14. AIR-TO-AIR CROSS-LINK

14.1 Purpose

14.1.1 Mode S transponders are equipped with 255 transponder data registers of 56 bits each. These transponder data registers can contain a variety of aircraft state and intent information. A definition of the contents of these registers is contained in Doc 9871.

14.1.2 The technique for extracting transponder data register information over the air-ground link has already been described. The technique used for air-air transfer is described in the following paragraphs.

14.2 DS field in UF = 0

14.2.1 The BDS is currently defined in the SARPs as the code that specifies the transponder data register to be accessed. The short air-air format UF = 0 contains a DS field for the code of the transponder data register whose contents are to be returned in the reply to the UF = 0 interrogation.

14.2.2 This field is not included in the long air-air interrogation UF = 16. This long interrogation is only used for ACAS air-to-air coordination. The reply to this interrogation will always include coordination information in the 56-bit MV field, so cross-link data cannot be carried. In addition, omitting the DS field from the long ACAS interrogation has the desirable effect of completely separating the coordination and cross-link protocols.

14.3 CC field in DF = 0

An indication of a transponder's ability to support the air-to-air cross-link communications capability is provided in order to allow for a transition phase where not all of the transponders have this capability. A one-bit flag CC field is provided in the short air-air reply to indicate the transponder has cross-link capability when this field is set to 1. In operation, an aircraft using ASA would not attempt a cross-link transaction unless it first interpreted this field. The first transponder register data extracted would be the Mode S specific service capability report so that the ASA could determine what data were specifically available.

14.4 Protocol for long reply with transponder register data

The extraction of transponder register data over the air-air link is defined in terms of the reply length (RL) and DS fields in the short air-air interrogation. Note that BDS = 0 does not access a legal transponder data register so it is not permitted. In fact, BDS = 0 accesses the transponder register used for an AICB.

15. ACQUISITION SQUITTERS

15.1 Transmission of acquisition squitters

15.1.1 When commanded to report the surface format by TCS commands, aircraft without automatic means of determining the on-the-ground condition, and aircraft with such means that are reporting airborne status, will transmit acquisition squitters, in addition to the surface type ES's, unless acquisition squitter transmission has been inhibited. This action is taken to ensure ACAS acquisition in the event that the ground station inadvertently commands an airborne aircraft to report the surface type of ES.

15.1.2 If aircraft are commanded to stop emitting surface ES's by TCS command, these aircraft will begin to emit the acquisition squitter (if not already doing so). This will reduce the squitter rate from two ES's per second to one acquisition squitter per second.

15.1.3 In the event that the transponder generates acquisition squitters while in the surface state, these squitters will be generated using only the top-mounted antenna for aircraft with antenna diversity.

15.1.4 A summary of the acquisition squitter conditions is presented in Table H-9. In this table, Y indicates that the acquisition squitter is regularly broadcast, and N means that the acquisition squitter is suppressed. The condition of no transmission of any ES can result from (1) initialization with no position, velocity, identity or altitude data available, or (2) a surface squitter lockout command while reporting the surface type of ES.

15.1.5 The CA field of the acquisition (and extended) squitters reports the vertical status as determined by the aircraft. The TCS in SD controls the position format type reported by the transponder, either airborne or surface. These commands affect only the format type reported; they do not change the aircraft determination of its on-the-ground condition and therefore have no effect on the status reported in the CA, FS or VS fields.

16. ES

Note.— All the aspects of the ES technique are dealt with in detail in Appendix K, including protocol considerations.

17. DATA LINK CAPABILITY FOR AN INTERROGATOR USING AN SI CODE

17.1 Some of the data link protocols defined in this section require the use of an II code. These protocols cannot be used by an interrogator operating with an SI code.

17.2 The data link activity for an interrogator operating with an SI code is therefore limited to unlinked Comm-A, broadcast Comm-A, GICB, broadcast Comm-B and ACAS downlink transactions. This specifically excludes the use of the AICB protocol.

Note.— The AICB protocol is required for data flash and downlink MSPs.

Table H-9. Acquisition squitter transmission requirements

	Acquisition squitter not inhibited			*Acquisition squitter inhibited*		
Aircraft on-the-ground condition	*No transmission of any surveillance type ES*	*At least one surveillance type extended squitter transmitted*	*Reporting surface Format*	*No transmission of any surveillance type ES*	*At least one surveillance type extended squitter transmitted*	*Reporting surface format*
Airborne	Y	Y	Y	Y	N	N
Surface	Y	N	N	Y	N	N
Airborne or surface	Y	Y	Y	Y	N	N

Notes:
a) Y = regular transmission of acquisition squitters.
b) N = acquisition squitter suppressed.
c) Surveillance type ES's are airborne position, airborne velocity or surface position ES's.

Appendix I

MODE S SPECIFIC SERVICES

1. MODE S SUBNETWORK

1.1 Introduction

Mode S message formats and protocols provide data communication capability between air and ground systems. Mode S data link and subnetwork provide a high integrity means of exchanging information between air and ground.

1.2 Functional elements

1.2.1 The Mode S subnetwork is composed of the following functional elements:

a) a Mode S transponder (level 2, 3, 4 or 5 defined in Annex 10, Volume IV, Chapter 2);

b) an ADLP;

c) a ground data link processor (GDLP); and

d) a Mode S ground interrogator.

1.2.2 The Mode S ground interrogator is responsible for operating the Mode S protocols, in conjunction with aircraft Mode S transponders, as defined in Annex 10, Volume IV, Chapter 3. Once acquired by an interrogator (i.e. by identifying its unique 24-bit aircraft address), a suitably equipped aircraft within Mode S coverage may be selectively interrogated for surveillance purposes. The interrogations may include certain data in the uplink data fields that would invoke replies containing downlink data fields.

1.3 Service provided

1.3.1 The Mode S air-ground subnetwork has been designed to provide two types of communication services:

a) switched vertical circuit (SVC) communication service between two subnetwork points of attachment (SNPAs), one in the aircraft and the other on the ground. This connection-oriented communication service may be accessed by means of the protocol defined in ISO 8208 and is entirely conformant with the ATN architecture; and

b) a number of services particular to the Mode S system, known as Mode S specific services. These may be accessed by means of locally defined special purpose interfaces.

1.3.2 The first type of communication services supporting connection-oriented communication allows a transparent exchange of general-purpose messages. It is based on complex protocols and has not yet been used.

1.3.3 The second type of services (Mode S specific services) is based on simple exchanges of specific messages allowing easy implementation of certain applications. This capability of the Mode S subnetwork is used to support applications like EHS (downlinking of airborne information) or TIS (uplinking of aircraft position in close proximity of an aircraft). A number of other applications can be envisaged like meteorological data collection, airspace infringement alert, runway incursion alert, audio communication loss alert and ACAS sensitivity level control for the register formats and protocols of currently defined applications (see Doc 9871).

2. DATA LINK CAPABILITY REPORTING

2.1 Transponder capability levels

A number of different levels of SSR transponder are defined in Annex 10, Volume IV, Chapter 2, that indicate the data link capability. The basic transponder required to support data exchange is level 2. Such a transponder is capable of handling uplink and downlink SLM transactions. Level 3 adds the capability of handling uplink ELM transactions, while level 4 offers both uplink and downlink ELM capability. In order to provide a higher throughput compared to a level 4 transponder, the level 5 transponder provides a higher data link capacity with the added ability to operate with more than one interrogator at a time.

2.2 Data link services capability reporting

2.2.1 General

2.2.1.1 The amount and type of data link activity supported by an aircraft Mode S installation is defined by the Mode S data link capability report (Annex 10, Volume IV, Chapter 3, and Doc 9871). This report is extracted from the transponder by the ground interrogator at surveillance acquisition when notified by the transponder that the report has changed. This report specifies the aircraft data link capability class, level 2, 3, 4 or 5 and provides additional information regarding:

a) data rates that the aircraft installation can support;

b) presence and status of ACAS equipment;

c) availability of Mode S specific services; and

d) availability of SVC services.

2.2.1.2 The transponder capability is used by the ADLP and GDLP to determine an appropriate Mode S packet size and protocol for uplink and downlink transmissions.

2.2.2 Mode S specific services reporting

2.2.2.1 The "Mode S specific services capability" (bit 25) of register 10_{16} indicates that at least one Mode S specific service (other than data link capability reporting, aircraft ID reporting, or ACAS RA reporting) is installed when it is set to ONE (1).

2.2.2.2 Registers 18_{16} to $1C_{16}$ indicate which GICB services (transponder registers) are installed, i.e. the transponder manages the register, and there is an interface to load data in the register.

2.2.2.3 Register 17_{16} indicates which GICB services (transponder registers) are currently loaded with useful data.

2.2.2.4 Register $1D_{16}$ to $1F_{16}$ indicate which MSP services are installed.

2.2.3 Mode S SVC services reporting

Register 10_{16} indicates the status of on-board data terminal equipment (DTE) supported by the aircraft systems.

2.2.4 Mode S subnetwork version

Mode S subnetwork version available in Register 10_{16} is used to indicate which version of SVC services and Mode S specific services is installed. This indication allows compatibility and smooth transition between versions. The subnetwork version number is very important for managing the different versions of Mode S specific services which are expected to change more often than SVC services as they are application dependent. The correspondence between the version number and the format of Mode S specific services is given in Doc 9871.

2.3 Report generation

2.3.1 Within a particular level, the capability of transponders may be expected to vary in terms of peak and average data acceptance and reply rates. This information is required by the ADLP to construct and send the aircraft data link capability report to the ground system. If the ADLP is not combined with the transponder, this information must be made available by the transponder through a locally defined transponder interface. The approach used for such information transfer must ensure that transponder capability information to the ADLP is automatically updated if a transponder is replaced. An example of an acceptable means for this transfer is to incorporate transponder capability information into pins on the connector of the cable that interfaces the transponder with the ADLP.

2.3.2 If there is a change in the capability report (including the absence of the report from the ADLP due to an interface failure), the Mode S transponder will make the new report available as a broadcast Comm-B message in order to update the data link status for ground interrogators currently providing communications service.

2.4 Interrogator handling of incorrectly reported capability

2.4.1 In designing the data link communications function of a Mode S Interrogator, care must be taken to handle the case of an incorrectly reported data link capability, in particular, the case of the reported capability being greater than the actual capability. If an aircraft reports a higher than actual communication capability, its transponder may fail to reply to an addressed interrogation. This can happen when the transponder is not equipped for the service (e.g. an ELM interrogation to a level 2 transponder) or in a case where the interrogator exceeds the communications capacity of the avionics installation. In the latter case, a Mode S transponder may not reply to a data link interrogation if it cannot store the message field of the interrogation.

2.4.2 Since an incorrectly reported capability can lead to an absence of replies, the interrogator communications function should detect the absence of expected replies to communications interrogations and revert to 56-bit surveillance interrogations that command 56-bit surveillance replies in order to maintain the essential surveillance function. The initial transaction on subsequent scans should continue to be for surveillance only. After a successful surveillance transaction, additional attempts may be made in the beam dwell to see whether the aircraft has recovered its communications capability. Repeated communications failures should lead the interrogator to downgrade the aircraft capability to a level corresponding to the observed reply performance.

2.5 Interrogator capability

Interrogators with advanced antenna and transmission capabilities will be able to transfer a greater amount of data in a given period of time. The interrogator capability will be used to determine the quality of service that is available over a particular subnetwork connection.

3. MODE S SPECIFIC SERVICES

3.1 Protocols used by Mode S specific services

Mode S specific services include:

a) the GICB protocol;

b) an MSP corresponding to a datagram service developed for specific real-time applications; and

c) the Mode S broadcast protocols (uplink and downlink).

3.2 SSE

3.2.1 Provision is made for Mode S specific services to be accessed by means of one or more special purpose interfaces, routing data directly between applications and the Mode S SSE of the ADLP or GDLP. Alternatively, an application may access the SSE by means of the DTE/data circuit-terminating equipment (DCE) interface.

3.2.2 Access to the SSE must take account of the following factors:

a) the SSE is dedicated mainly to time-critical applications. In this context, it is generally better to tolerate sporadic loss of real time information that will be replaced with more current data, than to enforce reliable, ordered, end-to-end transmission of messages. Enforcing this discipline will put the communication system at risk of failing to keep up with the pace of the application;

b) the Mode S specific services support real time connectionless communication protocols with minimum overhead and do not fit into the basic concept of open system interconnection (OSI). Implementing intermediate connection-oriented services between the SSE and its users would require the development of specific protocols, e.g. to ensure the proper end-to-end delivery of broadcast messages; and

c) most applications using Mode S specific services have a high probability of being run on stand-alone end-systems that have a direct connection with the GDLP, rather than communicating across the ATC.

3.2.3 When connection-oriented intermediate layers are excluded, the responsibility for managing the dialogue between the SSE and its subscribers depends entirely on the applications.

3.3 Mode S specific services processing

Note 1.— There are three services to be handled by the SSE: broadcast, GICB and MSP.

Note 2.— Formats of data contained in aircraft registers, broadcast messages and MSP are defined in Doc 9871.

3.3.1 GICB processing

3.3.1.1 The GICB protocol was developed to make it possible to deliver real-time information, such as aircraft state data, in an efficient manner to several interrogators without requiring coordination. The technique used is to provide 255 transponder data registers of 56 bits in the transponder and provide coding in the interrogation to allow the interrogator to specify which, if any, of the register contents it wants to have transferred in the reply to that interrogation. Thus, only a single transaction is used to transfer the information, and no coordination with neighbouring interrogators is required since an interrogator cannot clear or alter the contents of the registers. Information stored in the registers must be kept current since the aircraft application loading the register does not know when it will be read. The overall operation is very similar to the readout of the altitude code in a surveillance reply.

3.3.1.2 The recommended protocol for GICB subscription is as follows:

a) a ground user sends a subscription message to the SSE indicating that it wants to receive GICB data for one or more registers;

b) a ground user can send a GICB request for single or periodic extractions of a given transponder register for a given aircraft;

c) when a GICB has been extracted, the response message is sent to the subscriber by the ground SSE; and

d) the user can cancel an active subscription at any time.

3.3.1.3 This recommended protocol is intended to minimize the data traffic between the ground SSE and the users. Developers might wish to build upon this minimum protocol and use more sophisticated features.

3.3.1.4 For example, EHS installations provide information about magnetic heading, ground speed, airspeed, vertical rate and selected altitude through three registers (40_{16}, 50_{16}, 60_{16}). The registers are periodically extracted by ground interrogators and the additional information is provided within the target report messages sent to users.

3.3.2 MSP

3.3.2.1 *Requirements for MSPs*. Messages transferred in support of certain real-time applications must be transferred with a minimum of delay and overhead. Furthermore, they must not be subject to retransmission in the event of a lost message or one received with a detected error. Real-time applications require that missing messages or messages with detected errors be ignored since the following messages will contain more recent data. If this retransmission service is applied, old messages would be retransmitted and current messages would be delayed waiting for the delivery process to catch up. The MSP was defined to support these real-time applications by defining a technique to bypass the ISO 8208 protocol and to permit data transfer with a minimum of overhead.

3.3.2.2 The operating characteristics of MSPs compared to SVCs show the following advantages:

a) they have the potential for shorter delivery time since they are not subject to flow control;

b) they operate with a total overhead of 1 or 2 bytes per packet; and

c) there is no set-up time.

For these reasons, they are well suited to support real-time data transfer.

3.3.2.3 However, MSPs are not as reliable as SVCs since:

a) they cannot have subnetwork-wide user addresses;

b) packets may be lost without notification to the sender (e.g. discarded by a flooded ADLP or GDLP); and

c) the order of packets is not guaranteed.

3.3.2.4 It is important to note that the speed advantage of MSPs might be reduced if the messages sent via an MSP channel are too long since:

a) they may become subject to segmentation and reassembly; and

b) their delivery may require more than one antenna scan.

3.3.2.5 *MSP processing and use.* The ground SSE must notify a subscriber of the successful delivery of an uplink MSP to the transponder (i.e. a technical acknowledgement). However, it is recognized that the only certain way to ensure that an MSP message has reached its peer application is through the use of an application acknowledgement.

3.3.2.6 In general, uplink and downlink MSP channels are simplex and independent. The simplest way to approximate a duplex MSP channel is to match an uplink and a downlink channel, both with the same channel number.

3.3.2.7 *MSP coordination in overlapping coverage.* The MSP achieves its bit efficiency, in part, through the use of limited addressing capability. On the uplink, the addressing consists of the MSP channel number. Downlink addressing also consists of the MSP channel number, although the II code can be used in a multisite-directed delivery. A second consideration for coordination is that the sequence numbers for L-bit processing are reset at the beginning of each message transfer on an MSP channel number basis. See Annex 10, Volume III, Part I, Chapter 5, 5.2.7.4, for the definition of L-bit processing and sequencing.

3.3.2.8 To ensure the correct downlink routing of aircraft request/response messages and the correct assembly of an L-bit sequence, some form of coordination is required between adjacent ground applications using the same MSP channel number. The simplest form of coordination is to ensure that there is no overlap in service volume between two ground applications using the same MSP channel number. An alternative technique is to have the ground applications (with overlapping coverage) coordinate their activities to ensure that only one application is active with a given aircraft at any one time.

3.3.2.9 In order to detect delivery errors, applications making use of MSPs may be developed with the ability to build and verify a checksum. For example, one such algorithm is defined in ISO 8073. Upon detection of an error, local procedures could be invoked to notify the user of the error.

3.3.3 Examples of applications using MSP

3.3.3.1 *TIS.* TIS is intended to improve the safety and efficiency of a "see and avoid" flight by providing the pilot with an automatic display of nearby traffic and warnings of any potentially threatening traffic conditions. TIS uses uplink MSP channel 2 to send keep-alive messages, goodbye messages and traffic data to aircraft.

3.3.3.2 *Dataflash.* Dataflash is a service that announces the availability of information from air-to-ground on an event-triggered basis. Dataflash is an application that runs on board aircraft and accepts different types of contracts to indicate to users when a register has changed. When "dataflash MSP service is implemented", bit 31 of Register $1D_{16}$ is set to 1 and uplink MSP channel 6 is used to send ground SRs to the airborne application. Downlink MSP channel 3 is used to downlink register values or to indicate contract status.

3.3.4 Broadcast processing

3.3.4.1 The broadcast Comm-A protocol was designed to permit a Comm-A message to be delivered efficiently and quickly to a number of aircraft. A Comm-A interrogation containing the message is transmitted using a 24-bit aircraft address of all ONEs. The transponder recognizes this as a broadcast message and accepts the interrogation but does not reply. To ensure delivery, the interrogation must be transmitted two or more times per beamwidth. Ground-to-air uses might include information of general interest such as the status of ATC services at a particular terminal or the transmission of hazardous weather information.

Note.— A similar protocol referred to as Comm-U is used by ACAS on the air-air link to announce its presence to other ACAS units to support interference-limiting calculations. It is also used by ACAS to broadcast its manoeuvre intent to omnidirectional Mode S receiving stations.

3.3.4.2 The recommended protocol for uplink broadcast is as follows:

a) a user generates a broadcast request that contains the broadcast message, an indication of the required broadcast area and the duration of the requested broadcast delivery; and

b) a user can cancel a request for broadcast delivery at any time.

3.3.4.3 The Comm-B protocol is designed to deliver a downlink message to a single interrogator. This is accomplished by the interrogator clearing the message after it is successfully transferred. The broadcast Comm-B protocol indicates its presence to the ground through an indication in surveillance and Comm-B replies. This indication remains set for at least 18 seconds and cannot be reset by an interrogator, which makes it possible for any interrogator in contact to read the message. This protocol is used by the transponder to deliver a change in either the capability report or aircraft ID.

Note.— A modified form of this protocol is used by ACAS to deliver intent messages to Mode S interrogators.

3.3.4.4 The recommended protocol for downlink broadcast is as follows:

a) a user sends a subscription message indicating that it wants to receive downlink messages for one or more specified broadcast channels;

b) the ground SSE adds the user to an internal list of downlink broadcast subscribers; and

c) a user can cancel its broadcast subscription at any time.