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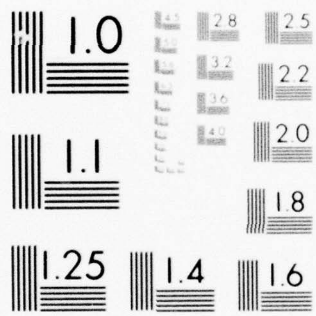
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16. Abstract

This report parallels the Proposed U.S. National Aviation Standard for the Discrete Address Beacon System. However, in addition to the material contained in the Proposed Standard this document provides a more detailed performance specification for the DABS transponder including specifications on transponder receiver sensitivity and performance in interference. It includes specifications for a proposed digital datalink interface and defines message and control fields associated with experimental transponder data applications. It also includes guidance material on the performance of an optional transponder antenna diversity scheme.

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Preface

The Discrete Address Beacon System is being developed in several phases. Phase I, Concept Validation and System Definition, was begun in 1972, when Lincoln Laboratory was selected as the DABS System Engineering Contractor. Lincoln Laboratory conducted a broad range of technical and economic studies designed to select the system parameters. An experimental DABS test facility was also established for critical experiments and feasibility tests.

Phase II, System Evaluation and Design Refinements, is currently in progress and consists of four parallel but interrelated efforts:

(a) Fabrication of engineering models of DABS sensors with corresponding avionics. The sensors will first be tested individually, and then as a multisensor DABS network.

(b) System engineering, design refinements, investigation of equipment variations and planning of a nationwide DABS deployment.

(c) Evaluation of functions that rely uniquely on DABS to verify the suitability of DABS to support them.

(d) Issuance of a production specification for DABS sensors, as well as a National Standard for DABS.

The material presented in this report was generated in the process of preparing that DABS National Standard and parallels it closely. However, additional material is contained herein which was not appropriate for inclusion in the National Standard, but which is of sufficient potential interest to warrant separate publication. This additional material includes detailed performance specifications for transponder receiver sensitivity and transponder performance in interference. Also included are specifications for a proposed data link interface and recommended definitions for certain experimental message and control fields which do not directly affect the operation of the transponder, but which are associated with experimental transponder data link applications. Guidance material is also included on the performance of an optional transponder antenna diversity scheme.

Although this document may serve as an interim reference standard to be used for procurement of experimental DABS equipment, it is not proposed or approved for official use by the FAA or any other agency, either domestic or international. Its principal function is to provide, in a single document a complete technical description of the DABS link and the airborne components of the DABS system.

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PROPOSED DISCRETE ADDRESS SYSTEM

TECHNICAL CHARACTERISTICS

1. GENERAL SYSTEM CHARACTERISTICS

1.1 Background.

1.1.1 The Function of DABS. The Discrete Address Beacon System (DABS) is an improved secondary radar system with an integral ground-air-ground data link. DABS differs from ATCRBS in the manner of selecting which aircraft will respond to an interrogation. In ATCRBS, the selection is spatial; in DABS, each aircraft is assigned a unique address code. Thus, an interrogator is able to limit its interrogations to those targets for which it has surveillance responsibility, and to time the interrogations to ensure that the responses from aircraft do not overlap. In addition, the discrete address provides the basis for a ground-air-ground digital link. The main requirements of DABS are to:

a. Support automated air traffic control (ATC) with improved surveillance and communication reliability in the projected 1995 traffic environment.

b. Permit evolutionary implementation at low user cost.

1.1.2 ATCRBS Compatibility. To facilitate the transition from ATCRBS to DABS over an extended period, DABS installations, both ground and airborne, include full ATCRBS capability. DABS interrogators provide surveillance of ATCRBS-equipped aircraft, and DABS transponders are capable of replying to ATCRBS interrogators. To accomplish this dual mode operation (ATCRBS and DABS) with minimum equipment complexity, DABS operates on the same interrogation and reply frequencies as ATCRBS.

1.1.3 Relationship Between DABS and ATCRBS Specifications. ATCRBS-only transponders are not affected by this DABS specification and the ATCRBS mode of DABS transponders adheres to the ATCRBS National Aviation Standard.

1.2 Scope of this Document.

1.2.1 Elements Covered. The system characteristics and performance specified herein are restricted to those system elements which must be treated in a uniform manner by all users if the surveillance requirements of the Discrete Address Beacon System are to be satisfactorily met. Additional specifications will be required for I/O devices which employ the DABS data link. Specifications and guidance material are included for the transponder data link interface. The elements covered include:

a. Link characteristics and signal formats.

b. DABS transponders and basic data link interface.

c. Airborne antennas.

Guidance material is provided for the following optional transponder configurations:

a. A general purpose data link interface with or without ATCRBS capability. (Standard Message Interface, paragraph 2.10).

b. Extended Length Message capability.

c. Dual (diversity) antenna capability.

1.2.2 Elements not Covered. The following elements are not covered by this document:

a. Sensor displays, input/output devices, and ATC interfaces.

b. Sensor antennas.

c. Multisite sensor network characteristics.

1.3 System Performance.

1.3.1 Coverage. The DABS sensor will perform surveillance of all beacon-equipped aircraft within its volume of coverage. The system is designed to operate reliably out to 200 nmi, but is site adaptable to other ranges. ATCRBS-equipped aircraft will be interrogated at the minimum rate that produces an adequate number of interrogations in a 3-dB beamwidth. DABS-equipped aircraft will be acquired by means of an All-Call interrogation, or by means of ground-to-ground handover. After acquisition, DABS-equipped aircraft will be interrogated with their unique address call. For both ATCRBS and DABS, azimuth will be determined by a monopulse technique.

1.3.2 Data Link. The DABS sensor will provide a two-way digital data link for all DABS-equipped aircraft. Messages originating on the ground will be sent to suitably equipped aircraft and appropriate acknowledgment received will be relayed to the sender. The DABS sensor will also manage the data link so that when an aircraft wishes to initiate an air-to-ground message, that message will be read out with minimum delay.

1.3.3 Accuracy.

1.3.3.1 Range Accuracy. Range accuracy is a function of both the transponder and the sensor. The nominal overall range errors for DABS targets will not exceed ± 150 ft bias and 50 ft rms jitter.

1.3.3.2 Azimuth Accuracy. The sensor and monopulse antenna will be capable of determining azimuth from a single DABS reply. The rms error will not exceed 0.1 degrees, under the specified peak loading conditions for the sensor site.

1.3.4 Link Reliability. High link reliability both for surveillance and for two-way data link will be achieved by means of several design features. Each sensor will be capable of reinterrogating within a beam dwell time, such that in case of failure to reach an aircraft on the first call, additional calls can be made before the antenna beam passes by the aircraft. Link reliability will be enhanced by the DABS signal formats which provide increased immunity to interference. The discrete addressing capability of the DABS system eliminates the problem of synchronous interference and an optional dual (diversity) antenna capability in the DABS transponders reduces the incidence of link failures due to fades.

2. PERFORMANCE REQUIREMENTS

2.1 Link Technical Characteristics.

2.1.1 Interrogation Signal Characteristics.

2.1.1.1 Classes of DABS Interrogations from DABS Sensors. Two classes of DABS-type interrogations are transmitted by a DABS sensor:

a. ATCRBS/DABS All-Call interrogations.

b. DABS interrogations.

Note: ATCRBS/DABS All-Call interrogations are used for surveillance of ATCRBS-equipped aircraft and for acquisition of DABS-equipped aircraft. DABS interrogations are used for surveillance and for data link communications with DABS-equipped aircraft on a sensor's surveillance roll-call; in addition, the DABS-Only All-Call may be used, if needed, for the initial acquisition of DABS aircraft without triggering replies from ATCRBS-equipped aircraft.

2.1.1.2 Interrogation Carrier Frequency. The carrier frequency of the main beam interrogation transmission shall be 1030 ± 0.01 MHz. The carrier frequency of SLS control pulses shall be as specified in FAA Selection Order 1010.51A, U.S. National Aviation Standard for the Mark X (SIF) Air Traffic Control Radar Beacon (ATCRBS) Characteristics.

2.1.1.3 ATCRBS/DABS All-Call Interrogations.

2.1.1.3.1 Structure: An ATCRBS/DABS All-Call interrogation consists of three pulses: P_1, P_3 and P_4, as illustrated in Fig. 2.1.1-1. One or two control pulses, P_2 or P_1 and P_2, may be transmitted using a separate antenna pattern to suppress responses from aircraft in the sidelobes of the interrogator antenna.

Note: The ATCRBS/DABS All-Call interrogations are similar to the corresponding ATCRBS interrogations as defined in FAA Order 1010.51A, but with an additional pulse P_4 following P_3. ATCRBS transponders are unaffected by the presence of the P_4 pulse, and respond with normal ATCRBS replies. DABS transponders recognize the interrogation as a DABS All-Call interrogation and respond with DABS All-Call replies.

2.1.1.3.2 Pulse Definitions. Pulse width, spacing, rise and fall times, and tolerances thereon for pulses P_1, P_2 and P_3 shall be as defined in FAA Selection Order 1010.51A.

2.1.1.3.3 Pulse Intervals. The interval between P_3 and P_4 shall be 1.5 ± 0.1 μsec.

2.1.1.3.4 Pulse Duration. The duration of pulse P_4 shall be 0.8 ± 0.1 μsec.

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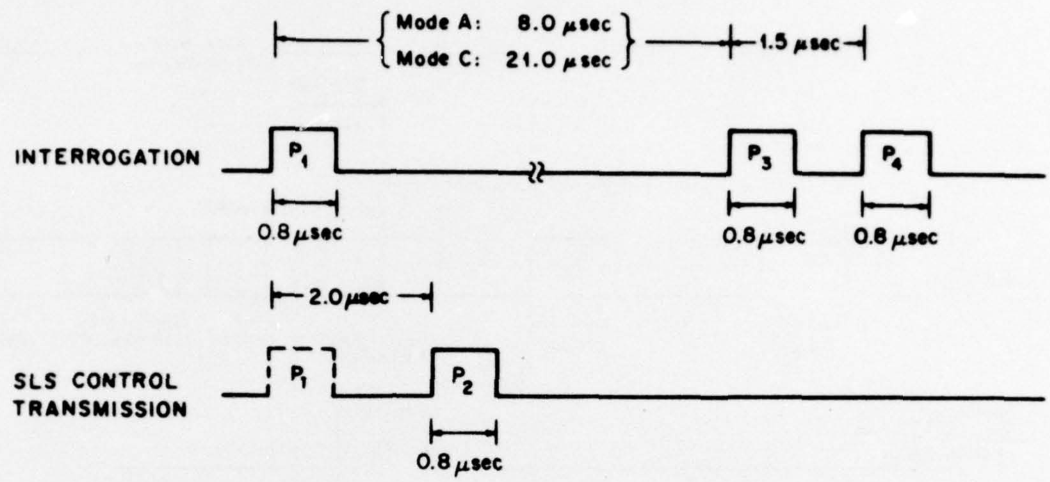


Fig. 2.1.1-1. ATCRBS/DABS All-Call Interrogations.

Note: DABS interrogators with omnidirectional antennas may interrogate ATCRBS targets with a modified Mode C ATCRBS/DABS All-Call interrogation in which the duration of P_4 is 1.6 ± 0.1 μsec. It is intended that this special interrogation elicit replies only from ATCRBS transponders and that DABS transponders reject this interrogation by discriminating against long P_4 pulses.

2.1.1.3.5 Pulse Shape. The rise time and decay time of pulse P_4 shall be as defined in FAA Selection Order 1010.51A for pulses P_1, P_2 and P_3.

2.1.1.3.6 Pulse Level, P_4. The radiated amplitude of P_4 shall be within 1 dB of the radiated amplitude of P_1.

2.1.1.3.7 Pulse Level, P_2, P_3. The radiated amplitudes of P_2 and P_3 compared to P_1 shall be as defined in FAA Selection Order 1010.51A.

2.1.1.4 DABS Interrogations. A DABS interrogation consists of a preamble followed by a data block containing 56 or 112 data bits. The signal format is illustrated in Fig. 2.1.1-2.

2.1.1.4.1 Preamble. The preamble consists of a pair of pulses P_1 and P_2, nominally spaced 2 μsec apart, which are both radiated in the mainbeam to intentionally suppress ATCRBS transponders which receive the interrogation. Pulse spacing, widths, and rise and decay times shall be as defined in FAA Selection Order 1010.51A for pulses P_1 and P_2 of an ATCRBS interrogation. (Spacing: 2 ± 0.15 μsec; Width: 0.8 ± 0.1 μsec; Rise: 0.05 to 0.1 μsec; Fall: 0.05 to 0.2 μsec.)

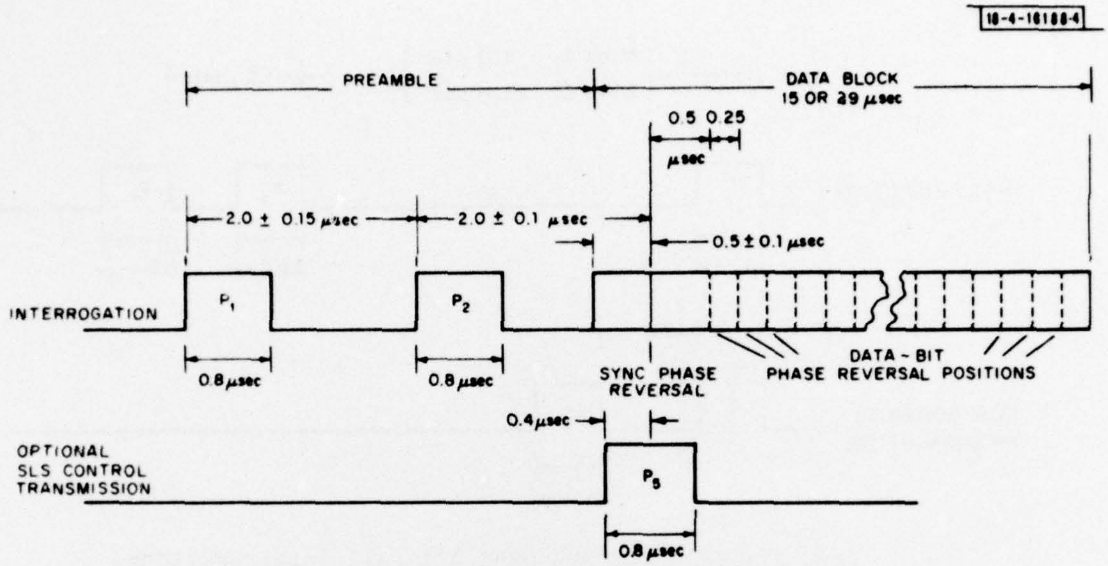


Fig. 2.1.1-2. DABS Interrogation

2.1.1.4.2 Data Block. The data block consists of a single RF pulse of 15 or 29 μsec duration beginning nominally 1.5 μsec after the leading edge of P_2. Data modulation is accomplished by phase reversals of the RF signal.

2.1.1.4.3 Data Block Shape. The rise and decay times of the RF carrier pulse for the data block shall be as defined in FAA Selection Order 1010.51A for pulses P_1, P_2, and P_3 of an ATCRBS interrogation.

2.1.1.4.4 Pulse Level. The radiated amplitude of P_2 and the initial 1-μsec segment of the data block shall be within ±0.25 dB of the radiated amplitude of P_1. The envelope droop of the data block over either a long (29-μsec) or short (15-μsec) DABS transmission shall not exceed 1 dB.

2.1.1.4.5 Sync Phase Reversal. The first phase reversal in the data block is the sync phase reversal and shall occur 2± 0.1 μsec after the leading edge of P_2. The leading edge of the data block shall occur 0.5 ± 0.1 μsec before the sync phase reversal.

2.1.1.4.6 Bit Content. Each data block includes 56 or 112 data bits transmitted at a 4-Mb/sec rate.

2.1.1.4.7 Modulation Type. Differential Phase Shift Keyed (DPSK) modulation is used, with a 180° phase change of the carrier at each data bit phase reversal position representing a binary one, and no phase reversal representing a binary zero.

2.1.1.4.8 Phase Reversal Spacing. Each carrier phase reversal shall occur at a time N x 0.25 $\pm$ 0.02 μsec ($N \geq 2$) after the sync phase reversal. Thus, the first time a data bit phase reversal can occur is 0.5 $\pm$ 0.02 μsec after the sync phase reversal.

2.1.1.4.9 Phase Reversal Timing. The time required for a phase reversal of the transmitted signal shall not be greater than 0.08 μsec.

2.1.1.4.10 Tolerance. The tolerance on the 0 or π phase relationship between successive chips in the DPSK signal (including the sync phase reversal) shall be $\pm$ 5 degrees.

2.1.1.5 DABS Transmit Sidelobe Suppression (SLS). A control pulse P_5 shall be transmitted to permit the DABS transponder to determine whether the interrogation has been received from the main beam or a sidelobe of an interrogator.

2.1.1.5.1 Pulse Shape. The control pulse P_5 shall be 0.8 $\pm$ 0.1 μsec long. The leading edge of pulse P_5 shall be transmitted 0.4 $\pm$ 0.05 μsec before the sync phase reversal. The rise time and fall time of pulse P_5 shall be as defined in FAA Selection Order 1010.51A for pulses P_1, P_2 and P_3 of an ATCRBS interrogation.

2.1.1.5.2 Pulse Level. The control pulse P_5 shall be radiated with the same antenna pattern and amplitude used for the P_2 control pulse of an ATCRBS/DABS All-Call interrogation.

> Note: For an aircraft not in the main beam of the interrogator, the received P_5 pulse amplitude will exceed that of the data block. The transponder then will not detect the sync phase reversal, and thus will not attempt to decode the remainder of the data block.

2.1.1.5.3 Pulse Carrier Frequency. The carrier frequencies of P_5 and the DABS data block shall not differ from each other by more than 0.1 MHz.

2.1.2 Reply Signal Characteristics.

2.1.2.1 Classes of Replies from DABS Transponders. Two classes of replies are generated by a DABS transponder:

a. ATCRBS replies (Mode A and Mode C).

b. DABS replies.

ATCRBS replies are generated in response to normal ATCRBS interrogations. DABS replies are generated in response to ATCRBS/DABS All-Call interrogations or DABS interrogations. DABS replies are also generated when no interrogations are received while the transponder is in the squitter mode.

2.1.2.2 Reply Carrier Frequency. The carrier frequency of the reply transmission shall be 1090 $\pm$ 3 MHz.

2.1.2.3 ATCRBS Reply. In response to an ATCRBS Mode A or Mode C interrogation, a DABS transponder shall generate the appropriate Mode A or Mode C ATCRBS reply, as defined in FAA Order 1010.51A. Reply pulse length, interval, and tolerances thereon are as defined in FAA Order 1010.51A.

2.1.2.4 DABS Reply. A DABS reply consists of a preamble followed by a data block containing 56 or 112 data bits. The signal format is shown in Fig. 2.1.2-1.

2.1.2.4.1 Preamble. The preamble consists of a series of four 0.5 μsec pulses. The intervals between the leading edge of the first preamble pulse and the leading edges of the second, third, and fourth preamble pulse shall be 1.0, 3.5 and 4.5 μsec, respectively.

2.1.2.4.2 Data Block. The data block begins 8.0 μsec following the leading edge of the first preamble pulse. Data bits are transmitted at a 1.0 Mb/sec rate using pulse position modulation (PPM) as follows: in the 1.0-μsec interval corresponding to each data bit, a 0.5 μsec pulse is transmitted in the first half of the interval if the data bit is a 1, and in the second half of the interval if the data bit is a 0.

2.1.2.4.3 Pulse Shape. All reply pulses shall have a pulse duration of 0.5 ± 0.05 μsec, except that when a 1 follows a 0 in the data block, the two 0.5-μsec pulses are contiguous, resulting in a single pulse of duration 1.0 ± 0.05 μsec. Pulse rise time shall be between 0.05 and 0.1 μsec, and pulse fall time shall be between 0.05 and 0.2 μsec. The pulse amplitude variation of one pulse with respect to any other pulse in a reply train shall not exceed 1 dB.

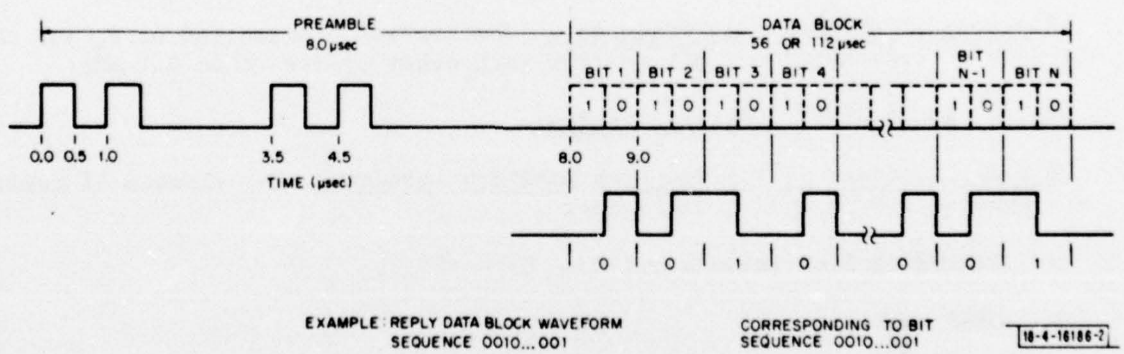


Fig. 2.1.2-1. DABS Reply Format.

Note: The intent of the lower limit of rise and decay times (0.05 μsec) is to reduce the sideband radiation. Equipment will meet this requirement if the sideband radiation is no greater than that which theoretically would be produced by a trapezoidal wave having the stated rise and decay times.

2.1.2.4.4 Pulse Interval Tolerances. The pulse interval tolerance for the leading edge of each pulse, with respect to the leading edge of the first preamble pulse of the reply, shall be ± 0.05 μsec.

2.1.2.5 Reply Delay and Jitter for DABS Interrogations. The leading edge of the first preamble pulse of the reply to a DABS interrogation shall occur at a time 128.0 ± 0.25 μsec following the sync phase reversal of the interrogation data block. The jitter of the reply delay shall not exceed 0.05 μsec, rms.

2.1.2.6 Reply Delay and Jitter for ATCRBS/DABS All-Call Interrogations. The leading edge of the first preamble pulse of the reply to an ATCRBS/DABS All-Call interrogation shall occur at a time 128.0 ± 0.25 μsec following the leading edge of the P_4 pulse of the interrogation. The jitter of the reply delay shall not exceed 0.06 μsec, rms.

Note: A jitter of 0.06 μsec, rms is consistent with the reply jitter of ± 0.1 μsec for ATCRBS replies specified in FAA Selection Order 1010.51A.

2.1.3 DABS Message Formats.

2.1.3.1 Interrogation and Reply Types. There are five DABS interrogation types, and five DABS reply types, as follows:

a. Interrogation Types:

DABS-Only All-Call
Surveillance (Unsynchronized or Synchronized)
Comm-A
Comm-S (Synchronized)
Comm-C

b. Reply Types:

All-Call (Standard or Squitter)
Surveillance (Unsynchronized, Synchronized or Special)
Comm-B
Comm-T (Synchronized)
Comm-D

In addition to the above interrogation types, a DABS Broadcast transmission is defined as a Surveillance or Comm-A interrogation with an all-zero address.

2.1.3.2 Interrogation Types.

2.1.3.2.1 DABS-Only All-Call. The DABS-Only All-Call is a short uplink interrogation which includes a data field containing a 2-bit header and a series of 30 undefined (spare) bits followed by a 24-bit parity field overlaid on the acquisition address. The first two spare bits (3, 4) shall be transmitted as zeros if there is no message to be delivered by the transmission and the remaining 28 spares (bits 5-32) shall be transmitted as ones if there is no message.

> Note: The DABS-Only All-Call interrogation (length, 56 bits) is used for the acquisition of DABS-equipped aircraft. It is used in place of the ATCRBS/DABS All-Call interrogation when the interrogator does not desire to elicit replies from ATCRBS-equipped aircraft. When the first two bits (F and L) of the DABS data block are 1 and 0 respectively, the interrogation is uniquely defined as a DABS-Only All-Call. Bits 5-32 are transmitted as ones (when there is no message) to distinguish it from an unmodulated transmission.

2.1.3.2.1.1 General Acquisition Address. The general acquisition address consists of twenty-four zeros, such that the overlaid parity field is represented by its true parity value.

2.1.3.2.1.2 Specific Acquisition Address. The specific acquisition address consists of twenty zeros and one of 15 combinations of the last transmitted four bits of the address field (excluding the combination 0000).

> Note: On subtracting the parity from the address field, the transponder will find either the general acquisition address (0000 0000 0000 0000 0000 0000) or the specific acquisition address (0000 0000 0000 0000 0000 xxxx). The specific acquisition address can be semi-permanently set via the the acquisition address interface (2.2.8.1.1) and is used for incremental acquisition of a large number of aircraft by a DABS sensor.

2.1.3.2.2 Surveillance. The Surveillance interrogation (length, 56 bits) is the normal DABS interrogation. It is used for surveillance when no data link message is to be transmitted.

2.1.3.2.3 Comm-A. The Comm-A interrogation (length, 112 bits) is used for the transmission of a 56-bit ground-to-air data link message. Longer messages may be accommodated by successive interrogation-reply cycles. The Comm-A interrogation includes the bit structure of the Surveillance interrogation, and thus may be used in its place for surveillance.

2.1.3.2.4 Comm-C. The Comm-C interrogation (length, 112 bits) is used for the more efficient transmission of long ground-to-air data link messages. Each Comm-C interrogation includes an 80-bit message field, and up to 16 Comm-C interrogations may be transmitted in a single burst and acknowledged with a single transponder reply. A Comm-C interrogation cannot be used for a surveillance update because it does not contain altitude information.

2.1.3.2.5 Synchronized Surveillance. The Synchronized Surveillance interrogation is timed to allow passive air-to-air ranging between DABS-equipped aircraft. Synchronized interrogations include an EP field to indicate the relative time of transmission. The transponder replies to a Synchronized Surveillance interrogation with a Synchronized Surveillance reply (2.1.3.3.6).

2.1.3.2.6 Comm-S. The Comm-S interrogation (length, 112 bits) is used to transmit a specialized synchronized message to the aircraft. The first 32 bits of the Comm-S have the structure of the Synchronized Surveillance interrogation while the message field (SF) in bits 33 through 88 contains additional data. The transponder replies to a Comm-S interrogation with a Comm-T reply (2.1.3.3.7).

2.1.3.2.7 DABS Broadcast Transmission. The DABS interrogation formats can also be used in a non-selective mode to broadcast data to all DABS-equipped aircraft within range. Upon decoding a Surveillance or Comm-A interrogation with an address of all zeros, the transponder transfers the contents of the uplink data block to the appropriate display or message interface, but does neither reply to this interrogation nor respond to the control fields therein.

Note: a) Because the discrete address of the interrogation is not available to transponder I/O devices, the Surveillance Data (SD) field or the MA field respectively must contain unique subfields (undefined) indicating to I/O devices interfaced to the transponder that the interrogation is a broadcast transmission.

b) An address of all zeros is not a valid discrete address for a DABS transponder since it is reserved for All-Call and DABS Broadcast use.

2.1.3.3 Reply Types.

2.1.3.3.1 All-Call.

2.1.3.3.1.1 Standard. The Standard All-Call reply (length, 56 bits) is used in response to an ATCRBS/DABS All-Call or a DABS-Only All-Call interrogation.

Note: Its function is to inform the interrogator of the presence of a DABS-equipped aircraft within its area of coverage. It includes the aircraft's discrete address code transmitted as part of its data field so that the interrogator can add the aircraft to its DABS target roll-call and discretely address subsequent interrogations to the aircraft. In addition, it includes a Capability (CA) field to designate the data link input/output capability of the aircraft. The All-Call reply is parity protected, but does not include an address overlaid on the parity bits.

2.1.3.3.1.2 Squitter. The Squitter is identical to a Standard All-Call reply with the exception that the All-Call Capability field (see 2.1.3.4.2.1) is replaced by a 6-bit Altitude (AT) field and the RT code is binary 11.

2.1.3.3.2 Surveillance. The Surveillance reply (length, 56 bits) is the normal DABS reply when no air-to-ground data-link transmission is required.

Note: This reply can contain, in a special field, either the aircraft's pressure altitude (encoded as in ATCRBS Mode C replies) or the ATCRBS identity (4096) code. The choice is commanded by the interrogator and normally the DABS interrogator's transmission requests altitude information. The aircraft can signal to the interrogator that 4096 readout is desired and on receipt of this signal the interrogator can sample the 4096 code.

2.1.3.3.3 Special Surveillance. The Special Surveillance reply is a type of unsynchronized Surveillance reply in which all externally-derived DABS data bits are available as special data bits.

2.1.3.3.4 Comm-B. The Comm-B reply (length, 112 bits) is used for the transmission of an air-to-ground data link message. Longer messages may be transmitted by successive interrogation-response cycles. The Comm-B reply includes the bit pattern of the (Unsynchronized) Surveillance reply, and thus may be used in its place for a surveillance update.

2.1.3.3.5 Comm-D. The Comm-D reply (length, 112 bits) is used for the efficient transmission of long air-to-ground data link messages. Each Comm-D reply includes an 80-bit message field; and up to 16 Comm-D replies may be transmitted as a single long response, and acknowledged with a single interrogation.

2.1.3.3.6 Synchronized Surveillance. The Synchronized Surveillance reply contains a replica of the timing field (EP) of the corresponding synchronous interrogation.

2.1.3.3.7 Comm-T. The Comm-T reply (length, 112 bits) is used for the transmission of a synchronized data link message. The Comm-T has the structure of the Synchronized Surveillance reply plus the additional 56-bit MT data field.

2.1.3.4 Data Block Formats. The data block formats for each interrogation and reply type are shown in Fig. 2.1.3-1. The listing in Table 2.1.3-1 includes each field abbreviation used in Fig. 2.1.3-1. In addition, the table identifies the paragraphs within this standard where each listed field is defined. A detailed description of the use of the control fields for implementing the extended length message functions is included in 2.1.5. The fields defined in these data blocks are divided into six types:

a. General (2.1.3.4.1).

b. Standard All-Call and Squitter replies (2.1.3.4.2).

c. Surveillance/Comm-A/Comm-S interrogation (2.1.3.4.3).

d. Surveillance/Comm-B/Comm-T reply (2.1.3.4.4).

e. Special Comm-C/Comm-D (2.1.3.4.5).

f. Special Surveillance reply (2.1.3.4.6).

2.1.3.4.1 General Fields.

2.1.3.4.1.1 F: (Format), Uplink Format Type. The first bit of the uplink data block designates the format type as follows:

F Bit	Uplink Format Type
0	Normal (Surveillance, Comm-A formats)
1	Special (DABS-only All-Call, Comm-C formats)

2.1.3.4.1.2 L: Length of Uplink Block. The second bit of the uplink data block designates the block length as follows:

L Bit	Length
0	56 bits
1	112 bits

2.1.3.4.1.3 IT: Interrogator Type. This one-bit field in all but Comm-C interrogations and DABS-only All-Call interrogations designates whether the interrogation is transmitted from a standard (IT=1) or auxiliary (IT=0) interrogator.

Note: A standard interrogator is defined as a DABS sensor with a directional antenna performing normal ATC surveillance and communications, while an auxiliary interrogator is an omnidirectional air-to-air or ground-to-air interrogator.

2.1.3.4.1.4 RT: Reply Type. This two-bit field designates the format of the DABS reply as follows:

RT	Reply Type
0 0	Surveillance
0 1	Comm-B or Special Surveillance
1 0	Standard All-Call
1 1	Comm-D or Squitter

Note: The 01 and 11 codes are each used to designate two reply formats. This lack of uniqueness does not result in ambiguity because the reply length is different for the two formats corresponding to each code. The RT field is not required to indicate to the decoder the length of the reply. The RT field is used primarily for distinguishing between Squitters and Standard All-Call replies.

2.1.3.4.2 Standard All-Call and Squitter Reply Fields.

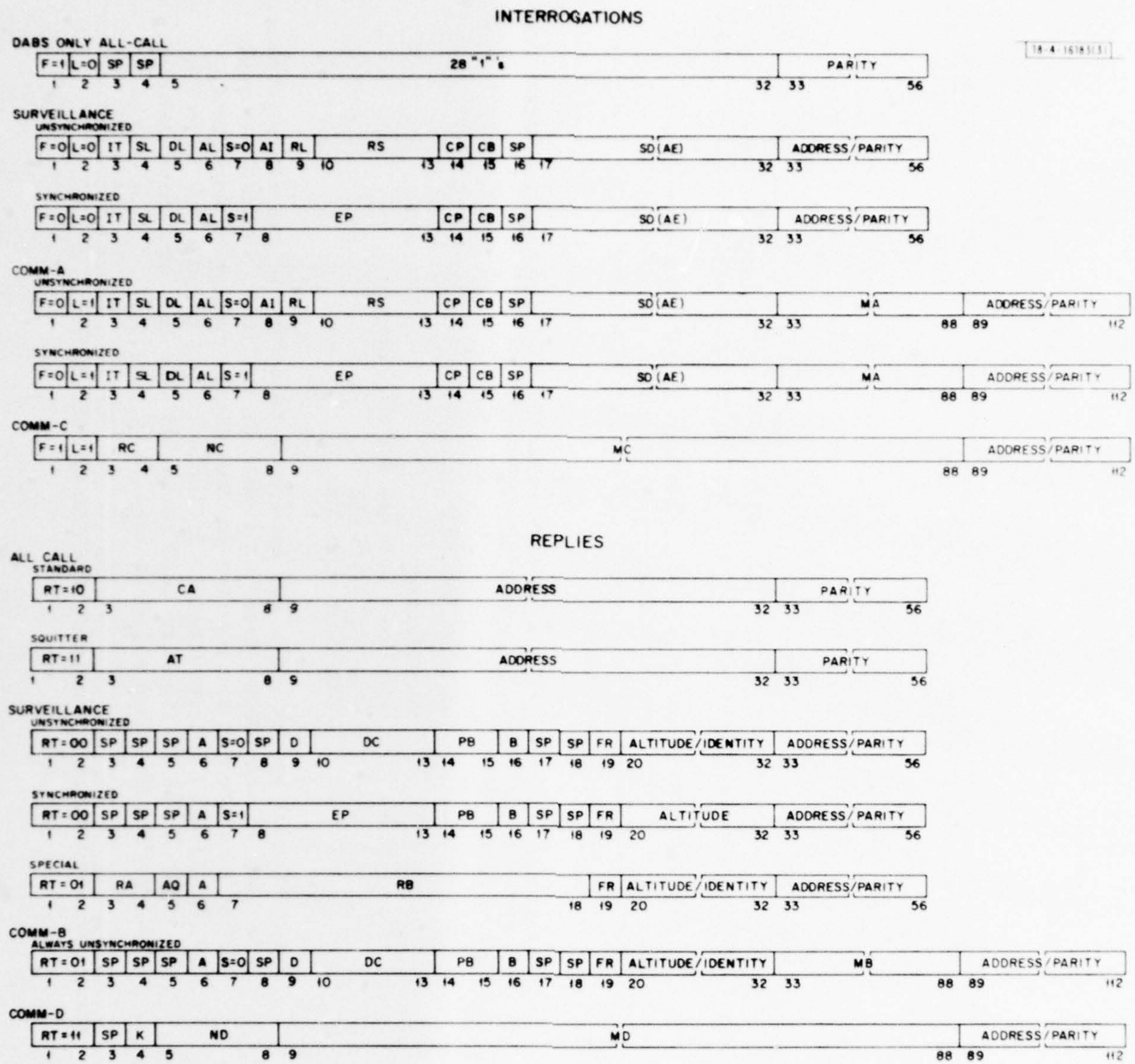


Fig. 2.1.3-1. DABS Interrogation and Reply Data Formats.

Table 2.1.3-1. Field Abbreviations.

Abbrev.	Name	Bit Number Interrog.	Bit Number Reply	Reference Paragraph
A	Alert	-	6	2.1.3.4.4.1
-	Address	-	9-32	2.1.3.4.2.3
-	Address/Parity	33-56,89-112		2.1.3.4.3.15
-	Address/Parity	33-56,89-112		2.1.3.4.4.14
AE	Altitude Echo	21-32	-	2.1.3.4.3.12
AI	Altitude/Identity Flag	8	-	2.1.3.4.3.5
AL	ATCRBS Lockout	6	-	2.1.3.4.3.3
-	Altitude/Identity	-	20-32	2.1.3.4.4.9
AQ	Acquisition Flag	-	5	2.1.3.4.6.1
AT	Altitude Truncated	-	3-8	2.1.3.4.2.2
B	Comm-B Message Waiting	-	16	2.1.3.4.4.7
CA	Capability	-	3-8	2.1.3.4.2.1
CB	Clear Comm-B	15	-	2.1.3.4.3.10
CP	Clear PB	14	-	2.1.3.4.3.9
D	Comm-D Message Waiting	-	9	2.1.3.4.4.3
DC	Length of Reply ELM	-	10-13	2.1.3.4.4.4
DL	DABS Lockout	5	-	2.1.3.4.3.2
EP	Synchronous Time	8-13	-	2.1.3.4.3.8
-	Synchronous Time	-	8-13	2.1.3.4.4.5
F	Format Type	1	-	2.1.3.4.1.1
FR	Flight Rules Indicator	-	19	2.1.3.4.4.8
IT	Interrogator Type	3	-	2.1.3.4.1.3
K	ELM Control Indicator	-	4	2.1.3.4.5.3
L	Data-Block Length	2	-	2.1.3.4.1.2
MA	Interrogation Data	33-88	-	2.1.3.4.3.13
MB	Reply Data	-	33-88	2.1.3.4.4.10
MC	Interrogation ELM Segment	9-88	-	2.1.3.4.5.2
MD	Reply ELM Segment	-	9-88	2.1.3.4.5.3
MS	Maximum Airspeed	-	11-13	2.1.3.4.6.2
MT	Synchr. Reply Data	-	33-38	2.1.3.4.4.11
NC	Interrogator ELM Segment No	5-8	-	2.1.3.4.5.2
ND	Reply ELM Segment No	-	5-8	2.1.3.4.5.3
-	Parity	33-56	-	2.1.3.2.1
-	Parity	-	33-56	2.1.3.4.2.4
PB	Pilot Acknowledgement	-	14-15	2.1.3.4.4.6
RA&RB	Special Surveillance Data	-	3-4,7-18	2.1.3.4.6.3
RC	Reply Type for Comm-C	3-4	-	2.1.3.4.5.1
RL	Reply Length	9	-	2.1.3.4.3.6
RS	Reply Selector	10-13	-	2.1.3.4.3.7
RT	Reply Type	-	1-2	2.1.3.4.1.4
S	Synchronization Indicator	7	-	2.1.3.4.3.4
-	Synchronization Indicator	-	7	2.1.3.4.4.2
SD	Surveillance Data	17-32	-	2.1.3.4.3.11
SF	Synchr. Interrogation Data	-	33-38	2.1.3.4.3.14
SL	Squitter Lockout	4	-	2.1.3.4.3.1
SP	Spare	3,4,16	3-5,8,17-18	-
SR	Segment Request	9-24	-	2.1.3.4.5.2
TA	Transponder Technical Acknowledgement	-	9-24	2.1.3.4.5.3

2.1.3.4.2.1 CA: Capability. This six-bit reply field indicates the data link input/output capability of the aircraft. Each bit in this field is dedicated to a specific capability. A one in a particular bit position indicates the following:

Bit No.	Significance
3	Equipped with ATARS display
4	Unassigned
5	Equipped with ATC message display
6	Unassigned
7	Unassigned
8	Equipped with extended capability (see 2.1.3.4.4.12)

Bit No. 8 is always set to "one" if the transponder has ELM capability.

2.1.3.4.2.2 AT: Altitude, Truncated for Squitter Transmissions. This special 6-bit altitude code is a truncated version of the full ATCRBS Mode C altitude code, which provides digitized altitude in 1000-ft increments quantized to $\pm$500 feet from -750 feet to +62,250 feet, as follows:

Bit Number:	3	4	5	6	7	8	Altitude Range			Average Altitude
Pulse Position:	A_1	A_2	A_4	B_1	B_2	D_4	(feet)			(feet)
Minimum Altitude	0	0	0	0	0	0	-1250	to	-250	-750
First step	0	0	0	0	1	0	-250	to	+750	250
Second Step	0	0	0	1	1	0	+750	to	+1750	1250
.										
.										
.										
Maximum altitude	0	0	0	0	0	1	+61750	to	+62750	62250

Note: Because of the altitude digitizer coding, an aircraft at an altitude above 62,750 ft will Squitter a code which will indicate an altitude below 62,750 ft. However, the AT code is intended only to provide a preliminary indication of altitude to allow minimization of acquisition interrogation rates in high aircraft-population density airspace. After the target is acquired by a discrete interrogation, the full altitude code will be available. Since the aircraft population density above 62,750 ft will always be relatively low, it is not necessary to increase the unambiguous range of the AT code to provide for higher altitudes.

2.1.3.4.2.3 Address. This 24-bit field contains the aircraft's discrete address code.

2.1.3.4.2.4 Parity. This 24-bit field contains 24 parity check bits generated by applying a parity check code to the preceding bits in the data block. The algorithms for generating the parity check bits are described in 2.1.4.

2.1.3.4.3 Surveillance/Comm-A/Comm-S Interrogation Fields.

2.1.3.4.3.1 SL: Squitter Lockout. This one-bit field allows the interrogator to prevent the transponder from transmitting Squitters and densitizes the transponder to auxiliary discrete address interrogations (i.e., interrogations with IT=0; see 2.1.3.4.1.3). Each time the transponder replies to a discrete interrogation containing SL=1, the transponder shall be immediately locked out to Squitters and auxiliary discrete interrogations for a period of T_{SL} seconds and a time-out shall be initiated (or reinitiated) for the full T_{SL} interval. The transponder shall be unlocked to Squitters and auxiliary discretes only if it has not replied to an interrogation with SL=1 within T_{SL} seconds. When an interrogation is received with SL=0, the lockout state and the T_{SL} time-out shall not be affected.

2.1.3.4.3.2 DL: DABS Lockout. This one-bit field allows the interrogator to prevent the transponder from accepting ATCRBS/DABS All-Calls. (This field does not affect sensitivity to ordinary ATCRBS interrogations.) Each time the transponder replies to a discrete interrogation containing DL=1, the transponder shall be immediately locked out to subsequent ATCRBS/DABS All-Calls for a period of T_{DL} seconds and a time-out shall be initiated (or reinitiated) for the full T_{DL} interval. The transponder shall be unlocked to ATCRBS/DABS All-calls only if it has not replied to an interrogation with DL=1 within T_{DL} seconds. When an interrogation is received with DL=0, the lockout state and the T_{DL} time-out shall not be affected.

2.1.3.4.3.3 AL: ATCRBS Lockout. This one-bit field allows the interrogator to prevent the transponder from accepting ATCRBS interrogations. (This field does not affect to ATCRBS/DABS All-Calls.) Each time the transponder replies to a discrete interrogation containing AL=1, the transponder shall be immediately locked out to ATCRBS interrogations for a period of T_{AL} seconds and a time-out shall be initiated (or reinitiated) for the full T_{AL} interval. The transponder shall be unlocked to ATCRBS interrogations only if it has not replied to an interrogation with AL=1 within T_{AL} seconds. When an interrogation is received with AL=0, the lockout state and the T_{AL} time-out shall not be affected.

2.1.3.4.3.4 S: Synchronization Indicator. This one-bit field designates whether or not the interrogation is synchronized, i.e., timed such that the resulting reply occurs at a precise clock time. A one in this field indicates that the interrogation is synchronized and requires that bits 8-13 be interpreted as EP (see 2.1.3.4.3.8).

2.1.3.4.3.5 AI: Altitude/Identity Designator. This one-bit field is used to designate whether the reply is to contain the pressure altitude code or the ATCRBS identity code in its Altitude/Identity field. A one is used to request transmission of the ATCRBS identity code.

2.1.3.4.3.6 RL: Reply Length. This one-bit field is used in interrogations to designate the reply type (length) as follows:

RL Bit	Reply Type
0	Surveillance (56 bits)
1	Comm-B (112 bits)

If the RL bit is a one and the transponder is equipped for Comm-B transmissions, the transponder shall transmit a Comm-B reply regardless of whether or not there is a Comm-B device attached. If the RL bit is a one and the transponder is not equipped for Comm-B transmissions, the transponder shall transmit a standard Surveillance reply. The RL bit also determines the definition of the RS code (see 2.1.3.4.3.7).

2.1.3.4.3.7 RS: Reply Selector. This four-bit field is used in conjunction with the RL code in Unsynchronous interrogations to specify the format and source of data to be transmitted in DABS replies. When an interrogation is received with S = 0, RL = 0, and RS = 0000, a Surveillance reply shall be transmitted. When S = 0, RL = 0 and RS $\neq$ 0000, a Special Surveillance reply shall be transmitted. (Particular Special Surveillance reply codes are specified in 2.1.3.4.6.) When RL = 1, the RS code specifies the source of the MB data in the Comm-B reply.

2.1.3.4.3.8 EP (EPOCH): Synchronous Reply Time. This six-bit field designates the six most significant bits of the synchronized reply time (see 2.1.3.4.4.5).

2.1.3.4.3.9 CP: Clear PB. This one-bit field is used to acknowledge and reset the pilot's acknowledgment device. A one in this field indicates acknowledgment.

2.1.3.4.3.10 CB: Clear Comm-B. This one-bit field is used to acknowledge receipt of an air-to-ground Comm-B message. A one in this field indicates acknowledgment. When an interrogation is received with CB=1, the B bit shall be cleared in the reply to that interrogation unless another Comm-B message is waiting; in that case, the B bit shall remain set.

2.1.3.4.3.11 SD: Surveillance Data. This 16-bit field is used for transmission of short, specialized data words. The first four bits of SD (Bits 17-20) are used as a Surveillance Data header. If these bits are all zeros, the remainder of SD (bits 21-32) contains the Altitude Echo (AE). (If the first four bits are not all zeros, the transponder is thereby instructed not to display the contents of the remainder of the SD field in the AE display.) Codes for the non-zero header are described in 3.5.4.

2.1.3.4.3.12 AE: Altitude Echo. This 12-bit subfield of SD is used when bits 17-20 are all zeros to transmit to the aircraft its altitude as reported on the previous transponder response. For convenience in display, AE is encoded as follows: bits 21-24 transmit the decimal integers 0-12, representing 10,000-ft increments through 120,000-ft (a binary code of 1111 in bit positions 21 to 24 is used to blank the AE display); bits 25-28 transmit the decimal integers 0-9, representing 1,000-ft increments; bits 29-32 transmit the decimal integers 0-9, representing 100-ft increments. In each 4-bit word representing a decimal integer, the least significant bit is transmitted last. For aircraft flying below the transition altitude to "flight level" readings, AE is corrected (on the ground) for local barometric pressure in the aircraft's operating area, so that the altitude displayed by AE corresponds to the indication on the aircraft's altimeter. The AE code is not corrected for aircraft above the transition altitude (see 2.2.7.2).

2.1.3.4.3.13 MA: Interrogation Data Link Message. This 56-bit field contains the interrogation data-link message.

2.1.3.4.3.14 SF: Synchronized Interrogation Data. This 56 bit field contains the interrogation synchronized data link message.

2.1.3.4.3.15 Address/Parity. This 24-bit field contains the 24-bit discrete address of the interrogated aircraft combined with 24 parity bits generated by applying a parity check code to the preceding bits in the data block. The algorithms for generating the parity check bits and their combination with the address code are described in 2.1.4 (also see 2.1.3.4.4.13).

2.1.3.4.4 Surveillance/Comm-B/Comm-T Reply Fields.

2.1.3.4.4.1. A: Alert. This one-bit field requests the sensor to transmit an interrogation with AI=1 so that the ATCRBS identity (4096) code setting may be transmitted to the ground. The A bit shall be automatically set each time the 4096 code setting is changed. Upon receipt of the next DABS Surveillance or Comm-A interrogation, the transponder shall reply with A=1. The A bit shall be cleared after a reply containing the 4096 code has been transmitted in response to an interrogation with IT=1 and AI=1, with the following exception: the transponder shall transmit the A bit continuously when the 4096 code indicates an emergency condition, and shall not be cleared upon receipt of AI=1 from the ground.

2.1.3.4.4.2 S: Synchronization Indicator. This one-bit field echoes the S bit in the corresponding interrogation (see 2.1.3.4.3.4), indicating (by S=1) that the reply is synchronized and can be used by suitably equipped aircraft for air-to-air ranging. Thus, the S bit of a Comm-B reply will always be a zero.

2.1.3.4.4.3 D: Extended-Length "Message Waiting" Indicator. This one-bit field designates to the interrogator that the transponder has an extended-length message waiting to be transmitted. A one in this field indicates the presence of such a message.

2.1.3.4.4.4 DC: Length of Reply ELM. This four-bit field is used to indicate the length of an extended-length message waiting to be sent. The four-bit binary integer in DC is one less than the number of segments in the extended-length message.

2.1.3.4.4.5 EP (EPOCH): Synchronous Reply Time. This six-bit field repeats, in a synchronized reply, the contents of the EP field in the corresponding synchronized interrogation (see 2.1.3.4.3.8).

2.1.3.4.4.6 PB: Pilot Acknowledgement Buttons. This two-bit field is reserved for a pilot acknowledgement code.

2.1.3.4.4.7 B: Data Link "Message Waiting" Indicator. A one in this field designates to the interrogator that the transponder has a Comm-B message waiting to be transmitted.

2.1.3.4.4.8 FR: Flight Rules Indicator. This one-bit field is set to indicate whether the aircraft is operating under visual or instrument flight rules. A one in this field indicates IFR operation.

2.1.3.4.4.9 Altitude/Identity. This 13-bit field contains the ATCRBS Mode A identity code or Mode C altitude code (including the X bit), as indicated by the AI field.

2.1.3.4.4.10 MB: Reply Data Link Message. This 56-bit field contains the air-to-ground data link message. If a Comm-B reply is transmitted for which the transponder and/or its peripherals cannot supply data, the MB field shall contain all zeros.

2.1.3.4.4.11 MT: Synchronized Reply Data. This 56 bit field contains the synchronized reply data. If a Comm-T reply is transmitted for which the transponder and/or its peripherals cannot supply data, the MT field shall contain all zeros.

2.1.3.4.4.12 Extended Capability and Flight Number Reply. In response to a correctly addressed interrogation with RL=1 and RS=0001 (see 2.1.3.4.3.7), the transponder shall, if so equipped, transmit a Comm-B reply whose MB field is reserved for extended capability and aircraft flight number codes. The specific codes are not yet defined, except as indicated in 2.1.3.4.4.13.

2.1.3.4.4.13 ELM Capability Code. If the transponder is ELM equipped, bit position 37 shall be transmitted as a one to indicate ELM capability in response to an interrogation with RL=1 and RS=0001. All remaining bits of the transmitted MB field shall be zeros unless ones are automatically entered in pre-assigned bit positions by I/O devices attached to the SM interface.

2.1.3.4.4.14 Address/Parity. This 24-bit field contains the 24-bit discrete address of the replying aircraft combined with 24 parity check bits generated by applying a parity check code to the preceding bits in the data block. The algorithms for generating the parity check bits and their combination with the address code are described in 2.1.4.

2.1.3.4.5 Special Comm-C/Comm-D Fields.

2.1.3.4.5.1 RC: Reply Type for Comm-C Interrogations. This special two-bit reply type and control field is used in conjunction with an extended-length message transmission. The RC codes are defined in Table 2.1.3-2.

2.1.3.4.5.2 NC and MC. Respectively, these four-bit segment number and 80-bit message fields are included in Comm-C transmissions. The interpretation of these fields is determined by the RC code, as defined in Table 2.1.3-2.

2.1.3.4.5.3 K, ND, MD (including TA). Respectively, these 1-bit, 4-bit and 80-bit, (including the 16 bit TA) Comm-D fields are used for extended-length message transfer as follows:

Table 2.1.3-2. Definition of Comm-C Fields.

RC	NC	MC	Reply	Function of Comm-C Transmission
0 0	0 0 0 1 to 1 1 1 1	Initial 80-bit Message Segment	No Reply	Contains highest-numbered segment of uplink ELM and indicates number of segments to follow
0 1	0 0 0 1 to 1 1 1 0	Intermediate 80-bit Message Segment	No Reply	Contains an intermediate segment of an uplink ELM and its segment number
1 0	0 0 0 0 to 1 1 1 0	Final 80-bit Message Segment	Comm-D with K=1 and TA in MD	Contains last segment of uplink ELM and requests cumulative Transponder Technical Acknowledgement (TA)
1 1	0 0 0 0	Segment Request (SR) Field (16 bits)	Multiple Comm-D transmissions	Specifies which downlink ELM segments the transponder should transmit
1 1	0 0 0 1	Bit 9 (first bit of MC) = 1, others = 0	Single Comm-D, contents arbitrary	Concludes an uplink ELM transaction
1 1	0 0 1 0	Bit 9 (first bit of MC) = 1, others = 0	Single Comm-D, contents arbitrary	Concludes a downlink ELM transaction
1 1	0 0 1 1 to 1 1 1 1	---	---	Undefined

K Bit	ND Bits	MD Bits
0	Segment number of message segment in MD	80-bit segment of reply extended-length message
1	Not used (all zeros)	16-bit cumulative Transponder Technical Acknowledgement (TA) of interrogation extended-length message in bit positions 9 to 24

If the interrogation requests a Comm-D reply and the transponder is ELM-equipped, the transponder shall transmit a Comm-D reply regardless of whether or not there are ELM data available. If a Comm-D reply is transmitted for which the transponder and/or the ELM device cannot supply data, the MD field shall contain all zeros. If the interrogation requests a Comm-D reply from a transponder which is not ELM-equipped, the transponder shall not reply.

2.1.3.4.6 Special Surveillance Reply Fields. Upon receipt of an interrogation with RL = 0 and RS ≠ 0000, the transponder shall transmit a Special Surveillance reply including the following internally generated fields to assure cooperation with air-to-air auxiliary interrogators.

2.1.3.4.6.1 AQ: Acquisition Flag. Upon receipt of an interrogation with RL = 0 and RS = xx1x (where x designates either a one or a zero), bit 5 (AQ) of the Special Surveillance reply shall be transmitted as a one, indicating an acquisition reply. When RL = 0 and RS = xx0x, but RS ≠ 0000, bit 5 shall be transmitted as a zero, indicating a roll call reply.

2.1.3.4.6.2 MS: Maximum Airspeed Field. On receipt of an interrogation with RL = 0 and RS = 0010, bit positions 11 to 13 (located in the RB field) of the reply shall contain the maximum airspeed code for the aircraft. MS indicates the maximum cruising airspeed of the aircraft in which the transponder is installed. The coding of this field is as follows:

MS Bit No. 11 12 13	Maximum Airspeed
0 0 0	No input
0 0 1	
0 1 0	Not yet defined
0 1 1	Not yet defined
1 0 0	Not yet defined
1 0 1	Not yet defined
1 1 0	
1 1 1	Squitters inhibited

The MS = 111 code shall be automatically set whenever the Squitter Inhibit interface (see 2.2.8.4) is activated.

Note: This airspeed information is used in scheduling reacquisition interrogations if the transponder is outside the range of interest of the auxiliary interrogator. The absence of an airspeed code results in a default to the all-zeros code. The Squitter Inhibit interface may be used to encode all ones in this field when the aircraft is on the ground so that the aircraft may be so identified.

2.1.3.4.6.3 RA and RB: Special Surveillance Reply Data. Bits 3, 4, and 7-18 of the Special Surveillance reply, with the exception of the MS code bits (11-13), shall be obtained from the SM interface (see 2.2.10) and shall not be acted upon by the transponder. In the absence of inputs from the SM interface, all externally-derived bits shall be transmitted as zeros.

2.1.4 Error Protection.

2.1.4.1 Technique. Parity check coding is used on DABS interrogations and replies to provide protection against the occurrence of undetected errors.

2.1.4.1.1 Parity Check Bits. Twenty-four parity check bits shall be generated for each DABS transmission. In all DABS interrogations and replies, except DABS-Only All-Call interrogations, All-Call replies and Squitters, these parity check bits shall be combined with the 24-bit discrete address thereby providing error protection without increasing the transmitted message length.

2.1.4.1.2 All-Call and Broadcast Transmissions. In DABS-Only All-Call interrogations and other interrogations which are directed to all DABS transponders (DABS Broadcast transmissions) no address shall be transmitted. In these transmissions the parity bits shall be transmitted as they are generated, or, in effect, combined with an address of all zeros.

2.1.4.1.3 DABS All-Call Replies. In DABS Standard All-Call replies and Squitters, the 24-bit address is transmitted as part of the information field. The 24 parity check bits are then transmitted as they are generated, i.e., without combining them with the address bits.

Note: An error occurring in the received data block (in either the information field or the Address/Parity field) will, with high probability, modify the bit pattern in the Address field at the completion of the decoding process. The probability of an undetected error, i.e., one which does not modify the address pattern after decoding, is extremely small. When an error occurs in an interrogation, the transponder to which the interrogation was addressed will not recognize its address and will not reply or accept any accompanying message.

It is possible that noise or interference-induced errors will cause an aircraft to accept an interrogation which was actually addressed to another aircraft. Because of the very large number of possible addresses ($2^{24} \approx 16$ million), the probability of occurrence of such a misdirected message is very low. Note that the aircraft receiving the misdirected message must be in the main lobe of the interrogator antenna pattern. Otherwise, the interrogation will be rejected by the DABS sidelobe suppression action.

In decoding the response to a discretly-addressed interrogation, the interrogator already knows the address of the replying aircraft. This fact allows the interrogator not only to detect errors in the reply, but also to correct certain error patterns without significantly compromising the reliability of error detection. The code properties permit the correction of error patterns resulting from interference caused by a single ATCRBS reply.

In decoding the response to an All-Call interrogation, the decoder does not know the address of the replying aircraft. However, since the parity check bits are not combined with the address bits in the DABS All-Call reply, the error detection and correction capability is the same as in the case of responses to discretely-addressed interrogations.

2.1.4.2 Parity Check Sequence Generation. A systematic code shall be employed in which the 32 or 88-bit information field (of a 56 or 112-bit data block, respectively) is transmitted unmodified. Twenty-four parity check bits shall be generated by operating on the information field with an encoder described by the following polynomial:

$$g(x) = \sum_{i=0}^{24} g_i x^i$$

where g_i = 1 for i=0 through 12, 14, 21, 24
= 0 otherwise

2.1.4.3 Address/Parity Combination. The 24 parity check bits shall be combined with the 24-bit discrete address (except in a DABS-Only All-Call interrogation, a Standard All-Call reply, or a Squitter) and transmitted sequentially following the information field.

Note: Two different procedures are used for combining the address and parity check bits, one for interrogations and one for replies. The procedure used for interrogations is chosen to minimize transponder hardware complexity. The procedure used for replies is chosen to facilitate the use of error correction in reply decoding.

Figure 2.1.4-1 illustrates a realization of the interrogator and transponder encoders. (The connection shown as a broken line is present only in the interrogator encoder.) Other functionally equivalent encoder realizations are equally acceptable, provided that the Address/Parity field generated for all information and address fields is identical to that of the encoder in Figure 2.1.4-1. As illustrated, the encoder is a 24-stage shift register, where the outputs of certain stages, as defined by the characteristic polynomial, are summed modulo 2 with the input sequence and applied to the shift register input.

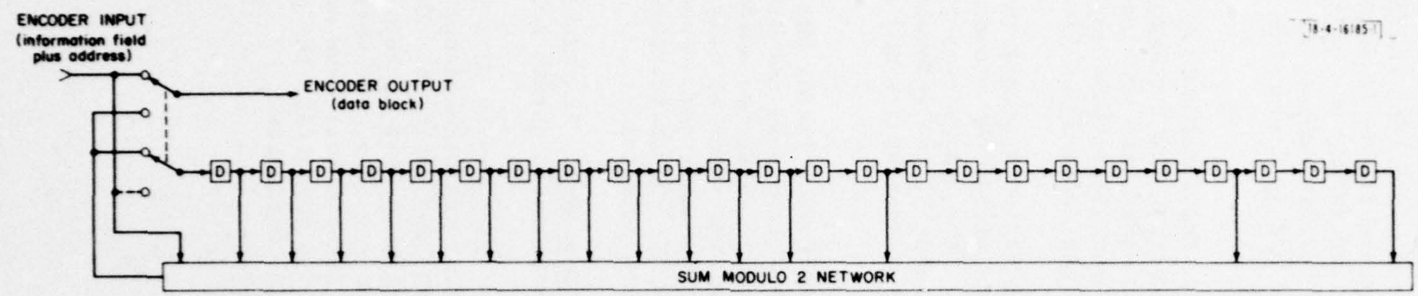
The encoder operates in two modes, the first during the transmission of the information field, the second during the transmission of the Address/Parity field. In the encoder shown, the mode is determined by the position of the switch; the position illustrated corresponds to the mode used during the transmission of the information field.

Encoding commences with all shift register stages initialized to "0". During transmission of the information field, the encoder output is connected directly to the input, i.e., the transmitted bits are identically the information bits. Simultaneously, the information bits are summed modulo 2 with selected shift register stages and applied to the shift register input.

During transmission of the Address/Parity field, the encoder output (i.e., the sequence of bits to be transmitted) is the output of the sum-modulo-2 network. In the interrogator encoder, the address bits are applied sequentially to the shift register input as well as to the sum-modulo-2 network. In the transponder encoder, the address bits are applied only to the sum-modulo-2 network; the shift register input is set to zero during Address/Parity field transmission.

2.1.4.4 Transponder Error Detection Decoding. The transponder shall employ error detection logic matched to the transmitted parity sequence.

> Note: The circuit of Fig. 2.1.4-1 also serves as a realization of an error detection circuit for decoding the encoded sequence. The decoder is operated with the switch in the "up" position. The entire received message is shifted into this circuit as well as into a storage buffer. After all 56 or 112 bits have been received, the shift register will contain the correct address only if no errors have occured in transmission. If the address is received correctly, the data in the storage register can be accepted with high confidence.



NOTES:
1. SWITCH IN "UP" POSITION (SHOWN) FOR INFORMATION FIELD TRANSMISSION AND DECODING.
2. SWITCH IN "DOWN" POSITION FOR ADDRESS/PARITY FIELD TRANSMISSION.
3. DOTTED CONNECTION PRESENT ONLY IN INTERROGATOR ENCODER.
4. INITIAL CONTENTS OF 24-BIT REGISTER ALL "0"'s.

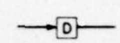


Fig. 2.1.4-1. Functional Diagram of Interrogator and Transponder Encoders.

2.1.5 Comm-C/Comm-D Extended-Length Message Protocol. Extended-length message (ELM) protocol provides for more efficient transmission of long data link messages to aircraft with optional ELM-equipped transponders by permitting the grouping of up to 16 message segments into a single entity which can be acknowledged by a single reply. Each single segment is included in a Comm-C or Comm-D transmission. (The limit of 16 segments refers solely to the manner in which the message is transferred over the link. Longer messages can be accommodated through the use of a message continuation indicator within the text field of the last segment of an ELM.)

2.1.5.1 Ground-to-Air ELM Transfer. Ground-to-air extended-length messages are transmitted using the Comm-C format with three different reply type codes (RC=00, 01 and 10). The three reply type codes designate an initializing segment, intermediate segments and a final segment.

> Note: The minimum length of a ground-to-air ELM is two segments. The transfer of all segments may take place without any intervening replies, as described in the next four paragraphs. In this way, channel loading is minimized. Message segments (one per Comm-C interrogation) may be transmitted at a rate of up to one per 50 μsec. This minimum spacing is required to permit the resuppression of ATCRBS transponders. Delivery of the message may take place during a single scan or over a few scans depending on the length of the message, the channel interference level, and the sensor loading. Normally, sufficient time will be available within one scan to permit complete delivery of the message.

2.1.5.1.1 Initializing Segment Transfer. The ELM transaction for an N-segment message (segment numbers 0 through N-1) is initiated by a Comm-C interrogation with RC=00. The transponder does not reply. Receipt of this interrogation (in effect a "dial up") causes the airborne ELM equipment to prepare for a new ELM transfer. Also delivered in the initial call is the text of the final message segment in MC, and its segment number (N-1) in the NC field.

> Note: This "last segment first" protocol is used to inform the transponder of the length of the message. If the ELM processor fails to receive an initializing segment, it may either ignore or store the data content of all further segments of the same message since the interrogator will retransmit the entire message (see 2.1.5.1.4), initializing segment and all other segments, without change.

2.1.5.1.2 Intermediate Segment Transfer . Message delivery proceeds with the transmission of intermediate segments (any sequence of N-2 segments chosen from segments N-2 through 1) via Comm-C interrogations with RC=01, again triggering no replies. Each message segment is identified with its segment number in the NC field. The ELM processor stores each segment in the appropriate storage location based upon this number. In this way, the message processor reassembles the message, and its bookkeeping function keeps track of which segments have been received.

Note: Intermediate segments may be delivered in any order, once the ELM processor has been initialized with segment N-1. If the entire message consists of only two segments, there will be no intermediate transfers.

2.1.5.1.3 Final Segment Transfer. The interrogator transmits the final segment of a Comm-C interrogation with RC=10. Its segment number (any number from 0 to N-2) is in NC, and the text is transmitted in MC. This RC code elicits a Comm-D reply with K=1 and a cumulative Transponder Technical Acknowledgement in the MD field. The cumulative Transponder Technical Acknowledgement (TA) consists of a bit string (maximum length 16 bits) which indicates which segments of the ELM have been received. The first bit represents the state of the first (N=0) segment, etc., with the states defined as: 1 = segment received, and 0 = segment not received. (The remaining 64 bits of MD are spares and shall be transmitted as zeros). Thus at all times this field represents the current status of segment delivery from the time of ELM initiation. If the interrogator does not receive a reply to the Comm-C interrogation containing the final segment, this interrogation is repeated until a reply is successfully received. When all segments have been received by the transponder, the interrogator knows that its last transfer was indeed final and closes out the transaction by the transmission of a special Comm-C interrogation with RC=11, NC=0001 and bit 9=1, thereby resetting the TA field and any other bookkeeping registers in the transponder. This "Clear Comm-C" interrogation elicits a single Comm-D reply (with arbitrary message content) which serves as a technical acknowledgement to the interrogator. To expedite the display of the message, the ELM processor in the transponder transfers the message to the appropriate output device as soon as it senses the presence of all segments (i.e., it does not await the receipt of the Clear Comm-C interrogation). However, output transfer shall be enabled only once for each ground-to-air ELM message to avoid displaying the same message more than once in the event of retransmission due to TA delivery failure.

Note: The interrogator will always send a Clear Comm-C message after partial delivery of an ELM which it wishes to cancel, as well as after normal complete delivery. This procedure ensures that there will be no confusion between segments of successive ELM's, even if the initializing segment of the second ELM is subject to link failure.

2.1.5.1.4 Segments not Received by Transponder. If one or more segments of the ELM are not received by the transponder, this fact is indicated by zeros in the corresponding bit positions in the TA. If the TA indicates that the initializing segment was not received, the interrogator retransmits the entire message. If segments other than the initializing segment are missing, they are retransmitted with RC=01, except for the last of the missing segments which has RC=10 to request an updated TA. This process continues until the ground receives a cumulative TA indicating that all segments have been delivered. At that point, the transaction is closed out as described above. If standard DABS contact is lost (i.e., if more than nominally 16 seconds has elapsed since the transponder last replied to a discrete address interrogation with IT=1) before a ground-to-air transaction is closed out, the ELM registers shall be returned to their initialized (power on) state.

2.1.5.2 Air-to-Ground ELM Transfer. The transfer of an air-to-ground ELM is similar to the ground-to-air process. Differences between the two protocols result primarily from the facts that (1) all channel activity is ground initiated and (2) the transponder can reply with a longer communications format only when given specific permission by the ground.

2.1.5.2.1 Initialization. An N-segment air-to-ground ELM transfer is initiated by a non-synchronized Surveillance or Comm-B reply containing the D bit set to 1, and DC set to N-1. The interrogator is fully initialized as soon as it receives this information.

2.1.5.2.2 Transmission. The interrogator requests the air-to-ground transmission of ELM segments using a single Comm-C transmission with RC=11. In this format, the NC field contains all zeros and the first 16 bits of MC form a special 16-bit Segment Request (SR) field, in which the successive bit positions correspond to segment numbers 0 through 15. (The remaining 64 bits of MC are spares and shall be transmitted as zeros). The designated response is a series of Comm-D replies with K=0 containing those message segments for which the corresponding SR bit is set to one. (The transponder thus is not told which segments have been successfully received, but those which are to be transmitted.) The successive Comm-D replies of the response are transmitted with a nominal spacing of 136 μsec between preambles (16 μsec between the end of a reply and the succeeding preamble). After the complete response to the Comm-C interrogation has been received, another Comm-C interrogation with RC=11, NC=0000 and an updated SR field is transmitted to request segments not yet received (either because they were not requested in the first response, or because they were received in error). The transponder replies again with the requested segments. The cycle is repeated until all segments have been received.

> Note: As with uplink ELM's, this process may take place within a scan or over several scans. Although the precise spacing of segments in the response is known to the interrogator, each segment is transmitted as a full Comm-D reply with a preamble to resynchronize the reply decoder in case the preceding segment is lost.

2.1.5.2.3 Termination. The transaction is terminated by a special Comm-C interrogation with RC=11, NC=0010, and bit 9=1. This interrogation resets the D-bit and DC field. It also elicits a single Comm-D reply (with arbitrary contents in the MD field) which serves as a technical acknowledgement to the interrogator.

> Note: The ground processor, which has control of message traffic, services ground-to-air messages in the order received except when a user-supplied priority tag indicates otherwise. The existence of a small number of priority message classes permits, for example, an urgent command to move ahead of other waiting messages. For air-to-ground messages, the possible priority classes are more limited, since there is less advance knowledge of the message parameters. However, ELM transfers are generally regarded as having lower priority than Comm-A or Comm-B messages. Delivery of a ground-to-air ELM can be interrupted at any time to permit the delivery of an urgent Comm-A message, and then resumed. Similarly, a Comm-B message can interrupt an air-to-ground ELM. Message numbering (as opposed to segment numbering) is not required for this protocol; if desired by the user, message IDs may be coded within the message text.

2.2 Transponder Performance and Technical Characteristics.

2.2.1 Configuration and Interfaces of Airborne Equipment.

2.2.1.1 Transponder. The transponder shall have the following minimum capability:

ATCRBS: Modes A, C
DABS: ATCRBS/DABS All-Call (2.1.1.3)
DABS-Only All-Call (2.1.3.2.1)
Surveillance interrogations and replies (2.1.3.2.2 and 2.1.3.3.2)
Comm-A and DABS Broadcast interrogations (2.1.3.2.3 and 2.1.3.2.7)
Squitter and Special Surveillance replies (2.1.3.3.1.2 and 2.1.3.3.3)

The transponder may have any or all of the following optional capabilities:

Comm-B replies (2.1.3.3.4)
Comm-C and Comm-D interrogations and replies (ELM capability) (2.1.5)
Synchronized Surveillance interrogations and replies (2.1.3.2.5 and 2.1.3.3.6)
Comm-S and Comm-T interrogations and replies (2.1.3.2.6 and 2.1.3.3.7)
Antenna Diversity (3.2)

If the transponder has ELM capability, it must also have Comm-B capability.

2.2.1.2 Interfaces and Displays. The transponder shall be provided with a Standard Message (SM) interface capable of transferring to appropriate displays the contents (exclusive of the Address/Parity field) of DABS Surveillance and Comm-A interrogations, and of reading in the contents of DABS Surveillance replies. Detailed technical characteristics of this interface are specified in 2.2.10. As an option, the transponder may have the additional capability of reading in the contents of DABS Comm-B (downlink) transmissions via the SM interface. As another option, the transponder may have the additional capability of transferring out and reading in the message contents of DABS extended-length uplink (Comm-C) and downlink (Comm-D) transmissions, respectively.

2.2.2 Reply Conditions.

2.2.2.1 ATCRBS. The transponder shall reply to standard ATCRBS Mode A and Mode C interrogations under the conditions prescribed in FAA Order 1010.51A, except when inhibited from replying by an ATCRBS lockout condition or during recovery following a DABS reply. The transponder shall not reply to ATCRBS interrogations when subject to the conditions prescribed in FAA Selection Order 1010.51A, for no reply.

2.2.2.2 ATCRBS/DABS All-Call. The transponder shall reply to an ATCRBS/DABS Mode A or Mode C All-Call interrogation, except when inhibited from replying by a lockout condition or during recovery following a DABS or ATCRBS reply. The transponder shall not reply (with either an All-Call, an ATCRBS, or a DABS reply) in response to an ATCRBS/DABS All-Call interrogation when the interrogation contains a P_2 pulse which satisfies the requirements for ATCRBS suppression, or when inhibited by an ATCRBS/DABS All-Call lockout condition. The transponder shall not produce a DABS All-Call reply in response to a CW transmission or a single pulse of long duration whose received amplitude variations do not approximate an All-Call interrogation. The transponder shall not produce a DABS All-Call reply in response to a P_1-P_3 pair alone. To elicit an All-Call reply, the P_1-P_3 transmission must be followed by a distinct P_4 pulse. In particular, there shall be no All-Call reply to a transmission containing a "filled-in" P_3-P_4 pulse, i.e., a long P_3 pulse. There also shall be no reply to a P_1-P_3-P_4 transmission in which the duration of P_4 is 1.5 μsec or more, or in which the P_4 pulse is displaced from its assigned position by more than 0.1 μsec.

> Note: The intent of this restriction on replies to wide P_4 pulses is to prevent DABS transponders from replying to special ATCRBS interrogations which include a 1.6-μsec P_4 pulse following P_3. Specifically, when all conditions for reply are satisfied, a) there shall be an All-Call reply if the duration of P_4 (designated W_4) is within the limits specified in 2.1.1.3, i.e., $0.7 \leq W_4 \leq 0.9$ μsec.; b) there may be an All-Call reply or no reply if $0.9 < W_4 < 1.5$ μsec.; and c) there shall be no reply of any type if $W_4 \geq 1.5$ μsec.

2.2.2.2.1 Suppression. Suppression as described in FAA Selection Order 1010.51A paragraph 2.7.4 shall apply to the responses to ATCRBS/DABS All-Calls.

2.2.2.3 DABS. The transponder shall reply (with probability specified in 2.2.2.4) to valid DABS-Only All-Call, Surveillance, Comm-A or (if so equipped) Comm-C interrogations, which are correctly addressed and within specified limits of received signal amplitude, except when the transponder is in a recovery state from a prior DABS or ATCRBS reply. The transponder shall not reply to a DABS interrogation whenever any one or combination of the following conditions occur:

a. The decoded bits corresponding to the Address/Parity field contain other than the transponder's unique discrete address, or - in the case of a DABS-Only All-Call - if the decoded parity field contains other than an all-zero sequence.

b. A lockout condition inhibits recognition of interrogations from auxiliary DABS sensors.

c. An all-zero address in a Surveillance or Comm-A interrogation indicates that the interrogation is a DABS Broadcast transmission (for which no reply is requested).

d. A DABS sidelobe-suppression (SLS) condition inhibits replies.

e. The interrogation requests a Comm-D reply which the transponder is not equipped to transmit.

The transponder shall not reply to a CW transmission or single pulse of long duration whose received amplitude variations do not approximate a DABS mode interrogation. The transponder shall reply with a standard Surveillance reply if the interrogation requests a Comm-B reply which the transponder is not equipped to transmit.

2.2.2.4 DABS Sensitivity and Dynamic Range. For any given interrogation conditions, the minimum triggering level, or MTL, is defined as the minimum input power level for at least 90 per cent reply ratio. When referred to the transponder RF port(s), the nominal value of MTL shall be -77 dBm, with a tolerance range of ±3 dB for any combination of the following conditions:

Modes - DABS Surveillance, DABS-Only All-Call, DABS Comm-A, DABS Comm-C (if so equipped).

Interference - none.

SLS - P_5 pulse absent.

RF port - either (if diversity equipped).

Other - any interrogation condition satisfying these specifications.

Under these conditions, the reply ratio shall be at least 90 percent for any input power level between MTL and -24 dBm, shall be at least 99 percent for any input power level between (MTL +3 dB) and -27 dBm, and shall not exceed 10 percent for any input power level less than -83 dBm, referred to the transponder RF port(s).

Note: This DABS transponder standard allows for cabling and other installation loss between antenna and transponder. The nominal value of the installation loss is 3 dB. If a particular installation requires excessive cable length, then an attempt should be made to employ low loss cable to prevent the loss from significantly exceeding 3 dB.

2.2.2.5 DABS SLS. The transponder shall not reply to DABS uplink transmissions in which a sync phase reversal is not detected in the assigned interval. When the received P_5 pulse power is 6 dB or more below that of the data block, and for any other interrogation conditions according to 2.2.2.4, the reply ratio shall be at least 90 percent for any interrogation power between -74 dBm and -24 dB referred to the transponder RF port(s).

2.2.2.6 Interference Rejection.

2.2.2.6.1 Presence of Standard Interfering Pulse. For all received signal levels between -71 dBm and -24 dBm (measured at the transponder RF port(s)), and when all other reply conditions are satisfied, the transponder shall reply to at least 95 percent of all DABS uplink transmissions in the presence of a standard interfering pulse (defined as a single 0.8-μsec wide pulse with carrier frequency of 1030 MHz ± 0.2 MHz, incoherent with the DABS signal carrier frequency and overlapping any part of the DABS transmission, except that its leading edge shall occur no earlier than 0.5 μsec following the sync phase reversal), with signal-to-interference ratio (defined as the ratio of the peak amplitude of the DABS signal to the peak amplitude of the interfering pulse) of 6 dB or more. Also, the transponder shall reply to at least 50 percent of the DABS uplink transmissions when the signal-to-interference ratio is 3 dB or more.

2.2.2.6.2 Pulse Pair Interference. For all received signal levels between -71 dBm and -24 dBm (measured at the transponder RF port(s)), and when all other reply conditions are satisfied, the transponder shall reply to at least 90 percent of all DABS uplink transmissions in the presence of an interfering P_1-P_2 pulse pair with a carrier frequency of 1030 ± 0.2 MHz, incoherent with the DABS signal carrier frequency and overlapping any part of the DABS transmission (except that the leading edge of the P_1 interference pulse shall occur no earlier than the leading edge of the P_1 pulse of the DABS signal), and with a signal-to-interference ratio of 9 dB or more.

2.2.2.6.3 Low Level Asynchronous Interference. For all received signal levels between -68.0 dBm and -30.0 dBm (measured at the transponder RF port(s)) and when all other reply conditions are satisfied, the transponder shall reply correctly with at least 95 percent probability to DABS uplink transmissions in the presence of asynchronous interference consisting of single 0.8-μsec wide RF pulses with carrier frequency of 1030 MHz ± 0.2 MHz generated at all repetition rates up to 10,000 Hz when the signal-to-interference ratio is 12 dB or more. Under these same conditions, except that the interference consists of P_1 - P_2 ATCRBS suppression pulse pairs (where the amplitude of P_2 equals the amplitude of P_1) generated at all repetition rates up to 10,000 Hz, the DABS reply probability shall exceed 99 percent. When, under these same conditions, the transponder is locked out to ATCRBS and ATCRBS/DABS All-Call interrogations, the DABS reply probability shall exceed 99 percent in the presence of either single pulses or suppression pulse pairs.

2.2.2.7 Dead Time. After replying to an ATCRBS or DABS interrogation, the transponder shall be capable of replying to a following ATCRBS or DABS interrogation whose P_1 pulse is received at any signal level above MTL at least 125 μsec following the transmission of the last pulse of the reply, provided the transmitter duty cycle limits of 2.2.5.2 are not violated.

> Note: It is recommended that the dead time be as low as possible to maximize the transponder round reliability.

2.2.2.8 Random Triggering Rate.

2.2.2.8.1 Unwanted DABS Replies. With the transponder adjusted to comply with the provisions of 2.2.2.4, and in the absence of a valid interrogation, and when subject to the test conditions for audio frequency magnetic field susceptibility associated with the applicable RTCA DO-160 environmental categories of the transponder, the random triggering rate of unwanted DABS replies shall not be greater than one reply per five seconds averaged over a period of at least 30 seconds, and the random triggering rate of false data transfers over the Standard Message interface (see 2.2.10) shall not exceed one per hour.

2.2.2.8.2 Squitter Rate. When Squitter transmissions are not locked out, the interval between successive Squitters shall be random with a nominal mean value of one second and a standard deviation of 0.1 to 0.2 second. Squitter transmissions shall be capable of being inhibited via the Squitter Inhibit interface (see 2.2.8.4). Squitters shall be inhibited following the decoding of an ATCRBS, an All-Call, or a correctly-addressed DABS interrogation until the completion of the corresponding reply. Squitter transmissions may be suppressed during transponder suppression intervals controlled by other avionics equipment in the aircraft. Squitter transmissions shall not be suppressed during ATCRBS sidelobe suppression intervals.

2.2.3 Lockout Control. Replies to ATCRBS interrogations, replies to ATCRBS/DABS All-Call interrogations, and Squitters and replies to auxiliary discrete-address interrogations shall be independently locked out (i.e., the transponder shall be insensitive to such interrogations) upon receipt of an interrogation with the appropriate code bits set, as described in 2.1.3.4.3. Each lockout shall be cleared or unlocked independently of the others as determined by the time elapsed since that lockout was last initiated (or reinitiated).

2.2.3.1 ATCRBS Lockout Time-out Duration. The duration T_{AL} of the ATCRBS lockout time-out shall be 16 ± 2 seconds.

2.2.3.2 DABS Lockout Time-out Duration. The duration T_{DL} of the DABS lockout time-out shall be 16 ± 2 seconds.

2.2.3.3 Squitter Lockout Time-out Duration. The duration T_{SL} of the Squitter lockout time-out shall be 16 ± 2 seconds.

2.2.4 Recovery Times.

2.2.4.1 ATCRBS. All transponder recovery times related to ATCRBS interrogations and replies shall be as prescribed in FAA Selection Order 1010.51A.

2.2.4.2 DABS.

2.2.4.2.1 Receiver Desensitization. Upon receipt of any pulse of more than 0.7 μsec duration, the transponder receiver shall be desensitized in accordance with the provisions of FAA Selection Order 1010.51A, paragraph 2.7.7.1.

2.2.4.2.2 Recovery from a DABS Interrogation. Following receipt of a DABS interrogation in which either the sync phase reversal is not detected (SLS condition) or the address is not correct, or the data block is decoded, but there is no reply for one of the reasons specified in 2.2.2.3, the transponder shall recover sensitivity after the end of the DABS interrogation at the rate prescribed for recovery times in FAA Selection Order 1010.51A, paragraph 2.7.7.2.

2.2.4.2.3 Recovery from a Single Pulse. In the event that a P_2 pulse is not received following a single pulse meeting the specifications for a DABS P_1 pulse, the transponder shall recover sensitivity at the rate prescribed for recovery times in FAA Selection Order 1010.51A, paragraph 2.7.7.2.

2.2.4.2.4 Recovery from an ATCRBS Suppression Pair. When ATCRBS is not locked out, ATCRBS suppression shall be in effect following the receipt of a P_1-P_2 suppression pair. The transponder shall not generate ATCRBS replies or suppressions in response to interrogations for which P_1 is received during an ATCRBS suppression interval. If a DABS data block is not received following a P_1-P_2 pair, the transponder receiver may be desensitized in accordance with 2.2.4.2.1 and shall recover sensitivity at the rate prescribed for recovery times in FAA Order 1010.51A, paragraph 2.7.7.2. ATCRBS suppression pairs shall not otherwise interfere with the reception of DABS interrogations regardless of the ATCRBS lockout state of the transponder.

2.2.4.2.5 Recovery From a Broadcast Transmission. After receipt of a broadcast transmission (2.1.3.2.5) the transponder shall recover sensitivity 128 μsec after receipt of the sync phase reversal at the rate prescribed for recovery times in FAA Selection order 1010.51A, paragraph 2.7.7.2.

2.2.5 Reply Rate Limiting.

2.2.5.1 ATCRBS Replies. ATCRBS reply rate limiting shall operate in accordance with the provisions of paragraphs 2.7.10.1 and 2.7.10.3 of FAA Selection Order 1010.51A.

2.2.5.2 DABS Replies. DABS All-Call and discrete replies may be included along with ATCRBS replies as part of the total reply count used to determine the receiver sensitivity for ATCRBS reply rate limiting specified in 2.2.5.1. It is permissible for the sensitivity to DABS All-Call and discrete address transmissions to be reduced when ATCRBS reply rate limiting is in effect. If the ATCRBS reply rate limit is not exceeded and the provisions of 2.2.2.7 and 2.2.4.1 are not violated, the transponder shall be capable of replying to all combinations of ATCRBS and DABS uplink transmissions for which the resulting transmitter duty cycle is no greater than 2.0 per cent, averaged over a 10-ms period. (If the transponder includes optional ELM capability, the duty cycle requirements are increased as indicated in 2.2.6.4.)

2.2.5.3 Squitters. Squitters may be included as part of the total reply count used for ATCRBS reply rate limiting. The Squitter rate shall not be affected by reply rate limiting.

2.2.6 RF Characteristics.

2.2.6.1 Power Output. The transponder power output, measured at the transponder RF port(s), shall be 27 $\pm$ 3 dBW for all pulses of all required replies for any load impedance at the RF port(s) with a VSWR of 1.3:1 or less.

Note: This standard allows for cabling and other installation loss between transponder and antenna. The nominal value of the installation loss is 3 dB. If a particular installation requires excessive cable length, then an attempt should be made to employ low loss cable to prevent the loss from significantly exceeding 3 dB.

2.2.6.2 Frequency. The frequency of all reply transmissions shall be 1090 $\pm$ 3 MHz for any load impedance at the RF port(s) with a VSWR of 1.3:1 or less.

Note: Care must be exercised when installing the antenna(s) and antenna cabling in the aircraft so that the voltage standing wave ratio (VSWR) as seen by the transponder RF port(s) is minimized. DABS sensors rely on monopulse angle processing to determine the off-boresight angle of each target (both DABS and ATCRBS). The accuracy of the monopulse processor may be degraded if the carrier frequency of the transponder reply falls outside the specified frequency band. The carrier frequency of the transponder transmitter may be pulled out of the allowed frequency band if the VSWR at the RF port exceeds 1.3:1.

2.2.6.3 DABS Peak Reply Rate. At least once every four seconds, the transponder shall be capable of transmitting six short (56-bit), or, if equipped with the capability to generate them, three long (112-bit) DABS replies in each of five consecutive ten-millisecond intervals.

2.2.6.4 Extended Length Message (ELM) Transmissions. Within a single 30-msec period, corresponding to a typical interrogator antenna dwell time, a transponder with optional ELM capability shall be capable of transmitting a minimum of forty Comm-D (112-bit) replies, arbitrarily spaced in the 30-msec period, except that no more than twenty replies shall be required within any 4-msec subperiod.

2.2.7 Controls and Indicators.

2.2.7.1 Controls Required. Means shall be provided for manual control of the following functions in the cockpit:

a. Selection of the 4096 ATCRBS codes.

b. Setting the FR bit in DABS replies.

2.2.7.2 Indicators/Displays Required. Means shall be provided for indicating the following in the cockpit:

a. That the transponder has replied to a Surveillance, Comm-A, or Comm-C interrogation from a standard DABS sensor (IT=1) within the last 16 seconds.

Note: This DABS contact indicator shall be activated (or reactivated) upon replying to a properly addressed DABS interrogation, and shall remain activated for 16 seconds following the interrogation. It shall not be activated upon receipt of an All-Call interrogation or an interrogation from an auxiliary DABS sensor.

b. The contents of the AE field.

Note: This display shall be activated upon receipt of a properly-addressed DABS interrogation containing an AE code. The display shall be updated by each succeeding valid DABS interrogation containing an AE code. The AE control and coding algorithms shall be as specified in 2.1.3.4.3.12. Decoding and display for altitudes above aircraft ceiling are not mandatory. The display shall be blanked upon loss of DABS contact (see above) or upon receipt of binary code 1111 in bit positions 21 through 24.

2.2.8 Code Interfaces.

2.2.8.1 Address Code. A means shall be provided for semi-permanent setting of the address code without opening the transponder case.

Note: The use of a plug-in connector configured with 24 jumper wires, the removal of any of which sets the corresponding bit in the address, represents one acceptable implementation. It is preferable that the means for setting the address code be associated with the installation mounting configuration, so that a change of transponder will not require further action to reset the address code.

2.2.8.1.1 Acquisition Address Code. A means shall be provided for semipermanent setting of the variable acquisition address code (2.1.3.2.1.2) without opening the transponder case.

2.2.8.2 Pressure-Altitude Code. A means shall be provided for entering the 12-bit pressure-altitude code (specified in FAA Selection Order 1010.51A) into the transponder for inclusion in ATCRBS and DABS replies.

2.2.8.3 Maximum Airspeed Code. A means shall be provided for semi-permanent setting of the maximum airspeed code without opening the transponder case.

Note: It is preferable that the means for setting the code be associated with the installation mounting configuration, so that a change of transponder will not require further action to reset the code.

2.2.8.4 Squitter Inhibit. A means shall be provided for accepting an external signal to inhibit Squitter transmissions.

2.2.9 Unavailable Data. If a reply is transmitted containing one or more data fields for which there is no available data input device, or for which there is an input device with no data to transmit, the transmitted data field(s) shall consist of all zeros.

2.2.10 Standard Message (SM) Interface. The SM interface shall provide a "party line" type serial connection to and from data input and output devices which may be attached to the transponder. Several devices can be connected in this manner to the same I/O bus. After a DABS uplink transmission has been received and verified, all data except the Address/Parity field of the transmission shall be shifted out from the SM interface to peripheral devices. This process shall be completed before the transponder downlink transmission begins. At the time of the downlink transmission, data, if available, shall be shifted in on the data line for direct insertion into that transmission. Two lines shall be used to accomplish these data shifts; the data line, operating serially in either direction and the clock line, which provides the necessary timing. Activity on the SM interface shall occur only during the interrogation-reply cycle of the transponder. It shall begin when the first clock pulse appears on the clock line and terminate after the last clock pulse has been sent out by the transponder.

Note: The DABS system includes bidirectional data link capability. All data sent to and from the transponder fall into two classes:

1. Data which have direct influence on subsequent and immediate transponder reaction.

2. Data which pass through the transponder in either direction without affecting the interrogation-reply protocol.

Both classes of data shall appear at the terminals of the Standard Message (SM) interface. I/O devices connected to this interface can extract and/or supply information as needed. Although the SM interface specified in this section is capable of handling only DABS data formats, the interface can be configured optionally to handle ATCRBS formats as well. Most ATC-related messages can be accommodated by the SM interface; however, an additional Extended-Length-Message (ELM) interface option, designed to permit efficient handling of longer messages, may be used in more sophisticated airborne installations.

2.2.10.1 Data Line. The data line shall be a differential data transmission medium. Line levels and impedances shall be equivalent to those generated by a differential tri-state line driver. The line shall operate in three states: HIGH, LOW and OFF, to permit control by either the transponder or the I/O devices. A high, or more positive voltage on the "true" wire and a low, or less positive voltage on the "complement" wire shall be interpreted as a logical "one" or HIGH state. A low, or less positive voltage on the "true" wire and a high, or more positive voltage on the "complement" wire shall be interpreted as a logical "zero" or LOW state. In the high impedance or OFF state, both wires shall be terminated in high impedances, allowing other devices to control the line. The transponder shall bias the line so that when all the line drivers connected to the line are in the OFF state, all line receivers detect a LOW condition.

2.2.10.2 Clock Line. The clock line shall be a differential line carrying the timing pulses for reference in data transmission. Line levels and impedances shall be identical to those of the data line except that the OFF state is not used. The signal on the clock line shall consist of a Qualifier (Q) pulse followed by a series of strobe pulses occurring at the downlink transmission rate appropriate to the reply transmission. The Q pulse generated on receipt of a DABS interrogation shall be identical to the following strobe pulses, except that no data bit is coincident with it.

> Note: For optional ATCRBS SM implementation the Q pulses can have longer duration as described in Section 3.

2.2.10.3 Strobing. The strobe pulses shall be symmetrical, i.e., the pulses shall have equal on and off times. Data on the data line shall be positioned in such a manner that the trailing edge of each strobe pulse occurs at the center of a data chip. (A chip is the time interval in which the value of the bit occurs on the data line.)

2.2.10.4 Interface Initiation. Action at the SM interface shall be initiated with the beginning of the first pulse on the clock line. The first clock pulse shall start 34 μsec after the sync phase reversal or the leading edge of P_4 if the transponder has recognized a valid DABS interrogation for which a reply is required. The SM interface shall not be initiated by a Comm-C interrogation.

2.2.10.5 Time and Level Assignments. When the interface is not active, the clock line shall be held LOW and the data line shall be left in the OFF state.

2.2.10.6 DABS Transactions. After receipt and verification of a DABS interrogation, the data content of the interrogation shall be shifted out from the SM interface to the peripheral devices. At the time of the downlink transmission, data shall be shifted in on the data line two clock periods before actual transmission to permit proper timing in the transponder. The timing diagram of Fig. 2.2.10-1 and the event timing of Table 2.2.10-1 shall apply.

2.2.10.7 Timing Convention.

> Note: For DABS transactions, events in the transponder are referred to the time of the sync phase reversal in the DABS data block. All events on the SM interface are referred to the beginning of the first strobe pulse on the clock line. As illustrated in Fig. 2.2.10-2, t_n is defined as the instant at which the nth strobe upstroke occurs after the beginning of the clock cycle. The time at the beginning upstroke is t_o. The data are strobed at the downstroke of each strobe pulse on the clock line.

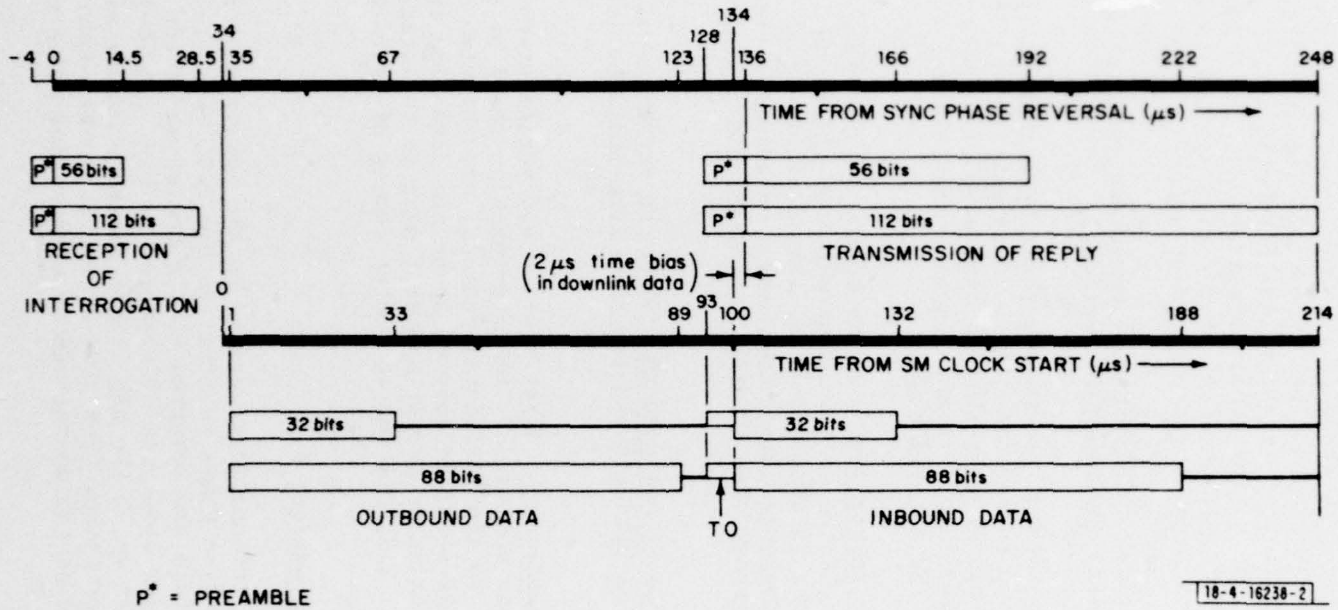


Fig. 2.2.10-1. SM Interface Timing Diagram for DABS Transactions.

Table 2.2.10-1. Relationship Between Uplink/Downlink Timing and SM Interface Timing.

Event	Time From Sync Phase Reversal (μsec)	Time From Clock Start (μsec)
Start, uplink preamble	-4	-
Sync phase reversal or P_4 upstroke	0	-
End, 56-bit uplink	14.5	-
End, 112-bit uplink	28.5	-
Start, SM clock	34	0
Start, SM data or All-Call artificial data out	35	1
End, 32-bit data out	67	33
End, 88-bit data or All-Call artificial data out	123	89
Start, TO signal	127	93
Start, downlink preamble	128	94
Start, SM data in	134	100
Start, downlink data	136	102
End, 32-bit data in	166	132
End, 56-bit downlink	192	158
End, 88-bit data in	222	188
End, 112-bit downlink	248	214
Stop, SM clock	248	214

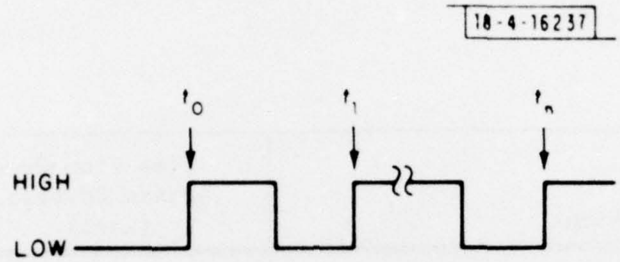


Fig. 2.2.10-2. Clock Line Waveform for DABS Transactions.

2.2.10.8 Uplink Data Transfer. In the SM clock time interval between t_0 and t_1, the data line shall remain off. Beginning at t_1, the complete information content of the uplink transmission, starting with bit 1 and ending with the last bit before the Address/Parity field, shall be impressed on the data line. The data line shall remain in the state (HIGH or LOW) of the first uplink information bit from t_1 to t_2 and then shall assume the state of the next bit in the time between t_2 and t_3, etc. The data shall be strobed at the midpoint of each data chip. For an ATCRBS/DABS All-Call interrogation, the transponder shall maintain the data line at a high level between t_1 and t_2 and at a low level between t_2 and t_{89}, thereby simulating a DABS-Only All-Call interrogation. For a Comm-A interrogation, the data transfer shall terminate at t_{89}. If a Surveillance interrogation is received, meaningful data end at t_{33}; in this case, the transponder shall generate an OFF state signal on the data line between t_{33} and t_{89}.

2.2.10.9 Downlink Data Transfer. Beginning at t_{89}, the transponder shall relinquish control of the data line by setting the line into its OFF state. At t_{94}, the transponder begins the downlink transmission. Downlink data transfer on the wirelink shall begin at t_{100}. Data bits, if available, shall be transferred to the transponder 2 μsec before they are to be transmitted to provide margin for proper synchronization. The transponder shall assemble the downlink data stream from the data generated internally and from information supplied by the data line. The transponder shall accept downlink bit values for all bits which are not generated internally, including those bits designated as spares in the DABS reply formats. When no interface device is active, these spare bits shall be transmitted as zeros.

> Note: Each input device contributes only the bit or bits which it is designed to handle by holding the data line either HIGH or LOW during the assigned time slot, and leaving the data line OFF at all other times. The I/O devices are addressed by uplink content or interrogation protocol so that only one device can occupy the data channel at a time during the transmission of a Comm-B message.

2.2.10.10 Automatic Capability Reporting. Upon receipt of an All-Call interrogation, each active peripheral device will report its presence by injecting the appropriate code bits into the downlink transmission. A valid All-Call can be received either as an ATCRBS/DABS or as a DABS-Only interrogation. The SM interface shall transfer an uplink data block, either artifically generated as described in 2.2.10.8, or as actually received and shifted out as described in Table 2.2.10-1 and Fig. 2.2.10-1. (The first two bits (F and L) of this data block will be 10; the pattern is unique for All-Call.)

> Note: All I/O devices will recognize this pattern and any given I/O device will indicate its presence by holding the data line HIGH at its assigned time slot between t_{102} and t_{108}. Of the six available slots, five will be assigned to the most used I/O devices. All other I/O devices will set the sixth bit (bit 8 of the All-Call reply), their identity then will be reported via Comm-B upon specific interrogation as described in Section 3. A disconnected or malfunctioning peripheral device will not report its presence and I/O device installation changes can be made without disturbing the transponder.

2.2.10.11 TO: The Reply Take Over Signal. If the transponder detects a HIGH on the data line from t_{93} to t_{100}, it shall assemble the downlink transmission entirely from the data presented on the data line beginning at t_{100}.

> Note: The TO signal is generated by I/O devices. This mechanism provides a flexible growth capability for generating DABS reply patterns which are not currently programmed into the internal circuitry of the transponder. On receipt of any interrogation pattern which contains the correct address, a transponder will always reply unless the interrogation is of the Comm-C type. Special interrogation patterns to be implemented later, may require special reply formats. Retrofit of an I/O device which recognizes the special pattern will result in the "take over". The new desired reply type will be sent instead of the standard reply. It is understood that the new reply type will be uniquely identified.

2.2.10.12 Tolerances. A summary of tolerances for the serial SM interface is given in Table 2.2.10-2.

Table 2.2.10-2. SM Interface Tolerances for DABS Functions.

Reference	Item	Tolerance
Fig. 2.2.10-1	SM Clock Start	$\pm$ 0.15 μsec
	Strobe Pulse Clock Rate	Derived from downlink clock of transponder.
	Clock/Data Skew	$\pm$ 0.15 μsec
	TO Signal Start	$\pm$ 0.15 μsec

3. GUIDANCE MATERIAL RELATED TO THE DISCRETE ADDRESS BEACON SYSTEM

3.1 Optional Addition to the SM Interface Operation. The SM interface can be operated in such a manner that the transponder becomes transparent to ATCRBS signals. It is then possible to consider the SM interface clock and data lines as a universal I/O bus which can handle the 4096 code and altitude digitizer data in serial form.

3.1.1 ATCRBS Transactions. Upon receipt of a valid ATCRBS interrogation, the transponder will generate a Q pulse on the clock line. The Q pulse is followed by 17 strobe pulses generated at the pulse rate of the downlink transmission. These strobe pulses are used to clock the ATCRBS reply code into the transponder via the data line. To permit proper timing within the transponder, the data at the interface occur one strobe period before downlink transmission. For ATCRBS/DABS All-Call transactions, which involve an ATCRBS-like interrogation and a DABS reply, the 6-μsec Q pulse is followed at time P_4 + 34 μsec by a 0.5-μsec DABS Q pulse and 213 strobe pulses which shift out data into the SM interface as if a DABS uplink were received. The outbound data are generated internally by the transponder to simulate a DABS-only All-Call interrogation. The formats of these pulse trains are specified in Table 3.1-1 and illustrated in Fig. 3.1-1. It should be noted that for Mode C operation, the trailing edge of the Q pulse coincides with the leading edge of the first strobe pulse.

3.1.2 Tolerances. A summary of tolerances for the ATCRBS functions of the SM interface is given in Table 3.1-2.

3.2 Diversity Operation. A transponder with optional diversity capability shall have two RF ports, permitting two separately-located antennas to be simultaneously connected to the transponder.

3.2.1 Diversity Antenna Switching. Selection of the antenna shall be automatic. The transponder shall select one of the two antennas on the basis of the relative strengths of the detected interrogation signals, provided both channels simultaneously receive a valid interrogation or pulse pair. Antenna selection and switching may occur after the receipt of: a. The P_3 pulse of a P_1-P_3 pulse pair, indicating an ATCRBS or ATCRBS/DABS All-Call interrogation, or b. the P_2 pulse of a P_1-P_2 pulse pair, indicating a possible DABS preamble, or c. A complete, error-free DABS interrogation.

The selected antenna shall be used for transmission of the DABS or ATCRBS reply and (if necessary) for reception of the remainder of the interrogation.

3.2.2 Switching Threshold. The transponder shall nominally select the antenna connected to the RF port having the stronger P_1 signal. To allow for for unbalance in the characteristics of the two channels, a transition zone is permitted, as indicated in Fig. 3.2-1, in which either antenna may be selected. For example, if the received power at the RF port having the larger P_1 signal is -60 dBm or less, the RF port having the larger signal shall be selected if the larger signal exceeds the smaller by 3 dB or more.

Table 3.1-1 SM Interface Timing

Interrogation Type	Q Clock Pulse		Strobe Clock Pulses				Data Outbound		Data Inbound		Last Bit
	Start	End (μsec)	Qty	Duration (μsec)	Spacing (μsec)	Start (μsec)	Start	End	Start	First Bit	
ATCRBS A	P_3	$P_3 + 2$	17	0.725	1.45	$P_3 + 3$	None	-	$P_3 + 3$	C_1*	SPI
ATCRBS C	P_3	$P_3 + 3$	17	0.725	1.45	$P_3 + 3$	None	-	$P_3 + 3$	C_1*	D_4
ATCRBS/DABS All-Call	P_3	$P_3 + 6$	214	0.5	1.0	$t_0 = P_4 + 34$	t_1†	t_{89}	t_{100}	F	No. 32
Discrete DABS	-	-	214	0.5	1.0	$t_0 = \emptyset + 34$††	t_1	t_{33} or t_{89}	t_{100}	F	No. 32 or No. 88

*F_1 and F_2 bracket reply pulses are generated by the transponder and do not appear at the interface.

†The transponder maintains the data line HIGH between t_1 and t_2, LOW between t_2 and t_5 and HIGH from t_5 to t_{89}.

††$\emptyset$ is the time of the sync phase reversal in a DABS uplink data block.

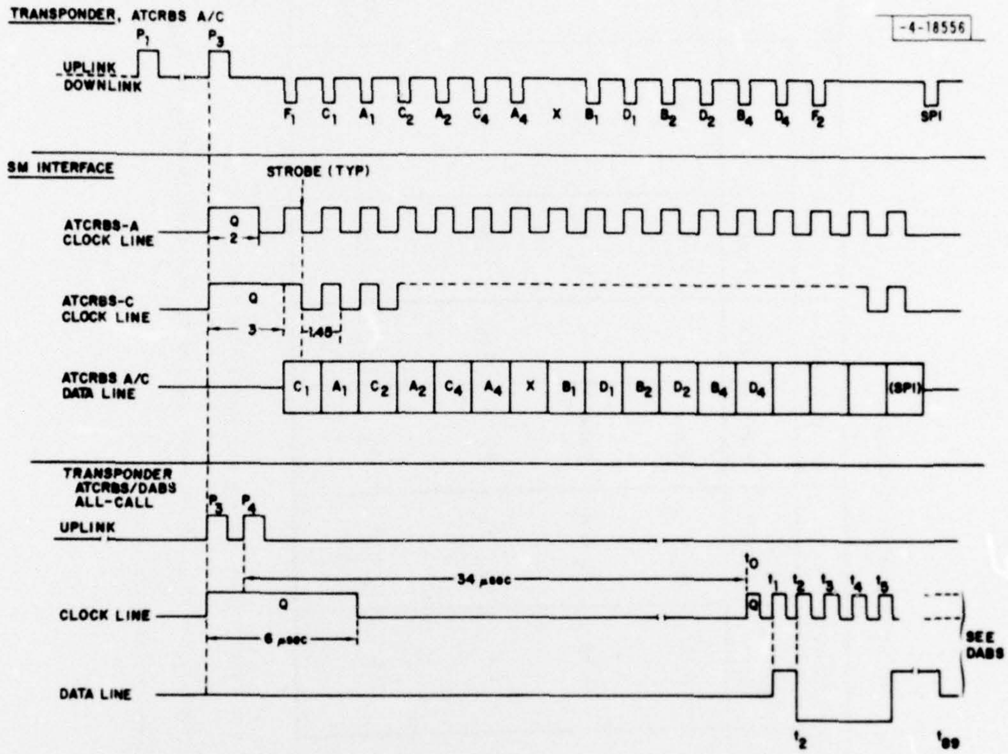


Fig. 3.1-1. SM Interface Timing Diagram for ATCRBS Type Transactions.

Table 3.1-2. SM Interface Tolerances for ATCRBS Functions.

Reference	Item	Tolerance
Table 3.1-1	Clock Q pulse	
	Start	+ 0.15, -0 μsec.
	End, ATCRBS A	± 0.1 μsec.
	End, ATCRBS C	Identical to upstroke of first strobe pulse.
	Strobe Pulse Clock Rate	Identical to downlink clock of transponder.
	Clock/Data Skew	± 0.15 μsec.
	Clock Q Pulse End, All-Call	+ 3, -1 μsec.
	Simulated Data Block Start	±0.15 μsec.

3.2.3 Received Signal Delay Tolerance. Amplitude comparison shall control the antenna selection only when the times of arrival (at the transponder antennas) of the two received signals differ by less than 0.25 μsec. If one antenna receives a valid pulse pair or interrogation 0.25 μsec or more in advance of the other antenna, the antenna receiving the early signal shall be selected regardless of relative signal strength.

3.2.4 Reply Delay in the Diversity Mode. At any fixed input signal level, the average value of the reply delay when RF port No. 2 is selected and the average value of the reply delay when RF port No. 1 is selected shall differ by no more than 0.1 μs as measured at the transponder RF ports.

3.2.5 Antenna Selection for Squitter Transmissions. Squitter transmissions shall alternate between the two RF ports of the diversity transponder.

3.2.6 Diversity Channel Isolation. The isolation between the two RF transmitter channels shall be such that the power transmitted from the selected RF port exceeds the power transmitted from the port not selected by at least 20 dB.

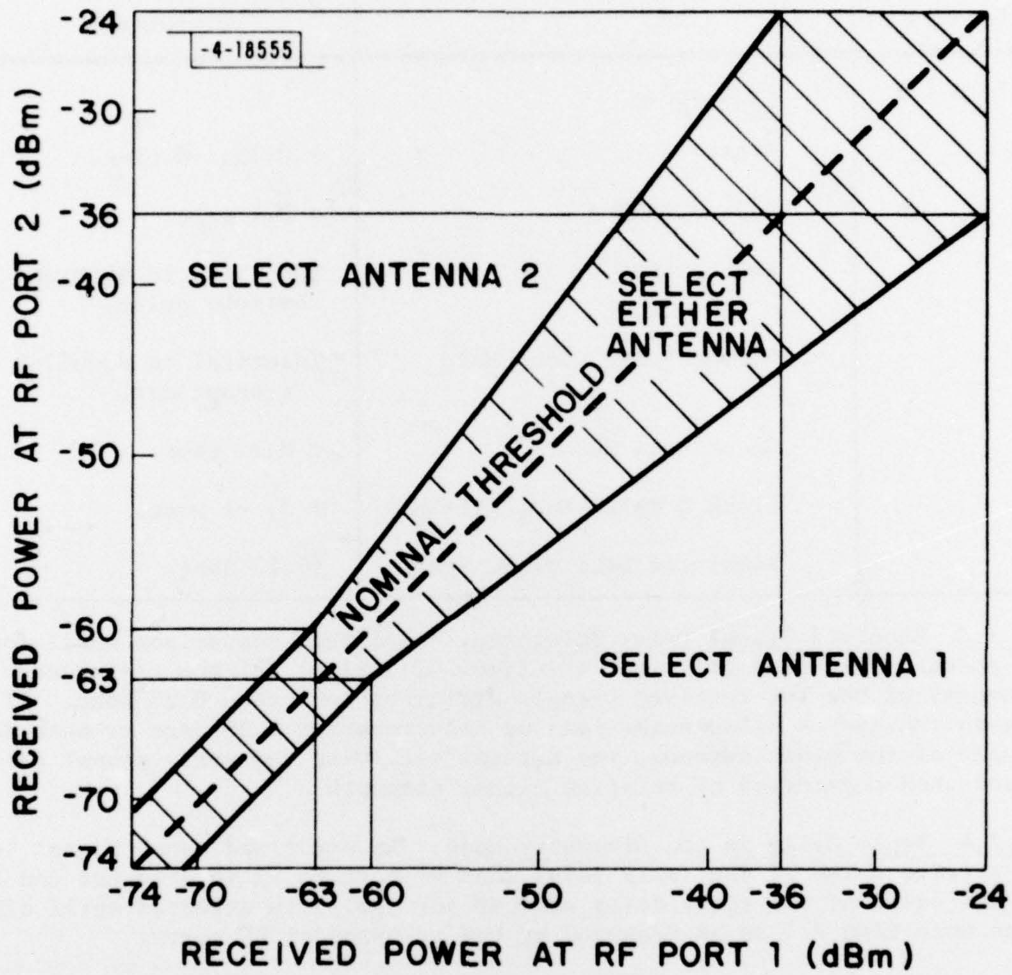


Fig. 3.2-1. Tolerance on Threshold for Selection of Diversity Antennas.

3.3 Altitude Echo.

In each Surveillance and Comm-A interrogation, the Surveillance Data (SD) field normally contains an Altitude Echo (AE), which is the most recently reported value of the aircraft's altitude (adjusted for local barometric pressure by the sensor prior to retransmission to aircraft flying below transition level). The AE display provides the pilot with a complete loop check on the accuracy of this altitude report. The continuous availability of this check is required to enhance reliability in an automated ATC system when automatic altitude reporting is used for separation assurance for VFR aircraft, as there is normally no other link between VFR aircraft and the ground control system to provide periodic accuracy validation of the altitude reports.

3.4 Transponder Self-Test and Monitor.

If self-test and/or monitor devices are installed and used in aircraft to indicate normal or faulty operation, care should be exercised to minimize any interference to the system that may result. The duration of the test mode should be an absolute minimum and limited to that required by the pilot to determine the transponder status. To minimize suppression of replies to ground interrogations, the test signal interrogation rate and level should be the lowest practicable for test.

3.5 Independent Protocols. This section describes the coding and operational use of certain uplink and downlink data which have no direct effect on transponder operation. All of the codes described herein are employed in experimental systems and therefore it is recommended that these codes not be used for other purposes.

3.5.1 Pilot Acknowledgement Protocol. A special procedure is used for pilot acknowledgement of ground-to-air messages. Action is ground initiated by transmission of bit 33 (AR), together with the address of the device (see 3.5.3) associated with the requested acknowledgement, in an uplink Comm-A interrogation. On receipt of this bit, two reply buttons are armed, the armed state being signaled to the pilot by appropriate flashing indicators or an audible signal. This indicates the request for acknowledgement. The pilot's response is expressed by actuating one of the two acknowledgement buttons associated with the addressed device. The button which is selected by the pilot inserts an appropriate message bit into a subsequent downlink transmission, causes the arming indicator associated with the other button to be turned off, and changes the arming indicator associated with the selected button to a steady indication. The acknowledgement message transmitted to the ground is handled in one of two ways. The "principal" I/O device acknowledges via the short Surveillance formats. All other devices require Comm-B reply capability for acknowledgement. For the principal I/O device, bits 14 and 15 of the Surveillance and Comm-B reply formats are used; other I/O devices use the procedure described in 3.5.6.4. On receipt of the pilot's response, the ground closes out the transaction in a subsequent interrogation by transmitting CP (for a PB acknowledgement) or by the standard Comm-B close-out procedure described in 3.5.6.2 (for a Comm-B acknowledgement). Closing out the transaction extinguishes the remaining indicator. As soon as the pilot has acknowledged, the acknowledgement sequence can be reinitiated by the ground without closing out the previous sequence.

3.5.2 Pilot Test Protocol. This is an air-initiated communications sequence intended to test proper operation of certain I/O devices. The pilot is provided with a push button which sets both bits 14 and 15 in Surveillance and Comm-B replies. Upon receipt of this signal, the ground generates an agreed-upon sequence of test patterns for one or more I/O devices. The test sequence is followed by the transmission of bit 33 as described in 3.5.1. The pilot acknowledgement protocol (see 3.5.1) is used to verify proper operation of the data link and I/O devices.

3.5.3 Uplink Message Field (MA). The MA field includes bits 33 through 88 in the Comm-A interrogation format. Bit 33 is used for AR as described in 3.5.1. Bits 34 through 40 are used to address the various I/O devices or multiple functions associated with a given I/O device. All addresses in the following list are assigned to existing experimental functions: 111 0001, 111 0010, 111 0011, 111 0100, 111 0101.

3.5.4 Surveillance Data (SD). The field is formed by bits 17 through 32 in both the Surveillance and Comm-A interrogation formats. Bits 17 through 20 define the device or function which is addressed. For these four bits, the following codes are assigned: 0000, for AE; 1xxx (i.e., all codes beginning with 1), for experimental data functions; and 0010, for air-to-air interrogations.

3.5.5 Reply Length and Message Source (RL, RS). RL, bit 9 in Surveillance and Comm-A interrogations, determines the length of the reply which the transponder must generate. RS (bits 10 through 13) defines the message source which is required to provide the data for the reply. When RL=0, i.e., a short reply is commanded, then RS is also used to modify the meaning of the content of the first 32 bits of the downlink transmission as follows:

RL=0, RS=0000: An Unsynchronized Surveillance reply is requested.

RL=0, RS≠0000: A Special Surveillance reply is requested.

RL=0, RS=0001 or 0010: Reserved for air-to-air interrogations.

The remaining codes can be used for special purposes and in connection with the TO signal described in 2.2.10.11. The use of RS in conjunction with RL=1 is described in 3.5.6.

3.5.6 The Comm-B Protocol. The Comm-B protocol describes the orderly sequences followed in downlink (Comm-B) message transmission. Downlink messages are contained in the MB field, bits 33 through 88 in the Comm-B reply, see Fig. 2.1.3-1. Downlink message transactions can be ground initiated or air initiated.

3.5.6.1 Ground Initiated Comm-B Sequence. Transmitting RL=1 (bit 9) in an interrogation from the ground requires a long reply from the transponder. Together with this RL command, a code is transmitted in the RS (10 to 13) field which designates the source which is to supply the data for inclusion into the Comm-B downlink field. Both RL and RS appear at the SM interface and are interpreted by suitable I/O devices which then insert the data as needed. If RL=1, RS is assigned as follows:

RS=0000 designates a message previously initiated by the pilot, see 3.5.6.2.

RS=0001 designates a message containing the description of on-board DABS equipment, see automatic extended capability reporting, 3.5.6.3.

RS=0010 used for experimental flight status reporting equipment.

3.5.6.2 Air Initiated Comm-B Sequence. After a message has been assembled in the aircraft, the transmission sequence is initiated by setting bit 16 (B) in a Surveillance or Comm-B reply. The ground then interrogates with RL=1, RS=0000 to extract the message. The first four bits in the MB message field identify the source of the message. This 4-bit field is designated Down Source (DS) and uses bits 33 through 36. The following codes have been assigned:

DS=0000 universal acknowledgement channel

DS=0001 extended capability report

DS=0010 flight status report.

After receipt of the message, the ground clears the B bit and concludes the Comm-B transaction by transmitting bit 15 (CB) in a Surveillance or Comm-B interrogation.

3.5.6.3 Automatic Extended Capability Reporting. Any I/O device which cannot report its presence directly in an All-Call reply (see 2.2.10.10) will do so in a dedicated Comm-B transmission. Receipt of RS=0001 (see 3.5.6.1) is recognized by all I/O devices affected and any such device indicates its presence by setting the data line high at its assigned time slot. The time slots assigned begin at t_{140}; none have been assigned so far. At all other times during that reply, I/O devices will hold the data line in its high impedance state (see 2.2.10.9).

3.5.6.4 Universal Acknowledgement Channel. The universal acknowledgement channel provides a protocol similar to the one described in 3.5.1 for I/O devices other than the principal I/O device. The acknowledgement data are transmitted in a Comm-B message with DS=0000. A location in the MB field for a pair of acknowledgement bits is assigned to each I/O device with acknowledgement capability, and each such I/O device inserts its acknowledgement bits at the time assigned to it. Bits 41 and 42 are assigned to the ATC message display. If the ground has requested an acknowledgement by sending the AR (33) bit, the pilot actuates one of the two acknowledgement buttons associated with the appropriate I/O device. This condition automatically sets into motion the air-initiated Comm-B sequence described in 3.5.6.2 and 3.5.6.5.

3.5.6.5 B-Bit Priority Protocol. On receipt of the B bit, the ground interrogates with RL=1, RS=0000 to extract the waiting message. Several such messages from several sources may be waiting, but the simultaneous operation of message sources must be prevented. Any message source which has a message waiting to be transmitted inserts the B bit into all downlink transmissions, i.e., the B bit outputs of all sources are effectively OR-ed.

Priority intercommunication between I/O devices takes place on the data line (2.2.10.1). Each message generating device has a 1 μsec (1 count) time slot assigned to it between t_{188} and t_{214}. If a source has a message to transmit, it inserts the B bit into the next downlink transmission and then probes its own assigned time slot. If this slot is found "low" the source "locks on" by pulling up the data line immediately for the rest of the cycle and pulling up the data line beginning at t_{188} in all subsequent cycles. All other probing message sources are thereby kept from locking on. On receipt of the RL=1/RS=0000 authorization to transmit, the waiting message from the locked-on source will be transmitted. The lock-on condition for this source remains in force until after the message has been transmitted and is released only upon receipt of CB (2.1.3.4.3.10) to permit other message sources to lock on in order of their priority position.

The first priority slot, t_{188}, is assigned to all I/O devices which have an acknowledgement function (3.5.6.4).