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THE MODE SELECT (MODE S) SURVEILLANCE AND COMMUNICATIONS, ATC AND NON-ATC LINK PROTOCOLS, AND MESSAGE FORMATS

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1.0 INTRODUCTION

The Mode Select Beacon System is an evolutionary upgrading of the Air Traffic Control Radar Beacon System (ATCRBS). Mode S provides improved surveillance and an integral ground-air-ground digital data link for transmission of Air Traffic Control (ATC) communication messages and other user messages.

It is the purpose of this report to specify the message transport and link protocols between Mode S sensors and the National Airspace System (NAS).

The report treats surveillance interfaces separately from communications interfaces.

The surveillance transport and link will be used to interface the Mode S system with Air Traffic Control (ATC) systems, this includes: ARTS-IIA, ARTS-IIIA, 9020 computer, Host computer and Direct Access Radar Channel.

Communications transport and link are defined with a listing of all message types. Message formats are categorized according to user type. Messages passing between a Mode S sensor and an ATC facility are specified separately from, messages passing between a Mode S sensor and providers of data link services other than ATC facilities (designated "non-ATC").

2.0 MODE S SURVEILLANCE INTERFACES WITH THE NATIONAL AIRSPACE SYSTEM

The Mode S surveillance interface has two formats: enroute (2.1) and terminal (2.2). The terminal and enroute interface link protocol shall be Common Digitizer-2 (CD-2), as specified in FAA-E-2679a, June 22,1982. The formats of the messages are described below.

In a field where the bit orientation is not specified; the left most bit, lowest numbered bit, top most bit and MSB are all equivalent representations of the same bit. This holds true for descriptions in the text, and for graphics in tables and figures.

Any adaptable parameters that have a numeric value and range are specified in standard FAA-E-2716 notation, for example: 1(1-7,1) scans.

Azimuth in the CD-2 formats are in ACPs, Mode S uses azimuth units (Au). The conversion is: 1 ACP = 4 Au (1 Au ~ 0.022°).

A radar report used by Mode S to replace a missing beacon report during Mode S surveillance processing shall be reported with a search (radar) message.

2.1 Enroute surveillance format

All surveillance links in this configuration shall use the CD-2 formats of FAA-E-2679a, June 22,1982. Table II of FAA-E-2679a provides a diagram of these message formats. The use of these messages, by Mode S, is specified in the following paragraphs.

The CD-2 formats are intended for use by an ATCRBS beacon digitizer, and as such, Mode S cannot use its internal data to directly set all beacon fields in the messages. The specification of the fields in the messages is limited to these fields that Mode S cannot set directly, from its internal data.

The information necessary to allow Mode S to set the fields, not described herein, is found in FAA-E-2679a. This includes fields, and sometimes whole messages, set using data from the search (primary) radar, and fields that are set directly by Mode S with its internal data.

2.1.1 Beacon message

Mode S shall report both beacon targets and the beacon real time quality control (RTQC) target using this message.

Beacon targets are both ATCRBS and Mode S, and the reports from these targets are used to generate beacon messages. The Mode S duplicate address alert table (DAAT) shall also be used to generate beacon messages. A DAAT target message shall be placed in the output data stream at the time that normal surveillance messages (if any), having azimuths within ± 128 Au of the DAAT target azimuth, would be placed in the output data stream.

The beacon RTQC target is not a real target or a test target, it only exists as a surveillance message. The data for the RTQC target message shall be site adaptable. The RTQC message shall be issued when; the current antenna azimuth equals the azimuth in the message plus a bias of 1536(0-2048,32) Au. The

first bit of the message shall leave the sensor's modem interface drivers with an accuracy of ± 24 Au, relative to the antenna position at the above message azimuth plus bias. The azimuth of the beacon RTQC will not be any closer to the search RTQC than 1/32 of a scan. By means of site adaptation, it shall be possible to issue or not issue the RTQC target message, when the sensor is in a red condition.

2.1.1.1 RTQC/test

This bit is set to one for the RTQC messages. This field shall be set to zero for CPME target reports (even though the CPME is a test target of sorts).

2.1.1.2 Mode 2

This field indicates the validity of the Mode 2 code data. If the sensor indicates Mode 2 code confidence as all high confidence, then the data is valid, and this field is set to one. If the code confidence is not all high confidence, or if the Mode 2 code data is not present, then the data is not valid, and this field is set to zero.

2.1.1.3 Mode 3/A

This field indicates the validity of the Mode 3/A code data.

For ATCRBS targets; if the sensor indicates Mode 3/A code confidence as all high confidence, then the data is valid, and this field is set to one. If the code confidence is not all high confidence, or if the Mode 3/A code data is not present, then the data is not valid, and this field is set to zero.

The sensor may replace the Mode 3/A code of an ATCRBS report with the Mode 3/A code from a track. When this happens, the Mode 3/A confidence bits from the track shall be used, instead of the report code confidence bits, to validate the report code according to the above ATCRBS target rules.

For Mode S targets; The ATCRBS 3/A code is acquired by the sensor in a different way than for ATCRBS targets. As long as there is an 3/A code in the surveillance file for a Mode S target, that code is present and valid, and this field is set to one. If the code is not present this field is set to zero.

2.1.1.4 Mode C

This field indicates the validity of the Mode C altitude data.

For ATCRBS reports; if the sensor has successfully decoded the Mode C data for a report, then the data is valid, and this field is set to one. If the sensor has not successfully decoded the Mode C data, or if the Mode C data is not present, then the data is not valid, and this field is set to zero.

For Mode S targets; if there is a surveillance reply with altitude data (not just the altitude field), the Mode C data is present and valid, and this field is set to one. If the altitude data is not present in any reply, this field is set to zero.

2.1.1.5 Ident

This field is the SPI bit in the Mode S sensor. For ATCRBS targets, this is set to one when the SPI bit is one with high confidence. For Mode S targets, this is set to one when the FS field in the Mode S reply indicates the identify (SPI) function is set in the transponder. Otherwise this field is set to zero.

2.1.1.6 Spec. tgt

This field (special target) shall always be set to zero.

2.1.1.7 R/L

The data for this field shall be site adaptable, the default is zero. Note: the different settings of this field cause changes in the beacon message format.

2.1.1.8 Beacon run length reporting

The beacon run length has different settings depending on conditions related to a given beacon target report. The conditions for a given report and the setting, in ACPs, are given below.

Condition	ACPs
ATCRBS, meets FAA-E-2716, 3.4.6.4.14(a)	24
ATCRBS, meets FAA-E-2716, 3.4.6.4.14(b)	22
ATCRBS, flagged as code in transition	10
ATCRBS, uncorrelated, code all high confidence	20
ATCRBS, other than above	8
Mode S target report	26

2.1.1.9 Mode C altitude

If the validation bit has been set to one, this field is the altitude as shown in the message format. If the validation bit has been set to zero, this field is set to all zeros.

2.1.2 Not used

2.1.3 Strobe message

The Strobe message is used to report both search and beacon strobes.

2.1.3.1 Test

Mode S does not produce test strobe messages, so this field shall be set to zero, for the beacon strobe message.

2.1.3.2 Range

Mode S does not report beacon strobes by range, so this field shall be set to 200 nmi., for the beacon strobe message.

2.1.4 Search Message

The search message is used to send search reports (primary radar reports) that do not correlate with beacon reports.

2.1.5 Search RTQC Message

The search RTQC message is used to send search RTQC reports (one message per scan). The message shall be transmitted (after receipt from the CD-2) when; the current antenna azimuth equals the azimuth in the message plus a bias of 1536(256-2048,32) Au. The first bit of the message shall leave the sensor's modem interface drivers with an accuracy of ± 24 Au, relative to the antenna position at the above message azimuth plus bias.

2.1.6 Not used

2.1.7 Status Message

The status message is used to send the status of Mode S and the search (primary) radar. The setting of the beacon status is discussed below. If there is no current status report from the radar (i.e. there is no report or the existing report is 2(1-5,1) scans old), the search status fields shall be set to indicate failure of the radar.

2.1.7.1 Beacon channel

This field is set to indicate which sensor (beacon) channel has been selected as the active channel, one = channel A and zero = channel B.

2.1.7.2 On-line beacon alarm

This field shall be set to one when the active sensor channel is in a yellow condition.

2.1.7.3 Beacon offset on

This field shall be site adaptable, the default shall be zero. The setting of this field, to one, will cause the special formatting of search and beacon messages to be invoked. The requirements for this processing are discussed below. This processing is not intended to be used during capacity loading of the sensor. Therefore; additional sensor load, that results when this processing is active, shall not be considered as part of the sensors capacity. The following shall be done when this field is set to one:

(a) Formatting shall add 0.5 nmi. to the range of all output beacon report messages.

(b) Formatting shall provide messages for all search targets received by the sensor. This requires that the search reports, normally lost during radar beacon correlation, be retained for formatting. Search messages, produced under these conditions, shall not be released any sooner or later than as if they were produced under normal formatting.

The beacon offset process allows the current ATC facilities to use their current data extraction and data reduction programs. These programs are used during facility checkout.

2.1.7.4 Standby beacon alarm

This field is set to one when the standby sensor channel is in a red condition.

2.1.7.5 Beacon RTQC alarm

This field is set to one when the sensor is reporting a red condition.

2.1.8 Map Message

The map message is used to send search weather data.

2.2 Terminal surveillance format

All surveillance links in this configuration shall use the CD-2 formats of FAA-E-2679a, June 22,1982, as modified in the following paragraphs.

The CD-2 formats are intended for use by an ATCRBS beacon digitizer, and as such, Mode S cannot use its internal data to directly set all beacon fields in the messages. Also, the CD-2 formats are intended for use by enroute ATC facilities. This requires CD-2 format modifications that were unnecessary for the enroute surveillance link format. The specification of the fields in the messages is limited to these fields that Mode S cannot set directly, from its internal data; and to the modifications required for the terminal format.

The information necessary to allow Mode S to set the fields, not described herein, is found in FAA-E-2679a, and in the appropriate specification for the colocated search (primary) radar. These undescribed fields include fields, and sometimes whole messages, set using data from the search (primary) radar, and fields that are set directly by Mode S with its internal data.

Fields specified in the enroute section (2.1), that have the same use in this section, are not respecified here.

2.2.1 Beacon message

This message is the same as the enroute message (2.1.1), with exceptions described below.

The RTQC target shall not be reported (an RTQC message) when the sensor is in a red condition. The RTQC target message shall be placed in the output data stream at the time that normal surveillance messages (if any), having azimuths within ± 128 Au of the RTQC azimuth, would be placed in the output data stream.

When this message is used for the RTQC sector synchronization message, all fields are set to zero unless otherwise specified below. Special timing is also required for the sector synchronization message. The sector message

shall be issued when; the current antenna azimuth equals the azimuth in the message plus a bias of 1536(0-2048,32) Au. The the first bit of the message shall leave the sensor surveillance link modem interface drivers with an accuracy of ± 24 Au, relative to the antenna position at the above message azimuth plus bias.

2.2.1.1 Mode 3/A validation

This new field has the same function as the CD-2 field Mode 3/A (2.1.1.3). This field is composed of the CD-2 fields "Mode 3/A" and "Mode C".

When the conditions exist that would cause the CD-2 Mode 3/A field to be set to one, this field shall be set to all ones. When the conditions exist that would cause the CD-2 Mode 3/A field to be set to zero, this field shall be set to zero.

2.2.1.2 Mode C validation

This new field has the same function as the CD-2 field Mode C (2.1.1.4). This field is composed of the CD-2 fields "R/L flag" and "MTI flag".

When the conditions exist that would cause the CD-2 Mode C field to be set to one, this field shall be set to all ones. When the conditions exist that would cause the CD-2 Mode C field to be set to zero, this field shall be set to zero.

2.2.1.3 FAA

This CD-2 field shall be used to report the Mode 3/A "X" bit.

2.2.1.4 AF

This CD-2 field shall be set to one to indicate an RTQC sector synchronization message, otherwise this field is set to zero.

2.2.1.5 Terminal range

This new field is the measured range of the beacon target. This field is composed of the CD-2 fields "Range" and "Spec. tgt". The LSB of this new field is in Spec. tgt, (bit 25) and has the value of 1/64 nmi.

2.2.1.6 ARTS-IIIA Quality

This new field is composed of the CD-2 fields "AIMS present" and "AIMS code". When this beacon report is radar reinforced; the ARTS-IIIA quality field, of the reinforcing radar report, is used to fill this field. When the beacon report is not radar reinforced; this field represents the quality of the beacon report. The settings, in binary, for beacon quality and related conditions are listed below.

Condition	Setting
Mode 3/A validation = all ones	111
Mode 3/A validation = zero	011

5

2.2.1.7 Discrete

This CD-2 field shall be used as if the CD-2 field R/L were set to zero.

2.2.1.8 Mode 2 "X"

This CD-2 field shall be used as if the CD-2 field R/L were set to zero.

2.2.1.9 Beacon hit count

This new field is composed of the CD-2 fields "Mode 3/A 'X'" and "Time in storage". The CD-2 field Mode 3/A "X" (bit 45) is the MSB of the new field. This new field is an unsigned binary integer, the settings are given in decimal. The settings of this field and related conditions are listed below.

Condition	Setting
ATCRBS, meets FAA-E-2716, 3.4.6.4.14(a)	20
ATCRBS, meets FAA-E-2716, 3.4.6.4.14(b)	18
ATCRBS, flagged as code in transition	8
ATCRBS, uncorrelated, code all high confidence	16
ATCRBS, other than above	7
Mode S target report	21

2.2.1.10 Azimuth

This field is the same as in enroute (2.1.1.5), unless the message is an RTQC sector synchronization message. When used for sector synchronization, the azimuth setting represents the antenna position. The values are every 11.25° increment (0°, 11.25°, 22.5°, ...) from north (zero) to 348.75°. The MSB of this field is 180°.

2.2.2 Not used

2.2.3 Strobe message

This message is not used in the terminal format for the surveillance link.

2.2.4 Search message and search RTQC message

These messages are the same as the enroute messages (2.1.4 and 2.1.5), with the following exceptions.

The search RTQC target message (CD-2 field AF set to zero in the message received from the radar) has the following timing. This message shall be placed in the output data stream at the time that normal surveillance messages (if any), having azimuths within ± 128 Au of the RTQC azimuth, would be placed in the output data stream.

The sensor shall dispose of any sector synchronization RTQC messages received from the radar. The sensor shall create its own search RTQC messages. All fields shall be set to zero unless otherwise specified below. These messages

shall be created with the same azimuth settings as the beacon RTQC sector synchronization messages (2.2.1). The message shall be issued in parallel to, or as the next message after, the beacon RTQC message with matching azimuth. Note: the CD-2 rules, for using the idle word with messages, still apply.

2.2.4.1 FAA

This CD-2 field is set to zero.

2.2.4.2 AF

This CD-2 field is set to one to indicate an RTQC message that is a sector synchronization message, otherwise this field is set to zero.

2.2.4.3 Terminal range

This new field is the range of the search target. This field is composed of the CD-2 fields "Range" and "0" bit 25. The LSB of this new field is in "0" bit 25, and has the value of 1/64 nmi.

2.2.4.4 Additional field modifications

The fields AIMS present, Run length and Time in storage are modified to this format:

Bit	Field
40	Radar quality
41	
42	Radar confidence
43	
44	
45	Tracking eligibility
46	
47	ARTS-IIIA radar quality
48	
49	
50	Spare set to 0
51	Scan to scan correlated

2.2.5 Not used

2.2.6 Not used

2.2.7 Status Message

The status message is used to send the status of both Mode S and the search (primary) radar. This message has a different format than the CD-2 message, the new format is shown in table 2.2.7-1. The setting of the beacon status is discussed below. If there is no current status report from the radar (i.e. there is no report or the existing report is 2(1-5,1) scans old), the search status fields shall be set to indicate failure of the radar.

2.2.7.1 Beacon channel on-line

This field is set to indicate which sensor channel has been selected as the active channel, one = channel A and zero = channel B.

2.2.7.2 Beacon channel A alarm

This field is set to one when channel A is in a red condition.

2.2.7.3 Beacon channel B alarm

This field is set to one when channel B is in a red condition.

2.2.7.4 Reserved for Mode S

The contractor shall define the use of these bits to provide important status information about the operation of the sensor. The contractor shall submit an ECP to the government for approval, that defines the proposed use of these bits. This ECP shall be submitted against this document.

2.2.8 Map Message

This message is the same as the enroute message (2.1.8).

Table 2.2.7-1.

Terminal Surveillance Status Message Format

Bit	Field	
1	Test	
2		0
3		0
4		0
5	Message Label	1
6		1
7		0
8		0
9		0
10		0
11		0
12		0
14	Channel On-Line	
15	Channel A Alarm	
16	Channel A Unavailable	
17	Channel B Alarm	
18	Channel B Unavailable	
19	Post Proc. On-line	
20	Post Proc. A Alarm	
21	Post Proc. A Unavailable	
22	Post Proc. B Alarm	
23	Post Proc. B Unavailable	
24	Wx Proc. On-Line	
25	Wx Channel Alarm	

Bit	Field
27	High Voltage On
28	Antenna Polarization
29	Antenna Rotation
30	SCIP On-Line
31	SCIP Channel A Alarm
32	SCIP Channel B Alarm
33	Maintenance Alarm
34	Comm Link A Alarm
35	Comm Link B Alarm
36	RMS Alarm
37	Spare (set to zero)
38	
40	Beacon Channel On-Line
41	Beacon Channel A Alarm
42	Beacon Channel B Alarm
43	
44	Reserved for Mode S
45	
46	
47	
48	
49	
50	
51	

(Note: CD-2 parity fields omitted for clarity)

3.0 NOT USED

4.0 MODE S COMMUNICATIONS INTERFACES WITH THE NATIONAL AIRSPACE SYSTEM

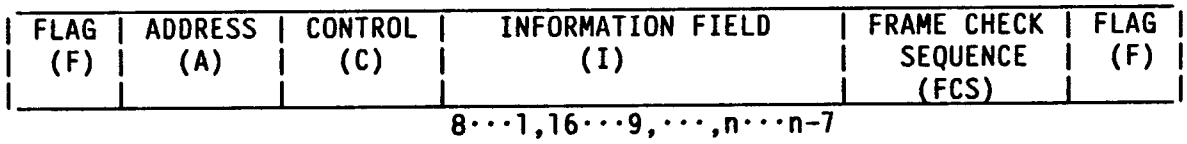
A Mode S sensor has communication interfaces with two types of users: ATC and non-ATC. Currently, the only non-ATC user is the Weather Communications Processor; additional users may be added in the future. Message types for both users are summarized in 4.3 and their formats detailed for ATC and non-ATC.

Each interface shall use the protocol specified in appendix A of this document, that of CCITT X.25.

> Note: Even though different type codes are assigned to ATC and non-ATC messages, many types of messages have exactly the same content and format in the ATC and non-ATC versions.

4.1 Frame Formats

The Information field (I) carries the ATC and non-ATC messages. Each message represents one (I) field in one X.25 frame. The diagram below, of the X.25 frame, illustrates the bit orientation of a message, n bits long, in the (I) field. All the messages are an integer number of bytes long. The bit numbers below the (I) field correspond to the bit numbers of the messages.



4.2 Not used

4.3 Summary of Message Types

The following is a list of all messages which cross the communications interfaces. They are grouped according to the sender and recipient of the message and to the character of the information content.

1. ATC-to-Mode S Uplink Messages:
   Standard Uplink Message (to a Mode S aircraft)
   ELM Uplink Message (to a Mode S aircraft)
   Request for Downlink Data (from a Mode S aircraft)
   ATCRBS ID Request (to a Mode S aircraft)
   Message Cancellation Request (of a previous uplink Message)

2. ATC-to-Mode S Status/Control Messages:
   Test Message (to a Mode S sensor)
   ATC Failure/Recovery Message (to a Mode S sensor)
   Data Link Capability Request
   Sensor/Failure Recovery Message
   Mode S Aircraft Control State Message

3. Mode S-to-ATC Sensor Response Messages:
   Message Rejection/Delay Notice (with respect to a Mode S aircraft)
   Uplink Delivery Notice (with respect to a previous Uplink Message)

4. Mode S-to-ATC Downlink Messages, each from a Mode S aircraft
   Standard Downlink Message
   ELM Downlink Message
   Data Link Capability Message
   ATCRBS ID Code Message

5. Mode S-to-ATC Performance/Status Messages:
   Test Response Message (from a Mode S sensor)
   Status Message
   Track Alert Message (from a Mode S sensor on a given target)

6. Sensor-to-Sensor* Mode S Network Control Messages:
   Data Start
   Data Stop
   Data Request
   Track Data
   Cancel Request
   Primary Coordination

7. Sensor-to-Sensor* ATCRBS Network Control Messages:
   ATCRBS Data Start
   ATCRBS Data Stop
   ATCRBS Data Request
   ATCRBS Track Data
   ATCRBS Cancel Request

*Routed via ATC facility.

8. Sensor-to-Sensor* Status Messages:
   Status Message
   Adjacent Sensor Status Request
   Adjacent Sensor Status Response

9. Non-ATC-to-Mode S Uplink Messages:
   Standard Uplink
   ELM Uplink
   Request for Downlink Data
   Message Cancellation Request

10. Non-ATC-to-Mode S Status Reports:
    Data Link Capability Request
    Request for Aircraft State
    Request for Aircraft Position

11. Mode S-to-Non-ATC Response Messages:
    Message Rejection/Delay Notice
    Message Rejection/Delay Notice with Sensor IDs
    Uplink Delivery Notice

12. Mode S-to-Non-ATC Downlink Messages:
    Standard Downlink
    Standard Downlink with Position
    ELM Downlink
    ELM Downlink with Position
    Data Link Capability

13. Mode S-to-Non-ATC Status Messages:
    Aircraft State
    Aircraft Position
    Track Drop

Note: The term "standard uplink" refers to a message which is delivered to an aircraft by one or more Comm-A transmissions. Similarly, "standard downlink" refers to a message received from an aircraft by one or more Comm-B transmissions. (In FAA-E-2716, the term "tactical" is used in place of "standard".)

Each of these message types is identified by a unique type code, which serves to specify the format. Section 5 defines the format for each Mode S/ATC message type in terms of a fixed sequence of data blocks, and gives the definition and coding for each data block. Section 6 similarly defines the format for Mode S/Non-ATC messages.

*Routed via ATC facility.

5.0 MODE S/ATC COMMUNICATIONS MESSAGE FORMATS

5.1 General

The overall frame format for Mode S/ATC communications messages is given in 4.1. The remainder of this section defines the details of Information Fields, by message type.

Unless otherwise stated, all fields are encoded as right justified binary integers.

5.2 Information Field Type Codes

For each of the Mode S/ATC messages summarized in 4.3, Table 5.2-1 gives a value of a Type Code, which always appears as the first data block in an Information Field. These codes are 8 bits in length, the first 4 of which are a prefix which refers to a logically similar group of message types. It should also be noted that the code assignment scheme encompasses numerous other types of messages; hence, the codes shown in Table 5.2-1 refer only to the subset of messages between Mode S sensors and ATC facilities.

TABLE 5.2-1.

INFORMATION FIELD TYPE CODES FOR SENSOR/ATC MESSAGES

		Prefix	Suffix	
ATC-to-Mode S	Uplink Messages	0010	0001	Standard Uplink
		0010	0010	ELM Uplink
		0010	0011	Request for Downlink Data
		0010	0100	ATCRBS ID Request
		0010	0101	Message Cancellation Request
	Status/Control Messages	0110	0001	Test
		1001	1001	ATC Failure/Recovery
		0000	0010	Data Link Capability Request
		0110	0101	Sensor Failure/Recovery Message
		1001	1010	Mode S Aircraft Control State Message
Mode S-to-ATC	Sensor Response Messages	0011	0001	Message Rejection/Delay Notice
		0011	0010	Uplink Delivery Notice
	Downlink Messages	0100	0001	Standard Downlink
		0100	0010	ELM Downlink
		0100	0100	Data Link Capability
		0100	0101	ATCRBS ID Code
	Sensor Performance/ Status Messages	0110	0010	Test Response
		0110	0100	Status Message
		1001	1100	Track Alert Message
Sensor-to-Sensor	Mode S Network Control Messages	1001	0001	Data Start
		1001	0010	Data Stop
		1001	0011	Data Request
		1001	0100	Track Data
		1001	0101	Cancel Request
		1001	1101	Primary Coordination
	ATCRBS Network Control Messages	1101	0001	ATCRBS Data Start
		1101	0010	ATCRBS Data Stop
		1101	0011	ATCRBS Data Request
		1101	0100	ATCRBS Track Data
		1101	0101	ATCRBS Cancel Request
	Status Messages	0111	0001	Status Message
		0111	0010	Adjacent Sensor Status Request
		0111	0011	Adjacent Sensor Status Response

5.3 Information Field Formats

The Information Field formats for each ATC-to-Mode S and Mode S-to-ATC message type are shown in Fig. 5.3-1 and Fig. 5.3-2 respectively. A brief discussion of each data block follows.

5.3.1 ATC-to-Mode S Data Blocks

5.3.1.1 Type Code

The Type Code Block is an 8-bit control block which begins every Information Field. The code values are shown explicitly in Fig. 5.3-1, and have been summarized in Table 5.2-1.

5.3.1.2 Mode S Address

Mode S Address is the unique 24-bit identification code of a Mode S-equipped aircraft. The coding is the same as in FAA-E-2716.

5.3.1.3 Message Number (Msg. No.)

Message Number is a 8-bit binary integer unambiguously numbering all types of messages concerning a particular Mode S target and sent by a particular facility. This field is also kept as an unambiguous number in messages not concerning any one aircraft (like type codes 0110 0010 and 1001 1100). ATC facilities will only assign message numbers zero to 127, the sensor shall assign message numbers 128 to 255. Zero and 128 are excluded so that 127 messages about each aircraft and 127 messages not about any one aircraft, from ATC or Mode S, can be distinguished at a time. When a message, that has this field, is used as a response to a request, the message number assigned in the request is placed in this field. When the message is not used as a response, a new message number is assigned by the sender. Message numbers shall be assigned sequentially (this could allow the receiving facility to detect the loss of a message).

5.3.1.4 Priority (P)

Priority is a 4-bit block giving a user-supplied priority tag (for Uplink Messages only). It is a binary integer with 0 being the lowest and 15 the highest priority. Delivery of every Uplink Message is scheduled as promptly as possible regardless of the priority value; only if there is a queue of messages for a particular aircraft is a message given precedence over an earlier one with lower priority.

5.3.1.5 Expiration (EXP)

EXP is a 3-bit block encoding "Time to Expiration" of a message (for Uplink Messages only). It is a binary integer, with the values 1 through 7 representing the number of scans for which delivery should be attempted, encoded as follows:

EXP Value	Time to Expiration in Scan Periods
0	Default value
1	1
2	2
3	4
4	8
5	16
6	32
7	No expiration

5.3.1.6 Acknowledgment (ACK)

Acknowledgment is a 1-bit block containing a request for a response from a pilot or an on-board data system to a Standard Uplink message.

1 = Response requested
0 = No request

5.3.1.7 Segment Count (SC)

Segment Count is a 2-bit binary integer block present in a Standard Uplink or a Standard Downlink Message. Its value is one less than the number of message text segments comprising the complete message. Values of SC greater than zero correspond to "linked Comm-A's" (or Comm-B's).

5.3.1.8 Not Used

5.3.1.9 Spare (SP)

The SP field represents the needed spacing required in some messages in order to minimize shifting in the sensor and shall be set equal to zero.

5.3.1.10 Comm-A Message Text (MA)

MA is a 56-bit block present in Standard Uplink Messages. A message may contain up to 4 MA blocks, as specified by the value of SC. Coding of MA is not constrained by the Mode S sensor but must conform to FAA Order 6365.1A and the U.S. National Aviation Standard for Data Link Applications of the Mode Select Beacon System.

5.3.1.11 Length

Length is a 6-bit block present only in an ELM message. It is a binary integer specifying the number of 80-bit segments comprising the ELM Text block. Its value is one less than the number of segments. The minimum value of Length is 1 (2 segments) in an ELM Uplink message and zero (1 segment) in an ELM Downlink. The maximum value of Length is 63 (64 segments) in an ELM Uplink message and 15 (16 segments) in an ELM Downlink.

Note: A Length value greater than 15 in an ELM Uplink defines a set of linked ELMs. Processing of such a message to support the linking protocol is a task for the Data Link Processing function of the sensor.

5.3.1.12 ELM Text

ELM Text is a variable length ELM data field. For an ELM Uplink, its length is a multiple of 80 bits with a maximum of 5120 bits, corresponding to a sequence of 4 linked ELMs, each comprised of 16 consecutive Comm-C ground-to-air transmissions. For an ELM Downlink, its length is a multiple of 80 bits with a maximum of 1280 bits corresponding to a sequence of 16 consecutive Comm-D air-to-ground transmissions. Each transmission carries an 80 bit field of text. Coding of the ELM Text block is not constrained by the Mode S sensor but must conform to FAA Order 6365.1A and the U.S. National Aviation Standard for Data Link Applications of the Mode Select Beacon System.

5.3.1.13 BDS1 and BDS2

BDS1 and BDS2 are two 4-bit blocks present only in a Request for Downlink Data. Together they identify the particular data being requested from a Comm-B message device, as defined in FAA Order 6365.1A and the U.S. National Aviation Standard for Data Link Applications of the Mode Select Beacon System. BDS1=0001 and BDS2=0000 or 0001 signifies a request for an extended capability report from an airborne Mode S installation.

5.3.1.14 Referenced Message Number (Ref. Msg. No.)

Referenced Message Number is a 8-bit binary integer present only in messages that are in response to requests or are in reference to other messages. In a message cancellation request, it represents the message number of the message whose cancellation is being requested.

5.3.1.15 Referenced Type Code (Ref. Type Code)

Referenced Type Code is the 8-bit Type Code block corresponding to a message whose cancellation is being requested.

5.3.1.16 Test Data

Test Data is a 48-bit block present in a Test Message. The contents may be defined by the originator. Each message may be different.

5.3.1.17 State

State is a 2-bit data block occurring only in an ATC Failure/Recovery Message. It is used to inform a Mode S sensor of a change in the operational status of an ATC facility.

00 = Not used
01 = Failure
10 = Recovery from Failure
11 = Recover from Failure with loss of Data Base

5.3.1.18 Mode S Sensor ID (SID)

The Sensor ID field is 10-bit field which uniquely identifies the Mode S sensor whose status is being reported.

5.3.1.19 Sensor Status (SSTAT)

The 2-bit sensor status as reported by the ATC facility shall be interpreted as follows:

00 = Not used
01 = Sensor not failed
10 = Sensor failed
11 = Sensor communications failed

5.3.1.20 Primary Index (IP)

Primary Index is a 3-bit binary integer present in a Mode S Aircraft Control State Message. Its value is the number of Mode S addresses in the message representing controlled aircraft for which the sensor is being assigned primary. If IP is not zero, the corresponding Mode S addresses occupy Bit 17 through Bit 16+24*IP of the message.

5.3.1.21 Secondary Index (IS)

Secondary Index is a 3-bit binary integer present in a Mode S Aircraft Control State Message. Its value is the number of Mode S addresses in the message representing controlled aircraft for which the sensor is being assigned secondary. If IS is not zero, the corresponding Mode S addresses occupy Bit 17+24* (IP) through Bit 16+24* (IP+IS) of the message.

5.3.1.22 Uncontrolled Index (IU)

Uncontrolled Index is a 2-bit binary integer present in a Mode S Aircraft Control State Message. Its value is the number of Mode S addresses in the message representing uncontrolled aircraft. If IU is not zero, the corresponding Mode S addresses occupy Bit 17+24* (IP+IS) through Bit 16+24* (IP+IS+IU) of the message.

Note: The maximum length of the Mode S Aircraft Control State Message, corresponding to IP=7, IS=7, and IU=3, is 424 bits.

5.3.2 Mode S-to-ATC Data Blocks

Mode S-to-ATC Information Field formats are shown in Fig. 5.3-2. The following data blocks have already been defined as ATC-to-Mode S blocks: Type Code, Mode S Address, Segment Count, Referenced Message Number, Length, ELM Text, Sensor ID and SP. Definitions of the remaining blocks follow.

5.3.2.1 Qualifier (Qual)

The Qualifier is a 3-bit block present in a Message Rejection/Delay Notice only.

000 = Target not on file (rejection)
001 = Target not in roll-call mode (delay)
011 = Sensor not primary (rejection of ELM uplink)
100 = Targets lack ELM capability (rejection)

Other code values not assigned.

5.3.2.2 Delivery Indicator (DI)

The Delivery Indicator is a 1-bit block present in a Message Delivery Notice only. It reports on the success of a referenced Uplink Message with the following coding:

0 = Message successfully delivered
1 = Message expired, undelivered

5.3.2.3 Air/Ground Indicator (A/G)

The Air/Ground Indicator is a 1-bit block in a Standard Downlink message signifying the origination of the message request, with the following coding:

0 = Air-initiated
1 = Ground-initiated

5.3.2.4 Comm-B Message Text (MB)

The MB field is a 56-bit block used for downlink standard message text similar to the Uplink MA block. A message may contain up to four MB blocks as specified by the value of SC. However, when more than one such MB block is present, the 8-bit subfield BDS is omitted from each block except the first. Coding of MB is not constrained by the Mode S sensor but must conform to FAA Order 6365.1A and the U.S. National Aviation Standard for Data Link Applications of the Mode Select Beacon System.

5.3.2.5 Capability

Capability is a 55-bit block which indicates the input/output capability of the aircraft. It is divided into two subfields defined as follows:

CA (Basic Capability, bits 34-36): This field is the 3-bit CA field contained in Mode S All-Call replies. Its coding is defined in the FAA Order 6365.1A, 3.3.5.

ECA (Extended Capability, bits 37-88): This 52-bit field contains data when the CA field so indicates. Its coding is defined in FAA Order 6365.1A, 4.6.2.2. (Note: The 4 leading bits defined in FAA Order 6365.1A containing BDS1=1, are omitted in ECA).

5.3.2.6 ATCRBS ID

ATCRBS ID is a 12-bit block giving the 4096-code value from a Mode S transponder. The coding is the standard Mode 3/A format used in Surveillance Reports on ATCRBS targets.

5.3.2.7 Test Response Data

Test Response Data is a 48-bit block present only in a Test Response Message. The data must be an exact duplicate of the Test Data contained in the corresponding Test Message.

5.3.2.8 Range (1st or 2nd), Azimuth (1st or 2nd)

The range and azimuth fields, respectively 16 and 14 bits long, in the Track Alert Message, are the measured ranges and azimuths of the two targets that are involved in the duplicate address alert situation. Coding is the same as that used in the Mode S surveillance message.

5.3.2.9 Number of Mode S Tracks

Number of Mode S tracks in the sensor Track File. This number may be equal to or greater than the number of Mode S targets reported to a particular ATC facility.

5.3.2.10 Number of ATCRBS Tracks

Number of ATCRBS tracks in the sensor Track File. This number may be equal to or greater than the number of ATCRBS targets reported to a particular ATC facility.

5.3.2.11 Number of Radar Tracks

Number of Radar only tracks (i.e., tracks based on search returns which do not correlate with beacon reports or tracks) in the sensor Track File. This number may be equal to or greater than the number of radar targets reported to a particular ATC facility. For Mode S sensors which do not perform radar tracking, this field will be set to zero.

5.3.2.12 New Code Flag (N)

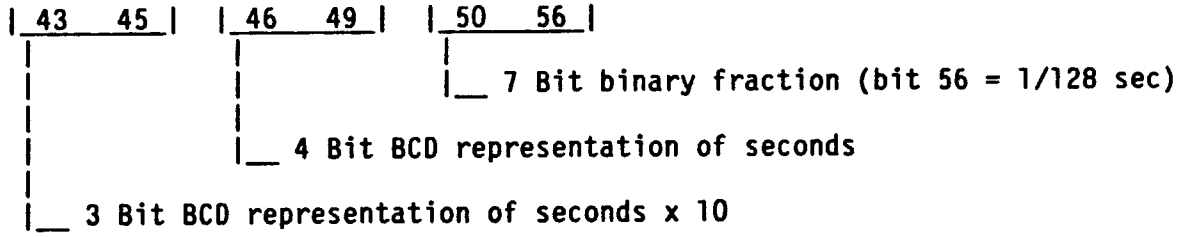
Set when a change (addition or deletion) is made to Beacon Strobe, Yellow or Red code list contained in the previous message.

5.3.2.13 Code Overflow Flag (V)

Set when either the number of red or yellow sensor conditions exceed the number that can be reported in this message. Codes are placed in the list in increasing numerical order, thus, when the number of red or yellow codes to be transmitted exceeds "k" or "j" (see 5.3.3.2.19 and 5.3.3.2.20) respectively, the higher number codes are truncated. The codes which have been truncated will not be sent as long as the quantity of lower numbered codes exceeds the maximum.

5.3.2.14 Northmark Time

The time that the antenna boresight passed through true north is given via the seconds portion of the sensor real-time clock, with a maximum decimal value of 59.992 seconds and a minimum value of 0 seconds. The northmark time segment has the following binary coded format:



5.3.2.15 Target Overload

0 = No overload condition
1 = Target overload

5.3.2.16 Sensor Status

00 = Green
01 = Yellow
10 = Red
11 = Red

5.3.2.17 Channel in Use (CH)

0 = Channel A
1 = Channel B

5.3.2.18 Number of Beacon Strobe Words

Number of strobe sections = i. Maximum value of i = 10. The maximum number of strobe words (=2i) therefore is 20.

5.3.2.19 Number of Red Codes = k

Maximum value of k = 255.

5.3.2.20 Number of Yellow Codes = j

Maximum value of j = 255.

5.3.2.21 Boresight Azimuth of Beginning of Strobe = $B_S(i)$ and Boresight Azimuth of End of Strobe Overload = $B_E(i)$

$B_S(i)$ and $B_E(i)$ always occur in pairs. In the event that the $B_E(i)$ has not been found at the end of the report, the hex value FFFF is substituted in the corresponding 16 bits reserved for the corresponding B_E report. The completed pair, B_S and B_E will occur as the first report in the next message. The units of B_S and B_E are Azimuth Units.

5.3.2.22 Yellow Condition Code (Y)

Yellow condition codes as detected by the sensor performance monitor are transmitted in ascending numerical order.

5.3.2.23 Red Condition Code (R)

Same comment as above applies to Red Codes.

5.4 Sensor-to-Sensor Messages

Sensor-to-Sensor messages are generated to support netted Mode S operations. For sites at which netted operation is implemented, the netting will be accomplished using Mode S/ATC data links rather than dedicated links. For this reason, these messages are part of the Mode S/ATC interface and must satisfy all of the format and protocol requirements of that interface.

As shown in Table 5.2-1, there are three groups of such messages: Mode S Network Control, ATCRBS Network Control, and Status. For each message type within these groups, Table 5.2-1 gives the name of the messages and its type code. Immediately following the type code, the Information Field of each message shall contain the following two data blocks: Sending Sensor ID (SSID) and Receiving Sensor ID (RSID). Each of these blocks is a 10-bit block encoded like the SID block (5.3.1.18).

The remainder of each Information Field is not interpreted by the ATC facility and therefore need not be given here. These fields are defined in FAA-E-2716, as follows:

1) Mode S Network Control Messages: FAA-E-2716, 3.4.8.4;

2) ATCRBS Network Control Messages: FAA-E-2716, 3.4.8.11.3;

3) Status Messages: FAA-E-2716, 3.4.10.3.2, item a;

4) Adjacent Sensor Status Request: no additional blocks are needed;

5) Adjacent Sensor Status Response: same as item 3 above.

In handling a Sensor-to-Sensor message, the only actions to be performed by an ATC facility are the following:

1) Determine that the message falls into the Sensor-to-Sensor category, based on its type code;

2) Determine the routing of the message, using the RSID data block; and

3) Retransmit the message to the receiving sensor with its Information Field unchanged.

Note: For the most part, the prefix of the type code of a Sensor-to-Sensor message identifies it as such. However, one sensor-to-ATC message type (Track Alert) uses the same prefix as the Network Control messages.

Standard Uplink

0010 0001	Mode S Address	Msg No	P	EXP	ACK	SC	SP	MA (repeated)
1	8	32	40	44	47	48	50	56	56+56(SC+1)

ELM Uplink

0010 0010	Mode S Address	Msg No	P	EXP	SP	Length	ELM Text (max 5120)
1	8	32	40	44	47	50	56	56+80(Length+1)

Request For Downlink Data

0010 0011	Mode S Address	Msg No	P	EXP	SP	BDS1	BDS2
1	8	32	40	44	47	48	52	56

ATCRBS ID Request

0010 0100	Mode S Address	Msg No
1	8	32	40

Message Cancellation Request

0010 0101	Mode S Address	Msg No	Ref Msg No	Ref Type Code
1	8	32	40	48	56

Test Message

0110 0001	Msg No	Test Data
1	8	16	64

ATC Failure/Recovery Message

1001 1001	Msg No	State	SP
1	8	16	18	24

Data Link Capability Request

0000 0010	Mode S Address	Msg No
1	8	32	40

Sensor Failure/Recovery Message

0110 0101	Msg No	SID	SP	SSTAT
1	8	16	26	28	32

Mode S Aircraft Control State Message

1001 1010	Msg No	IP	IS	IU	Mode S Address (repeated)
1	8	16	19	22	24	24+24(IP+IS+IU)

Fig. 5.3-1. Information field formats for ATC-to-Mode S messages.

Message Rejection/Delay Notice

0011 0001	Mode S Address	Ref Msg No	Qual	SP
1	8	32	40	43 48

Uplink Delivery Notice

0011 0010	Mode S Address	Ref Msg No	DI	SP
1	8	32	40	41 48

Standard Downlink

0100 0001	Mode S Address	Msg No	SC	A/G	SP	MB (repeated)
1	8	32	40	42	43 48	104+48(SC)

ELM Downlink

0100 0010	Mode S Address	Msg No	SP	Length	ELM Text (Max 1280)
1	8	32	40	42	48 48+80(Length+1)

Data Link Capability

0100 0100	Mode S Address	Msg No	SP	Capability
1	8	32	40	41 96

ATCRBS ID Code

0100 0101	Mode S Address	Msg No	SP	ATCRBS ID
1	8	32	40	44 56

Test Response Message

0110 0010	Msg No	Test Response
1	8 16	64

Track Alert Message

1001 1100	Msg No	Mode S Address	Range 1	SP	Azimuth 1	Range 2	SP	Azimuth 2
1	8 16	40	56	58	72	88	90	104

Fig. 5.3-2. Information field formats for Mode S-to-ATC messages.

Status Message

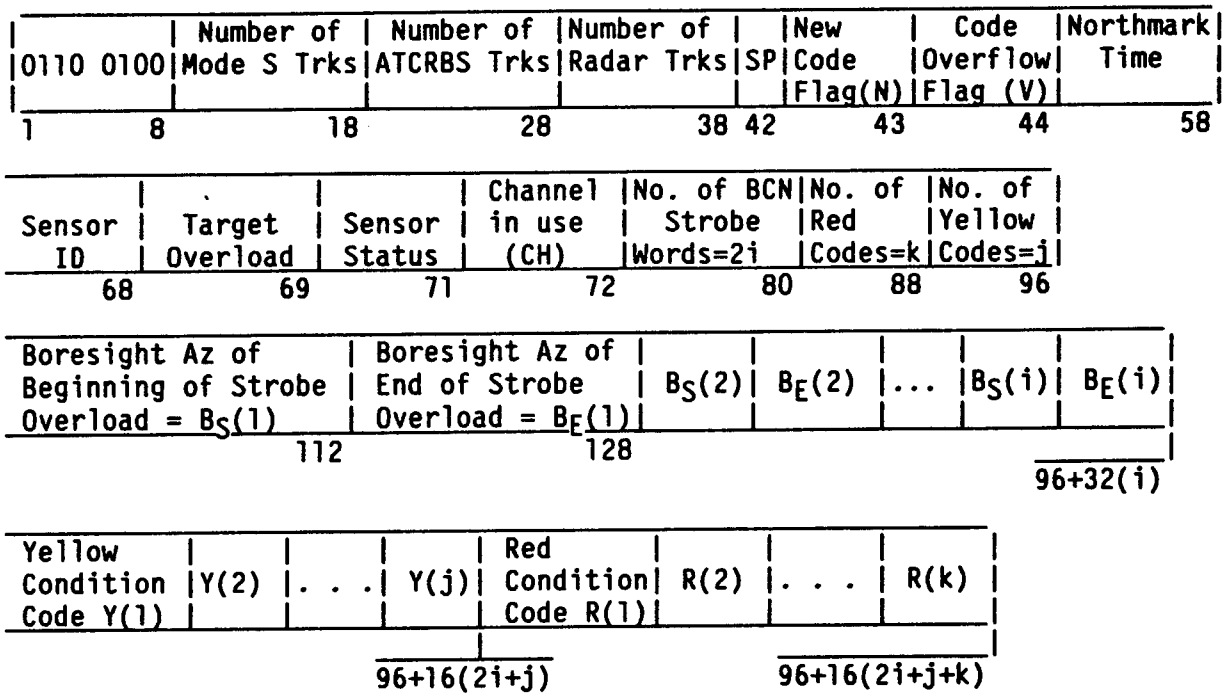


Fig. 5.3-2. Information field formats for Mode S-to-ATC messages (cont'd).

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6.0 MODE S/NON-ATC COMMUNICATION MESSAGE FORMATS

Each Mode S sensor will interface initially with a Weather Communications Processor (WCP) by means of a single data link. Ultimately, there may be other non-ATC users which communicate with the sensor. Each link will use CCITT X.25 LAPB and formats, like the sensor/ATC links. These requirements are not given here but are contained in appendix A. (Frame formats are briefly summarized in 4.1). The remainder of this section is concerned with the formats and coding of the Information Field of each message, which are not constrained by LAPB.

Unless otherwise stated, all fields are encoded as right justified binary integers.

6.1 Information Fields

6.1.1 General

The Information Field contains the actual message data which the sender wishes to communicate to the recipient. There are many different types of messages, as listed in 4.3. The interpretation of the Information Field format and coding is dependent on the particular message type. In the rest of 6.1, the formats of the various types of non-ATC-to-Mode S and Mode S-to-non-ATC messages are described in terms of data blocks, and the definitions and coding of the data blocks are given.

6.1.2 Information Field Type Codes

For each of the sensor/non-ATC messages defined in 4.3, Table 6.1-1 gives a value for the Type Code, which always appears as the first data block in an Information Field. These codes are 8 bits in length, the first 4 of which are a prefix which refers to a logically similar group of message types.

6.1.3 Information Field Formats

The Information Field formats for each non-ATC-to-Mode S and Mode S-to-non-ATC message type are shown in Fig. 6.1-1 and Fig. 6.1-2 respectively. A brief discussion of each data block follows. Where a data block is identical with one which occurs in a sensor/ATC message, a reference is given to the appropriate paragraph in Section 5.

TABLE 6.1-1.

INFORMATION FIELD TYPE CODES FOR SENSOR/NON-ATC MESSAGES

		Prefix	Suffix	
Non-ATC-to-Mode S	Uplink Messages	0010	1001	Standard Uplink
		0010	1010	ELM Uplink
		0010	1011	Request for Downlink Data
		0010	1101	Message Cancellation Request
	Status Requests	0000	1010	Data Link Capability Request
		0000	1000	Request for Aircraft State
		0000	1001	Request for Aircraft Position
Mode S-to-Non-ATC	Sensor Response Messages	0011	0001	Message Rejection/Delay Notice
		0011	1001	Message Rejection/Delay Notice with Sensor IDs
		0011	0010	Uplink Delivery Notice
	Downlink Messages	0100	0001	Standard Downlink
		0100	1001	Standard Downlink with Position
		0100	0010	ELM Downlink
		0100	1010	ELM Downlink with Position
		0100	0100	Data Link Capability
	Status Messages	0100	1110	Aircraft State
		0100	1111	Aircraft Position
		0100	1011	Track Drop

6.1.3.1 Non-ATC-to-Mode S Data Blocks

6.1.3.1.1 Type Code

The Type Code block is an 8-bit control block which begins every Information Field. The code values are shown explicitly in Fig. 6.1-1, and have been summarized in Table 6-1.

6.1.3.1.2 Mode S Address See 5.3.1.2.

6.1.3.1.3 Message Number (Msg. No.) See 5.3.1.3.

6.1.3.1.4 Priority (P) See 5.3.1.4.

6.1.3.1.5 Expiration (EXP) See 5.3.1.5.

6.1.3.1.6 Acknowledgment (ACK) See 5.3.1.6.

6.1.3.1.7 Segment Count (SC) See 5.3.1.7.

6.1.3.1.8 Not Used

6.1.3.1.9 Spare (SP) See 5.3.1.9.

6.1.3.1.10 Comm-A Message Text (MA) See 5.3.1.10.

6.1.3.1.11 Length See 5.3.1.11.

6.1.3.1.12 ELM Text See 5.3.1.12.

6.1.3.1.13 BDS1 and BDS2 See 5.3.1.13.

6.1.3.1.14 Reference Message Number (Ref. Msg. No.) See 5.3.1.14.

6.1.3.1.15 Reference Type Code (Ref. Type Code) See 5.3.1.15.

6.1.3.2 Mode S-to-Non-ATC Data Blocks

Mode S-to-non-ATC Information Field formats are shown in Fig. 6.1-2. The following data blocks have already been defined as non-ATC-to-Mode S blocks: Type Code, Mode S Address, Referenced Message Number, Spare, Segment Count, Length, and ELM Text. Definitions of the remaining blocks follow.

6.1.3.2.1 Qualifier (Qual) See 5.3.2.1.

6.1.3.2.2 Mode S Sensor ID (SID, SID1, and SID2)

SID is a 10-bit field containing the unique identity code of the Mode S sensor which is sending the message.

The SID1 and SID2 blocks are 10-bit fields each of which contain the unique identity code of an adjacent Mode S sensor. They are used by the reporting sensor when it is not primary for an aircraft to which an Uplink ELM is being

sent or when it is in the process of dropping a track. SID1 and SID2 will identify the adjacent sensors which are assigned to the aircraft, with the highest-priority sensor given in SID1 and the second-highest in SID2. If there are fewer than two adjacent sensors assigned, either SID2 or both SID1 and SID2 will contain zeroes.

6.1.3.2.3 Delivery Indicator (DI) See 5.3.2.2.

6.1.3.2.4 Air/Ground Indicator (A/G) See 5.3.2.3.

6.1.3.2.5 Comm-B Message Text (MB) See 5.3.2.4.

6.1.3.2.6 Aircraft Range (A/C Range)

Aircraft Range is a 10-bit block containing the measured one-way range to the aircraft coded as a binary integer, in units of nautical miles (MSB=128, LSB=0.25).

6.1.3.2.7 Aircraft Azimuth (A/C Az)

Aircraft Azimuth is a 12-bit block containing the measured azimuth of the aircraft coded as a binary integer, in units of degrees (MSB=180, LSB=0.088).

6.1.3.2.8 Range Rate

Range Rate is 6-bit block containing the predicted one-way range rate of the aircraft coded as a signed binary integer, in units of nautical miles/second (MSB=0.2, LSB=0.0125).

6.1.3.2.9 Azimuth Rate

Azimuth Rate is an 8-bit block containing the predicted azimuth rate of the aircraft coded as a signed binary integer, in units of degrees/second (MSB=2, LSB=0.031).

6.1.3.2.10 Aircraft State (A/C State)

Aircraft state is a 4-bit block containing the track state of the aircraft, its control state (controlled or uncontrolled), and the priority assignment of the sensor with respect to the aircraft (primary or secondary). The settings below are in decimal.

0 = Aircraft not on file
1 = Aircraft on file but not in full track (i.e., track is not currently being updated by roll-call replies)
2 = Aircraft in full track, controlled primary
3 = Aircraft in full track, controlled secondary
4 = Aircraft in full track, uncontrolled primary
5 = Aircraft in full track, uncontrolled secondary.

Other values are not assigned.

6.1.3.2.11 Altitude

Altitude is a 12-bit block containing the reported Mode C altitude of the aircraft. Coding is the same as that used in a surveillance message (2.1.1.8).

6.1.3.2.12 Capability See 5.3.2.5.

Standard Uplink

0010 1001	Mode S Address	Msg No	P	EXP	ACK	SC
1	8	32	40	44	47	48	50

SP	MA (repeated)
56	56+56(SC+1)

ELM Uplink

0010 1010	Mode S Address	Msg No	P	EXP	SP	Length
1	8	32	40	44	47	50	56

ELM Text (max 5120)
56+80(Length+1)

Request For Downlink Data

0010 1011	Mode S Address	Msg No	P	EXP	SP	BDS1	BDS2
1	8	32	40	44	47	48	52	56

Message Cancellation Request

0010 1101	Mode S Address	Msg No	Ref Msg No	Ref Type Code
1	8	32	40	48	56

Data Link Capability Request

0000 1010	Mode S Address	Msg No
1	8	32	40

Request for Aircraft State

0000 1000	Mode S Address	Msg No
1	8	32	40

Request for Aircraft Position

0000 1001	Mode S Address	Msg No
1	8	32	40

Fig. 6.1-1. Information field formats for non-ATC-to-Mode S messages.

Message Rejection/Delay Notice

0011 0001	Mode S Address	Ref Msg No	Qual	SP	SID
1	8	32	40	43	46	56

Message Rejection Notice with Sensor IDs

0011 1001	Mode S Address	Ref Msg No	Qual	SP	SID1
1	8	32	40	43	46	56

SP	SID2	SP	SID
62	72	78	88

Uplink Delivery Notice

0011 0010	Mode S Address	Ref Msg No	DI	SP	SID
1	8	32	40	41	46	56

Standard Downlink

0100 0001	Mode S Address	Msg No	SC	A/G	SP	MB (repeated)	SP	SID
1	8	32	40	42	43	48	N=104+48(SC)	N+6	N+16

Standard Downlink with Position

0100 1001	Mode S Address	Msg No	SC	A/G	SP	MB (repeated)	SP
1	8	32	40	42	43	48	N=104+48(SC)	N+2

A/C Range	A/C Azimuth	SP	Range Rate	Azimuth Rate	A/C State
N+12	N+24	N+26	N+32	N+40	N+44

Altitude	SP	SID
N+56	N+62	N+72

ELM Downlink

0100 0010	Mode S Address	Msg No	SP	Length	ELM Text (Max 1280)	SP	SID
1	8	32	40	42	48	N=48+80(Length+1)	N+6	N+16

Fig. 6.1-2. Information field formats for Mode S-to-non-ATC messages.

ELM Downlink with Position

0100 1010	Mode S Address	Msg No	SP	Length	ELM Text (Max 1280)	SP
1	8	32	40	42	48	M=48+80(Length+1) M+2

A/C Range	A/C Azimuth	SP	Range Rate	Azimuth Rate	A/C State
M+12	M+24	M+26	M+32	M+40	M+44

Altitude	SP	SID
M+56	M+62	M+72

Data Link Capability

0100 0100	Mode S Address	Msg No	SP	Capability	SP	SID
1	8	32	40	41	96 102	112

Aircraft State

0100 1110	Mode S Address	Msg No	A/C State	SP	SID
1	8	32	40	44	46 56

Aircraft Position

0100 1111	Mode S Address	Msg No	SP	A/C Range	A/C Azimuth	SP
1	8	32	40	42	52	64 66

Range Rate	Azimuth Rate	A/C State	Altitude	SP	SID
72	80	84	96	102	112

Track Drop

0100 1011	Mode S Address	Msg No	SP	SID1	SP	SID2	SP	SID
1	8	32	40	46	56 62	72	78	88

Fig. 6.1-2. Information field formats for Mode S-to-non-ATC messages (cont'd).

REFERENCES

1. American National Standard for Advanced Data Communication Control Procedures (ADCCP). American National Standards Institute ANSI X3.66-1979, approved January 9, 1979.

2. U.S. National Aviation Standard for the Mode Select Beacon System (Mode S), FAA Order 6365.1A, January 3, 1983.

3. U.S. National Aviation Standard for Data Link Applications of the Mode Select Beacon System (in preparation).

4. Mode Select Beacon System (Mode S) Sensor, FAA-E-2716 and Amendment 2 (incorporating Specification Changes 1 through 6).

5. ASR-9 External Interface Control Document for the ASR-9 C&I Processor to Mode S Sensor Interface and the Mode S to ASR-9 SP Interface. Westinghouse Data Item SE007-1 Rev. A (Preliminary). Westinghouse Electric Corporation, March 4, 1985.

6. ASR-9, Engineering Change Request ECR-16 to Specification FAA-E-2704, Westinghouse Electric Corporation, December 20, 1984.

7. Common Digitizer-2 (CD-2). FAA-E-2679a, June 22,1982.

8. CCITT Recommendation X.25 - 1984 "Interface Between Data Terminal Equipment (DTE) and Data Circuit Terminating Equipment (DCE) for Terminals Operating in the Packet Mode on Public Data Network - LAPB".

END OF FAA-RD-80-14B

APPENDIX A
INTERFACE DEFINITION FOR MODE S/ATC AND MODE S/NON-ATC COMMUNICATIONS

CONTENTS

FIGURES

A.1. INTRODUCTION

A.1.1 Purpose

This Appendix defines the data link control interface requirements for the ATC and non-ATC communications interfaces of the Mode S sensor.

A.1.2 Scope

This appendix specifies the data link control procedures to facilitate data communication across the ATC and non-ATC interfaces of the Mode S sensor. Paragraph 4 describes the protocol used. Specifically, standard control procedures to perform the communications functions necessary for the establishment and termination of transmissions and the transfer of messages are covered. It should be noted that more specific requirements for the organization and content of text messages, error, status, or alarm messages, or other information packed between the required control characters defining the beginning and end of real text, are defined elsewhere (i.e., the main body of this document and the U.S. National Aviation Standard for Data Link Applications of the Mode S Beacon System).

A.1.3 Applicable Documents

1. CCITT Recommendation X.25 -1984 "Interface Between Data Terminal Equipment (DTE) and Data Circuit Terminating Equipment (DCE) for Terminals Operating in the Packet Mode on Public Data Network - LAPB".

2. U.S. National Aviation Standard for the Mode Select Beacon System (Mode S), FAA Order 6365.1A, January 3, 1983.

3. U.S. National Aviation Standard for Data Link Applications of the Mode Select Beacon System (in preparation).

4. ANSI X3.24-1968, Signal Quality at Interface Between Data Processing Terminal Equipment and Synchronous Data Communication Equipment for Serial Data Transmission.

5. ANSI X3.36-1975, Synchronous High-Speed Data Signaling Rates Between Terminal Equipment and Data Communication Equipment.

6. FAA Order 1830.2, February 1978, Policy for Use of Telecommunications Data Transfer Standards.

7. FIPS PUB 78, Guidelines For Implementing Advanced Data Communication Control Procedures (ADCCP).

8. Mode Select Beacon System (Mode S) Sensor, FAA-E-2716.

9. Federal Standard 1003A, FED-STD-1003A, August 19, 1981.

A.2. NOT USED

A.3. TELECOMMUNICATIONS NETWORK

The data link control procedures defined in this document apply to the ATC and non-ATC interfaces in the Mode S environment and shall conform to FAA Order 1830.2. The factors characterizing Telecommunications Network (TCN) configurations are defined below.

A.3.1 Facility Type

The TCN facility type characterizes the physical communications path in the Mode S environment using a 4-wire link to provide two separate transmission paths such that Mode S and the ATC and non-ATC systems concurrently transmit using the same frequency without signal interference.

A.3.2 Channel Configuration

The TCN channel configuration characterizes the operational communications path in the Mode S environment as point-to-point (PTPT):

PTPT: Communication path is operationally used by only two communication parties.

A.3.3 Speed

The TCN speed characterizes the signaling rate, expressed in bits per second (b/s). TCN signaling rates shall comply with ANSI X3.1-1976, ANSI X3.36-1975, and FAA Order 1830.2. Where conflicts arise, FAA Order 1830.2 takes precedence over the related ANSI standard. The signaling rates are specified in FAA-E-2716 3.5.3.

A.3.4 Synchronization

The TCN shall utilize a synchronous transmission mode.

A.3.5 Circuit Arrangement

The TCN circuit arrangement in the Mode S environment will operate using dedicated communications paths between the Mode S ATC port and the Advanced Automation System (AAS), and between the Mode S non-ATC port and the Traffic processor. See Fig. A.3.1 (a) and (b).

A.3.6 Protocol Reference

The TCN configuration will utilize the following data link control standards. The link protocol used will be in accordance with CCITT Recommendation X.25 - 1984 "Interface Between Data Terminal Equipment (DTE) and Data Circuit Terminating Equipment (DCE) for Terminals Operating in the Packet Mode on Public Data Network - LAPB", level 2.

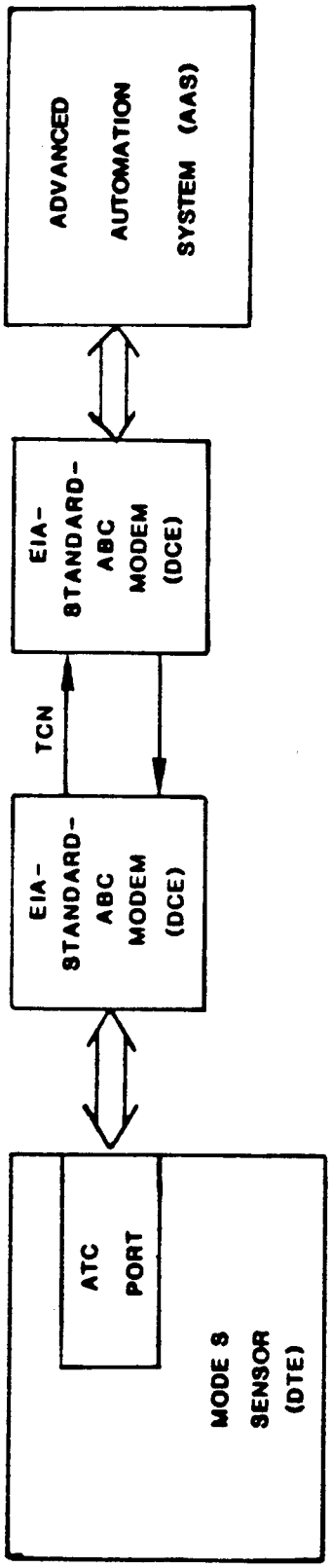

Fig. A.3.1 (a) Block diagram of ATC interface

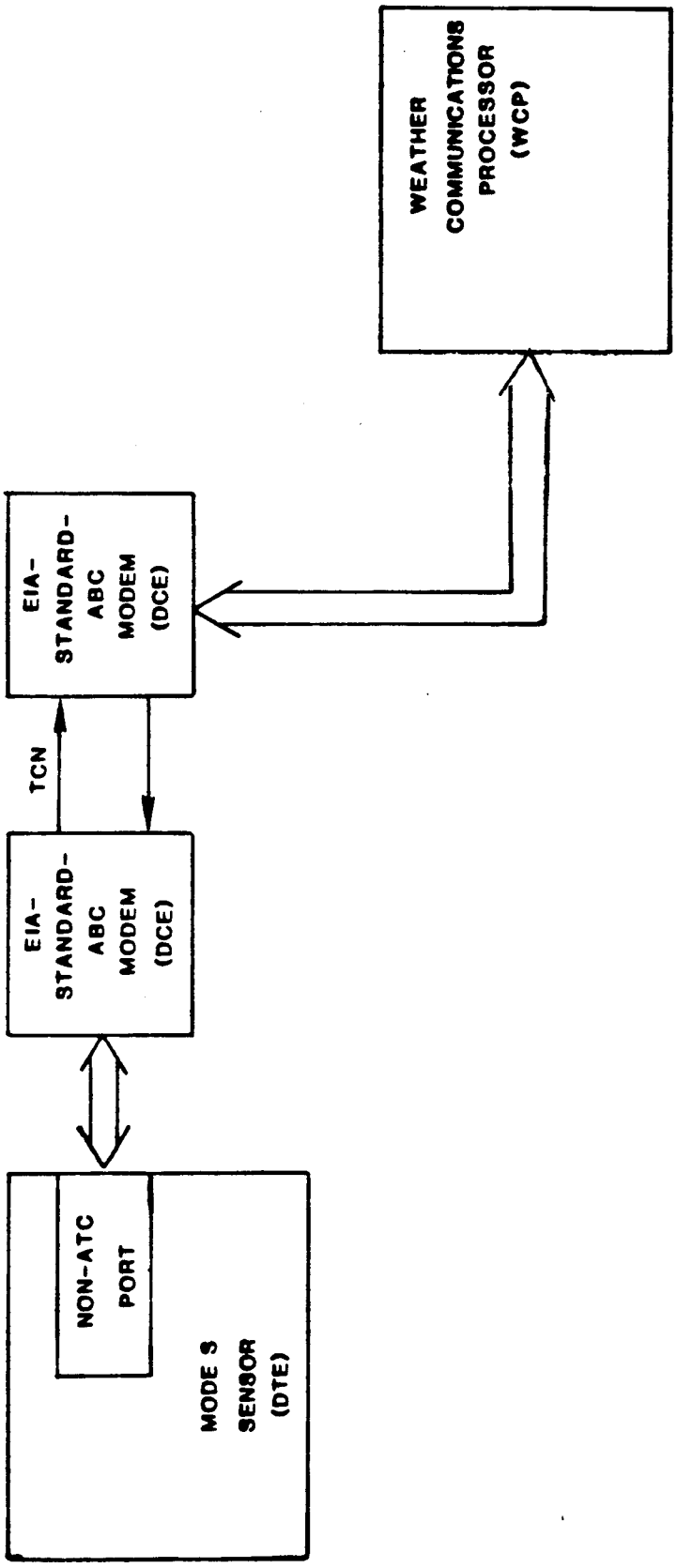

Fig. A.3.1 (b) Block diagram of NON-ATC interface

A.4. BIT-ORIENTED DATA LINK PROCEDURES

This section provides the procedure for implementing the bit-oriented data link protocol and formats specified in the CCITT X.25 -1984 LAPB standard.

A.4.1 Operational Summary

Transmission of messages between the Mode S sensor and the ATC and non-ATC facilities will utilize a balanced point-to-point, two-way simultaneous (TWS) data interchange. Mode S shall operate according to the requirements for DTE equipment in X.25.

A.4.1.1 Frame Structure

The basic unit of transmission is a frame which is a bit sequence containing not fewer than 32 bits between flag fields. The frame format consists, in general, of 6 "sequences" or data fields, as shown in Fig. A.4.1.

(1) The flag field (F) is an 8-bit sequence which indicates the beginning and end of each frame and is used for frame synchronization. The end flag of one frame can also serve as the beginning of the following frame.

Data Link Control Field				Data Link Control Field	
Flag (F)	Address (A)	Control (C)	Info Field (I)	Frame Check Sequence (FCS)	Flag (F)

Fig. A.4.1. X.25 frame structure.

(2) The address field (A) contains the link level address as described in paragraph A.4.1.5.

(3) The control field (C) consists of one octet which specifies formats used to transfer information and control functions. The formatting of the Control Field is described in paragraph A.4.1.6.

(4) The information field (I) shall contain the actual message data the sender wishes to communicate to the recipient. Specific formats are defined in the main body of this document.

(5) The Frame Check Sequence (FCS) field is included in each frame for the purpose of error detection.

A.4.1.2 Synchronization

Synchronous transmission shall be employed, with successive bits in a frame sequence immediately following one another. The flag octet with its unique bit pattern is used to indicate the start and the end of a frame.

A.4.1.3 Code

The bit-oriented data link control procedures do not impose a restriction on the coding or grouping of bits in the Info field, but to provide standardization, the code used must be approved by the FAA Contracting Officer prior to implementation.

A.4.1.4 Rules for Achieving Code Transparency

Frame contents (A, C, I and FCS) may contain any bit configuration. This is possible because X.25 provides transparency with zero bit insertion and deletion after strings of one bits to prevent confusion of data with flag sequences.

A.4.1.5 Addressing

Addressing is as specified in X.25 -1984

A.4.1.6 Control Field Formats

As specified in X.25, there are three basic formats defined for the Control Field. These are used to perform; information transfer (I), basic supervisory control functions (S), and special unnumbered control functions (U). The three Control Field formats are summarized as follows, for information only:

Control Field Bits:	1	2	3	4	5	6	7	8
Information Transfer, I Frame	0	N(S)			P/F	N(R)		
Supervisory Commands/ Response, S Frame	1	0	S		P/F	N(R)		
Unnumbered Commands/ Responses, U Frame	1	1	M		P/F	M		

Where: N(S) = The sequence number of the transmitted I frame.
N(R) = Transmitter receive sequence number.
P/F = Poll/Final (P/F) bit is referred to as the P bit in a command frame and the F bit in a response frame.
S = Supervisory function bits.
M = Modifier function bits.

Further details of these three formats are specified in X.25.

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A.4.1.6.1 Information Transfer Format - I Frame

The I frame is used to perform an information transfer. The structure of the Information Transfer Frame and its control field is explained in A.4.3.

A.4.1.6.2 Supervisory Format - S Frame

The S frame is used to perform link supervisory control functions such as acknowledge I frames.

A.4.1.6.3 Unnumbered Format - U Frame

The U frame is used to provide special link control functions.

A.4.2 Communications Functions

The DTE and DCE (terms from X.25) "communicate" with each other primarily through the interpretation of the control field. The contents of the control field are defined in X.25.

A.4.2.1 Poll/Final Bit

The Poll/Final (P/F) bit is used as defined in X.25.

A.4.3 Information Frame Structure

The DTE and DCE transfer message data using the information frame below.

Field Sequence	Interpretation
F	Opening Flag
A	Address of remote station
C	Control Field
I	Information Field (data)
FCS	Frame Check Sequence
F	Closing Flag

A.4.3.1 Address Field

The address field is as specified in X.25.

A.4.3.2 Control Field

The control field for an information (I) frame is as shown in A.4.1.6.

A.4.3.3 Information Field

The Information (I) Field contains the actual data which the sender wishes to communicate to the recipient. The length of the field is variable but shall not exceed 8192 bits.

Actual coding and message formats are defined in the main body of this report and the U.S. National Standard for Data Link Applications.

A.4.4 Recovery Procedures

Recovery procedures shall be as specified in X.25. Recovery actions taken shall be reported to the Mode S Performance Monitor function as required by FAA-E-2716.

A.4.4.1 Command/Response Time-Out

A.4.4.1.1 Timers T1, T2 and T3

Timer T1 is the period of time (from start of frame transmission) at the end of which retransmission of a frame may be initiated. T1 shall have a range of 0-90 seconds and shall be adjustable in increments of 0.01 seconds. The following initial values of T1 shall be used (for 1024 octet maximum information field size):

9600 bps Link: 1.35 seconds
19.2K bps Link: 0.70 seconds
56K bps Link: 0.26 seconds

Timer T2 is the maximum delay from the start of the response reception that a response to a command may be held before being transmitted. T2 shall have a range of 0-90 seconds and shall be adjustable in increments of 0.01 seconds. The following initial values of T2 shall be used:

9600 bps Link: 1.23 seconds
19.2K bps Link: 0.64 seconds
56K bps Link: 0.24 seconds

Timer T3 is the maximum time a link will be allowed to remain idle (i.e., after an interval of T3, with no traffic on the link, the DTE or the DCE will transmit an RR or other appropriate command requiring a response). T3 shall have a range of 0-180 seconds and shall be adjustable in increments of 0.01 seconds. The initial value shall be 4 seconds.

A.4.4.2 Exception Condition Recovery Procedures

A.4.4.2.1 Busy Condition Recovery

A busy condition occurs when a station temporarily cannot receive or continue to receive I frames due to internal constraints.

A.4.4.2.2 Frame Sequence Error Recovery

A frame sequence error condition is established in the receiving station when an I frame received error-free (no FCS error) contains a frame sequence number that is different from the expected sequence number .

A.4.4.2.2.1 Not used

A.4.4.2.2.2 Reject Recovery (REJ)

The REJ response is used to initiate retransmission of I frames.

A.4.4.2.3 Frame Reject Recovery (FRMR Response)

A frame reject condition is established upon the receipt of a frame without FCS error which contains an invalid control field, or other error conditions as specified in X.25.

A.4.4.2.4 Not used

A.4.4.2.5 FCS Error

Any frame with an FCS error is processed according to X.25 protocol (it is discarded).

A.5. NOT USED

END OF APPENDIX A

APPENDIX B

LIST OF ABBREVIATIONS

ADCCP	Advanced Data Communication Control Procedures
ARTS	Automated Radar Terminal System
ASR	Airport Surveillance Radar
ATC	Air Traffic Control
ATCRBS	Air Traffic Control Radar Beacon System
CCC	Central Computer Complex
CD	Common Digitizer
DCE	Data circuit terminating equipment
DPS	Data Processing Subsystem
DTE	Data terminal equipment
ELM	Extended Length Message
FEP	Front End Processor
JSS	Joint Surveillance Site
LAPB	Link Access Procedure Balanced
MPS	Maintenance Processor System
RTQC	Real Time Quality Control
WCP	Weather Communications Processor

END OF APPENDIX B