (UF 11)	Shall always be Inhibited	Shall always be inhibited	Refer to ICAO
Mode S (Roll Call UF= 0,4,5,16,20,21,24)	Shall not be possible to inhibit	Shall not be possible to inhibit	Refer to ICAO
Acquisition Squitter (Short Squitter)	shall be inhibited if surface type of extended squitter is transmitted	Shall not be possible to inhibit	Refer to ICAO
Extended Squitter (Long Squitter)	shall not be possible to inhibit	Shall not be possible to inhibit	Refer to ICAO

5

Transponder Antenna Selection

5.1 Summary Transponder Antenna Selection

If the aircraft has only one antenna it is at the bottom of the aircraft.
Due to antenna shielding, this might have a negative impact on the probability of detection by Airport multi-lateration systems while the aircraft is on the ground.

If aircraft are equipped with two antennas, one on top and one at the bottom, the antenna choice for squitter messages is under control of the Squitter Antenna Selection (SAS). In the absence of SAS the default antenna choice is the top antenna. Mode S interrogations/replies are working in diversity.

The following documents support in detail the transponder antenna selection. Subparagraph numbers are kept for reference in case more analysis have to be done.

5.2 ICAO - Annex 10 - Volume 4 Amendment 77

§3.1.2.8.5.3 *Acquisition Squitter Antenna Selection (SAS).*
Transponders operating with antenna diversity (3.1.2.10.4) shall transmit acquisition squitters as follows:
a) when airborne (3.1.2.8.6.7), the transponder shall transmit acquisition squitters alternately from the two antennas; and
b) when on the surface (3.1.2.8.6.7), the transponder shall transmit acquisition squitters under control of SAS (3.1.2.6.1.4.1 f)). In the absence of any SAS commands, use of the top antenna only shall be the default.
Note.— Acquisition squitters are not emitted on the surface if the transponder is reporting the surface type of extended squitter (3.1.2.8.6.4.3).

§ 3.1.2.8.6.5. - *Extended squitter antenna selection*:
Transponders operating with antenna diversity shall transmit extended squitters as follow:

b) when on the surface the transponder shall transmit extended squitters under control of SAS.

In the absence of any SAS commands, use of the top antenna only shall be the default condition.

§ 3.1.2.8.7.5. ES/NT (Enhanced Surveillance for Non Transponders) antenna selection.
Non-Transponder devices (e.g. mobiles) operating with antenna diversity shall transmit ES/NT squitters as follows:

b) When on the surface, the non-transponder device shall transmit ES/NT squitters using the top antenna

§3.1.2.10.4.3 *Antenna selection.*
Mode S transponders equipped for diversity operation shall have the capability to evaluate a pulse sequence simultaneously received on both antenna channels to determine individually for each channel if the $P1$ pulse and the $P2$ pulse of a Mode S interrogation preamble meet the requirements for a Mode S interrogation as defined in 3.1.2.1 and if the $P1$ pulse and the $P3$ pulse of a Mode A, Mode C or inter-mode interrogation meet the requirements for Mode A and Mode C interrogations as defined in 3.1.1.
Note.— Transponders equipped for diversity operation may optionally have the capability to evaluate additional characteristics of the received pulses of the interrogations in making a diversity channel selection. The transponder may as an option evaluate a complete Mode S interrogation simultaneously received on both channels to determine individually for each channel if the interrogation meets the requirements for Mode S interrogation acceptance as defined in 3.1.2.4.1.2.3.

5.3 EUROCAE ED 73B

§ 3.16.7.1 Non Diversity Installation:
In a non-diversity installation operating with one bottom antenna only, all squitter transmissions shall be directed to that antenna.

§ 3.16.7.2 Acquisition Squitter

b) When on the surface, the transponder shall transmit acquisition squitters under control of the SAS sub-field. In the absence of any SAS commands, use of the top antenna only shall be the default condition.

NOTE: Acquisition squitters shall only be transmitted on the surface if the transponder is not reporting the surface position.

NOTE: The surface report type may be selected automatically by the aircraft or by commands from a squitter ground station

§ 3.16.7.3. - Extended Squitter

b) When on the surface, the transponder shall transmit extended squitters under control of the SAS sub-field. In the absence of any SAS commands, use of the top antenna only shall be the default condition.

5.4 ARINC 718-A

§3.1.2.6.1.4.1 Subfields in SD.
f) If DI = 2:
TCS, the 3-bit (21-23) type control subfield in SD shall control the position type used by the transponder. The following codes have been assigned:
0 signifies no position type command
1 signifies use surface position type for the next 15 seconds
2 signifies use surface position type for the next 60 seconds
3 signifies cancel surface type command
4-7 not assigned.

RCS, the 3-bit (24-26) rate control subfield in SD shall control the squitter rate of the transponder when it is reporting the surface format. This subfield shall have no effect on the transponder squitter rate when it is reporting the airborne position type. The following codes have been assigned:
0 signifies no surface squitter rate command
1 signifies report high surface squitter rate for 60 seconds
2 signifies report low surface squitter rate for 60 seconds
3 signifies suppress all surface squitters for 60 seconds
4 signifies suppress all surface squitters for 120 seconds
5-7 not assigned.
Note.— The definition of high and low squitter rate is given in 3.1.2.8.6.4.3. SAS, the 2-bit (27-28) surface antenna subfield in SD shall control the selection of the transponder diversity antenna
that is used for (1) the extended squitter when the transponder is reporting the surface format, and (2) the acquisition squitter when the transponder is reporting the on-the-ground status. This subfield shall have no effect on the transponder diversity antenna selection when it is reporting the airborne status. The following codes have been assigned:
0 signifies no antenna command
1 signifies alternate top and bottom antennas for 120 seconds
2 signifies use bottom antenna for 120 seconds
3 signifies return to the default.
Note.— The top antenna is the default condition (3.1.2.8.6.5).

§4.2.21.4 Antenna Selection for Squitter Transmissions
When operated in installations not requiring antenna diversity, all Mark 4 transponder squitter transmissions should occur out the bottom antenna. When operated in installations requiring antenna diversity**,** for each squitter type, squitter transmissions should occur alternately out

the top/bottom antennas when the aircraft is airborne, and out the top antenna only, when the aircraft is on-the ground. See ICAO Annex 10 for further information regarding “airborne” and “on-the-ground” states.

Attachment 7
§ 1.0 Diversity Antenna Selection
§ 1.3 Approach B
Two independent receivers including video processing and preamble detection are foreseen (one per antenna). The antenna for the decoding of the Mode S interrogation data block and transmission of the reply is chosen according to the following rules:

a. Select the top antenna if the preamble signal strength (preferably based on P1 amplitude) received via the top antenna exceeds the transponder minimum triggering level (MTL) by 10 dB or more.
b. Otherwise, select the antenna which received the stronger signal. These rules, illustrated in figure 1, bias the selection decision in favour of the top antenna when strong signals are received via both antennas. This bias will improve system performance in air-to-air multi-path environments.
1.4 Approach C
Approach C is based on Approach B but the decision criteria for the antenna are modified dependent on
whether the aircraft is on the ground or airborne. If the aircraft is airborne the criterion a. and b. of Approach B are applied as in Approach B. If the aircraft is on the ground only criterion b. of Approach B is applied this removes the top antenna bias if the aircraft is on the ground.

5.5 Overview of Antenna choices

	ICAO		**MOPS**		**ARINC**	
Aircraft on the Ground	Inter-rogation	Squitter	Inter-rogation	Squitter	Inter-rogation	Squitter
Transponder + antenna diversity	**Diversity**	**SAS or Top**	**Div**	**SAS or Top**	**Diversity**	**Top**
Transponder with single antenna	**Bottom**	**Bottom**	**Bottom**	**Bottom**	**Bottom**	**Bottom**
ES/NT device	**Diversity**	**Top**	***TBD***	***TBD***	***TBD***	***TBD***

Diversity = replies following the antenna diversity protocol
Bottom = Bottom antenna
Top = Top antenna
SAS = Squitter Antenna Selection

ES/NT= Enhanced Surveillance for Non Transponder

6

Mode S Transponder Squitter formats

The following paragraphs describe the Mode S transponder squitter formats, the periodicity, by which system for what purpose it is used.

6.1 Acquisition squitter: DF 11 - (56 bits Short Squitter)

Acquisition squitter transmission shall be emitted at random intervals that are uniformly over the range from 0,8 to 1,2 seconds relative to the previous squitter.

6.2 Extended Squitter: DF 17 - (112 bits Long Squitter)

This format is used for all ADS B message transmission from transmission devices that are Mode S transponder based systems. DF= 18 is used for all ADS B message transmission from transmission devices that are **not** Mode S transponder based systems. DF=19 is used for all ADS B message transmission from transmission devices that are Military Application based systems. These messages are the same structure. Here, we present only the format used by transponder system.

- ***Airborne position Squitter***
  DF = 17 with GICB register 05 inserted into ME field:
  0,4 to 0,6 second (every half seconds +/- 0,200 seconds)

- ***Surface position Squitter***
  DF = 17 with GICB register 06 inserted into ME field
  Two cases: High rate/low rate [3]

High rate:	0,4 - 0,6 sec
Low rate:	4,8 - 5,2 sec

- ***Aircraft identification Squitter***
  DF = 17 with GICB register 08 inserted into ME field

In Air		4,8 - 5,2 sec
On the ground	High rate	4,8 - 5,2 sec
	Low Rate	9,6 - 10,4 sec

- ***Airborne velocity Squitter***
  DF = 17 with GICB register 09 inserted into ME field
  Rate 0,4 - 0,6 sec

- ***Event Driven Squitter***
  DF = 17 with GICB register 0A inserted into ME field
  Limited by the transponder to twice per second

[3] Low rate if the navigation source position data has not changed more than 10 m in a 30 second sampling interval.

6.3 Overview squitter formats and transmission rates.

	DF	Register	AIR Status	Ground Status	
			Rate	High Rate	Low Rate
Acquisition squitter	**11**	**N/A**	**0,8-1,2 sec**	**0,8-1,2 sec**	**0,8-1,2 sec**
Airborne position Squitter	**17**	**05**	**0,4-0,6 sec**	**None**	**None**
Surface position Squitter	**17**	**06**	**0,4-0,6 sec** **On request by selective interrogation for 60 sec [4])**	**0,4-0,6 sec**	**4,8-5,2 sec**
Aircraft identification Squitter	**17**	**08**	**4,8-5,2 sec**	**4,8-5,2 sec**	**9,6-10,4 sec**
Airborne velocity squitter	**17**	**09**	**0,4-0,6 sec**	**None**	**None**
Event Driven Squitter	**17**	**0A**	**Maximum twice per sec**	**Maximum twice per sec**	**Maximum twice per sec**

7

[4]) Surface position squitter gives a more accurate position then the airborne position.

Summary of (M)SSR and Mode S Interrogations and Replies

7.1 Main Interrogations and Replies of Air Traffic Transponders

1030 MHz Interrogation	1090 MHz transponder reply/transmission				Periodicity (sec)	Used By	Purpose/Content
	In the air		On the ground				
	SSR only	Mode S	SSR Only	Mode S			
Mode A/C (P1-P3)	Mode A/C	Mode A/C	not clear, "should not .."	No Reply recommended		(M)SSR station	➢ Independent Position ➢ Mode A ➢ Mode C
	Mode A/C	Mode A/C	not clear: "should not .."	No Reply recommended		Mode S station (in SSR mode - UK, USA)	Independent Position calculation If transponder not compliant with Annex10 (USA Terra fix, …)
Mode A/C-only (P1P3P4short)	Mode A/C	No reply	not clear: "should not .."	No Reply recommended		Mode S station	➢ Independent Position ➢ Mode A ➢ Mode C
Mode C-only (P1P3P4short)	Mode C	No reply	not clear: "should not .."	No Reply recommended		TCAS	Use Mode C only interrogation for SSR-only ac independent position and altitude acquisition combined with whisper-shout method to reduce garbling
Mode A/C/S All Call (P1P3P4long)	Mode A/C	**IF** no lockout on II=0 or lockout override **THEN** Mode S All Call reply (DF11)	not clear: "should not .."	No Reply		Mode S station	➢ Independent position ➢ Mode S acquisition Used by low duty cycle transmitter
Mode S All Call (P1P2P6 UF11)	No Reply	**IF** no lockout **or** lockout override **THEN** Mode S All Call reply (DF11)	No Reply	No Reply		Mode S station	➢ Independent position ➢ 24 bit address acquisition
Mode S Roll Call (UF4,UF5,UF20,UF21,UF24)	No Reply	Mode S Reply DF4 Altitude DF5 Mode A DF20 Altitude + DAP DF21 Mode A + DAP DF24 Message	No Reply	Mode S Reply DF4 Altitude DF5 Mode A DF20 Altitude + DAP DF21 Mode A + DAP DF24 Message		Mode S station	**Each scan:** ➢ Independent position ➢ Flight Status (FS) ➢ Altitude extraction ➢ DAPs if required **Track ini/on change:** ➢ Mode A extraction ➢ Aircraft capability ➢ Aircraft ID extraction
Mode S air-air (UF0, UF16)	No Reply	Mode S reply DF0, DF16	No Reply	As in the air (aircraft on the ground are not taken into account by TCAS)		TCAS	➢ Independent Position ➢ Altitude extraction ➢ TCAS-TCAS co-ordination

(Highlighted = default mode S station interrogations)

7.2 Spontaneous Mode S Transponder transmissions

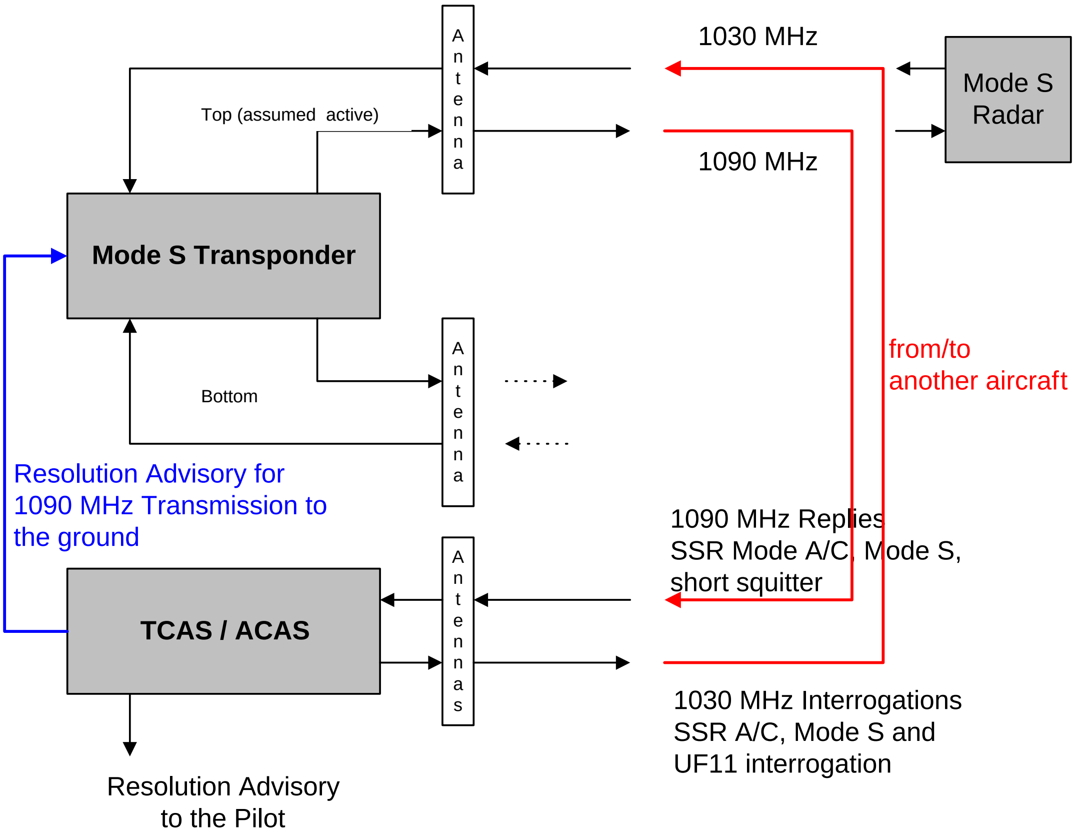
1030 MHz Interrogation	1090 MHz transponder reply/transmission		Periodicity (sec)	Used by	Purpose/Content
	In the air	On the ground			
	Mode S	Mode S			
None	**Acquisition squitter** (DF11) Alternatively from the two antenna	**Acquisition squitter** (DF11) On the top antenna by default. Antenna choice can be controlled on the new transponder (Amendment. 77)	1	TCAS Multi-lateration	➢ 24 bit address ➢ Capability
None[5]	**Extended squitter** (DF17) =	**Extended squitter** (DF17) =		ADS-B Multi-lateration TCAS	
	Airborne position squitter → (Airborne register 05)	Surface position squitter → (Airborne register 06)	0.5 0.5 or 5		➢ Altitude ➢ Latitude ➢ Longitude ➢ Surveillance status (SPI, alert) OR ➢ Ground speed ➢ Ground direction ➢ Latitude ➢ Longitude
	Aircraft identification squitter → (Airborne register 08)	→ Aircraft identification squitter (Airborne register 08)	5 5 or 10		➢ Aircraft category ➢ Aircraft identification (as in register 10)
	Airborne Velocity squitter (Airborne register 09)	Nothing	0.5		➢ Ground speed or Air speed ➢ Vertical rate
	Event driven squitter (Airborne register 0A)	Event driven squitter (Airborne register 0A)	0.5		➢ Content depending on application -To Be Defined
	Extended Squitter/Non Transponder (DF18)	**Extended Squitter/Non Transponder** (DF18)		TIS-B	➢ …
	Extended Squitter military application (DF19)	**Extended Squitter military application** (DF19)		Military system	➢ …

[5] (Surface position and aircraft identification transmission rate (low or high) on the ground is selectable from the ground using a dedicated 1030 Mode S interrogation. By default if the aircraft does not move more than 10m in a 30s sampling interval the low rate is automatically selected.)

8 Traffic Alert and Collision Avoidance System / Airborne Collision Avoidance System

8.1 The TCAS / ACAS system set up overview.

The TCAS / ACAS, Traffic Alert and Collision Avoidance System/Airborne Collision Avoidance System, in relation to the aircraft equipment (SSR/Mode-S/ACAS), the Mode S Transponder and the Mode S Surveillance radar, can be summarised as follows:



8.2 TCAS / ACAS on the ground.

⇒ The TCAS / ACAS can be activated when an aircraft is on the ground however the pilot can switch the TCAS in Stand By Mode.

⇒ Below 1000 ft the **Resolution Advisory transmission is** inhibited.

9

Mode S Interrogation by Airport Multi-Lateration systems

9.1 Introduction

In the context of Interrogator Code (IC) Allocation, it was decided to do some studies into the possible range and scope of active interrogations on 1030MHz issued by mutli-lateration systems.
Although multi-lateration systems itself do not require interrogations, these systems could acquire additional Aircraft Derived Data (like Callsign or Mode A) by active interrogations.
Such active interrogation could be transmitted omni-directionally or partially directionally on 1030MHz as part of normal system operation.

9.2 System Operation

Assuming a Mode S environment is available (common in the Core Area of Europe because of ACAS II mandates), the multi-lateration principle operates primarily using the Time-Difference Of Arrival (TDOA) computation on 1090MHz replies as received at multiple 1090MHz receivers.

The most common usage is through the reception of ACAS acquisition squitters (DF=11) which are transmitted by all ACAS aircraft on a regular but random basis roughly 1 second apart. However, other transmissions such as air-air co-ordination ACAS messages (DF0 and DF16), Mode S selective replies (DFs 4, 5, 20 and 21) and extended squitter (DF17, DF18 and DF19) transmissions could all be used. Systems can be flexibly configured to process (or not) a range of DF types.

From the acquisition squitter, only the 24-bit Mode S address can be acquired and a short indication of whether an alert condition is active (special Mode A is input or SPI) and a track is then initiated. However, this has some limitations in that the FS (Flight Status – indicating whether an aircraft is airborne or on the ground), Mode A Identity (or other identity) and Mode S altitude are not available using this technique. Some of these other parts of information are however available in the other downlink transmission types mentioned.

Altitude information can be derived using multi-receiver multi-lateration techniques. At least 4 receivers are required. However, solutions exist with 5, 6 and even 7 receiver nodes which can help improve the accuracy. The relative performance of the altitude (and the position) derivation may vary by azimuth as well as by range. This depends on the system and its configuration and central node.

The use of active interrogations elicits supplementary information including the Flight Status, the Mode A identity or other such as Aircraft Identification/Callsign (in the future) and altitude information.

Note that some configurations also involve the multi-lateration of en-route traffic, including the multi-lateration on classical Mode A and Mode C replies. The operational range of such multi-lateration systems may be quite significant as up to at least 130Nm can be achieved.

9.3 RF Issues

The commercially available solutions all provide for **active interrogation** on 1030MHz to supplement the information already derived on tracks. As stated earlier, a range of techniques can be employed to limit adverse effects on the RF environment.

Interrogation is commonly selective and commonly omni-directional (although sectorised quasi-directional antennas are also available). The optimum way is to interrogate with sufficient power only to reach the particular target selected so as to cause as little effect as possible on the RF environment. Selective interrogations are sent by ground stations to acquire additional information about tracks and to maintain or regain a target in coverage.

Due to RF interference possibilities, acquisition on UF=11 by multi-lateration systems could cause significant RF problems. If this were to be the case, lockout (at least temporary) would be required and hence an Interrogator Code [6]. This is not recommended.

A range of different transmitting antenna configurations are possible. Any with even limited directionality will clearly improve the local RF environment.

There is considerable overlap between the requirements of local airport SSR and active multi-lateration. This is especially the case if the local SSR is Mode S. Consideration on a local basis regarding integration by the two systems would be necessary.

The systems also have the ability to multi-laterate in a Mode A/C environment and could potentially use active classical SSR interrogations as well as either Intermode or Mode S only interrogations (UF11). This might be useful to increase the available range of a system but could also cause negative effects on the RF environment.

If using Mode S only acquisition on UF11, it would be necessary to ensure that no overlapping interrogators were locking out targets to II-Code=0 or that stochastic lockout override to II=0 was in place (II=Interrogator Identifier). Where possible, operation is similar in some ways to the whisper – shout principles of TCAS to further improve any adverse effects on the RF environment.

Systems may also self-calibrate their TDOA performance through the regular transmission of 1090MHz replies from reference transmitters.

Although mainly implemented for surveillance on the airport surface and nearby airborne targets, it is also configurable for tracking airborne targets over a wider range. En-Route multi-lateration solutions could also be foreseen although, at present, only one of these is in operation in Europe and is entirely passive and used for RVSM height monitoring. More are planned however.

9.4 In summary

In summary, there should be no problem of inter-operation between the Mode S radars under implementation and any local multi-lateration system. In Europe at present, active interrogation is carried out on a local basis with a range of only a few NM so implementation and inter-operability issues are addressable locally.

However, some rules of operation may be appropriate and some guidelines documented so that all the local users of SSR frequencies understand how their neighbours are operating.

With respect to IC allocation and system operation, the following statement was issued

"Actively interrogating multi-lateration systems have no need to be assigned a distinct II-Code as long as

- they do not send all-call interrogations (using UF=11),
- do not set lockout with any selective interrogations and that
- they do not perform advanced datalink activities such as dataflash.

The choice of code used (if any) shall be a local issue. Otherwise, system operators must apply for an interrogator code through their local regulator."

[6] To be requested via National Authorities. Code allocation will be handled by the Mode S IC Allocation (MICA) Cell at EUROCONTROL Surveillance Unit.

9.5 Airport multi-lateration interrogator restriction requirements:

Airport multi-lateration system that interrogate Mode S Transponders are required to be compliant with the following:

- Any active Mode S interrogations issued by an interrogator **shall** be selectively addressed.
- Operators/owners of multi-lateration systems **shall** decide locally on the use of an IC or not for active **selective** interrogation.
- Selective interrogations from multi-lateration systems **shall not** set “lockout” on any targets. This requirement must be strictly applied.
- Multi-lateration systems **shall not** carry out general purpose datalink activities using any of the advanced Mode S protocols beyond short surveillance and GICB (Ground Initiated COM-B) extraction.
- It is recommended that ‘replies of opportunity’ are used where possible in preference to active interrogation to limit the effects on the RF environment. To gather supplementary track information or to maintain or regain a track, an operator may configure the system to extract the following information using UFs 04, 05, 20 or 21 only:
    - Flight Status
    - Aircraft identity (Mode A)
    - Aircraft altitude
    - Aircraft identification (from BDS register 2,0)
    - Any GICB register available
- Multi-lateration systems **shall not** use dataflash functionality nor establish dataflash contracts for the extraction of event driven information.
- Multi-lateration systems **shall not** issue Mode S only all-call interrogations using UF=11 other than on a local basis agreed with the local regulator. If it is necessary to operate in this mode, the all-calls should be sent using lockout override, preferably stochastically.
- No specific limitations on the frequency that such interrogations are made but care should be taken to ensure that the omni- or quasi-directional selective interrogation rates are kept to a minimum to ensure that problems of excessive transponder occupancy do not affect the RF environment and hence Probability of detection (Pd) for ground radar systems and ACAS operation.
- For any systems planning long range multi-lateration operation with active interrogations, owners are requested to provide details of operational configuration to the EUROCONTROL Mode S IC Allocation Cell (via their National Authorities).

10

Surveillance Systems terms and definitions.

The following EUROCAE MASPS document ED-87A definition of (non) Co-operative Targets is applicable when referred to in A-SMGCS documents

However, to avoid misunderstanding, the following paragraphs 10.2. and 10.3. explain the Surveillance Systems phraseology and definitions currently used in EUROCONTROL Surveillance documents.

10.1 Definition EUROCAE ED-87A: Co-operative and Non co-operative Target

A **target** is defined as any aircraft, vehicle or obstacle, whether stationary or moving, which is located within the Coverage Volume of the A-SMGCS and which is of sufficient size to be operationally significant.

10.1.1 Co-operative Target

A target which is equipped with systems capable of automatically and continuously providing information including its Identity to the A-SMGCS.

10.1.2 Non co-operative Target

A target which is not equipped with systems capable of automatically and continuously providing information including its Identity to the A-SMGCS.

10.2 Surveillance Techniques and Technologies

The various ATC Surveillance techniques and technologies available include;

Surveillance Technique		**Surveillance Technology**
PSR/SMR		L band, S band, X band, Ku band Radar
SSR		1030 / 1090 MHz SSR
SSR Mode S		1030 / 1090 MHz Mode S SSR
Automatic dependent Surveillance - Broadcast (ADS-B)		1090 MHz Mode S SSR Extended Squitter VDL Mode 4 Universal Access Transceiver (UAT)
Automatic Dependent Surveillance - Contract (ADS-C (or ADS-A))		ATN VDL Mode 2 Satellite Communications
Multilateration		Radio frequency transmissions of: VHF data or radio UHF radio 1090 MHz SSR 1090 MHz Squitter (short and long) VDL Mode 4 UAT

10.3 Types of (ATC) Surveillance systems, current definitions:

Definitions Surveillance Systems:

Non-co-operative Surveillance:	No active reply from aircraft (avionics) required (one way transmission).
Co-operative Surveillance:	Active reply from aircraft (avionics) is required (two-way transmission: interrogation/reply)
Independent Surveillance:	The position of the aircraft is calculated and is not dependent of position data transmitted from the aircraft to the ground.
Dependent Surveillance:	The position of the aircraft is provided from (aircraft) avionics systems only.

Non-co-operative Independent Surveillance	
ATC Surveillance: **PSR, SMR**	***Other surveillance (examples):*** **Video camera**

Co-operative Independent Surveillance Note: The determination of the position is "Independent". However, with SSR/Mode S, the Mode A and Mode C are derived from aircraft avionics and are "dependent" on aircraft avionics (Co-operative Dependent).	
ATC Surveillance: **SSR** **SSR Mode S** **Multilateration** (according to the above definition: non co-operative [7])	***Other surveillance (examples):*** ACAS - non co-operative in monitoring status + co-operative interrogations)

Dependent Surveillance	
ATC Surveillance: **ADS-B** (according to the above definition: non co-operative [4]) **ADS-C** (according to the above definition: co-operative)	***Other surveillance (examples):*** Voice position reporting (co-operative)

[7] Active transmission of e.g. SSR Mode S Transponder Squitter required.

11

List of abbreviations

AC	Alternating Current
ACAS	Airborne Collision Avoidance System
ADD	Aircraft Derived Data
ADS B	Automatic Dependent surveillance Broadcast
ADS-C	Automatic Dependent Surveillance - Contract
ARINC	Aeronautical Radio Incorporated
A-SMGCS	Advanced Surface Movement and Ground Control System
ATC	Air Traffic Control
ATN	Aeronautical Telecommunications network
BITE	Built In Test Equipment
CA field	Capability field
DF	Downlink Format
EATMP	European ATM Programme
ECAC	European Civil Aviation Conference
ES/NT	Enhanced Surveillance for Non Transponder
EUROCAE	European Organisation for Civil Aviation Equipment
FS field	Flight Status field
GBIC	Ground Initiated COM-B
IC	Interrogator Code
ICAO	International Civil Aviation Organisation
II	Interrogator Identifier
JAA	Joint Aviation Authorities
JAA	Joint Aviation Authorities
MASPS	Minimum Aircraft System Performance Specification
ME	Message, Extended squitter
MHz	Mega Hertz
MICA	Mode S IC Allocation (Cell)
Mode A	SSR code
Mode C	Reported coded altitude
MOPS	Minimum Operational Performance Specifications
N/A	Not Applicable
NM	Nautical Mile
PANS	Procedures for Air Navigation Services
RF	Radio Frequency
RTCA	Radio Technical Commission for Aeronautics
RVSM	Reduced Vertical separation Minimum
SARPs	Standards and Recommended Practices
SAS	Squitter Antenna Selection
SI	Surveillance Identifier
SPI	Squawk Identity
SSR	Secondary Surveillance Radar
TBD	To Be Defined
TCAS	Traffic Alert and Collision Avoidance System
TCS	Type Control Sub-field
TDOA	Time-Difference Of Arrival
TIS-B	Traffic Information System Broadcast
UAT	Universal Access Transceiver
UF	Uplink Format
UHF	Ultra High Frequency
UK	United Kingdom
USA	United States of America
VDL	VHF Data Link
VHF	Very High Frequency
VS field	Vertical Status field
Xpdr	Transponder