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Mode S Transponder MOPS Maintenance

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Required DO-181D Changes driven by changes in RTCA DO-185B

Written and presented by:
R.H. "Bob" Saffell
Rockwell Collins, Inc.

SUMMARY : This Working Paper addressed changes that need to be made to DO-181D due to changes in definitions of bits provided by TCAS for the Data Link Capability Report. These changes are necessary due to changes that were made by SC-147 in the development of RTCA DO-185B.

Introduction:

The following sections provide all requirements and test procedures relevant to TCAS and the Transponder/TCAS interface. All changes that have been made are those necessary to compensate for the change in Data Link Capability bit definitions. All changes or additions are highlighted in light blue.

Start of MOPs Work:

2.2.22 TCAS-Compatible Mode S Transponder

In addition to the Level 2 Transponder capabilities defined in §2.2.19.1, the Mode S transponder used in conjunction with TCAS **shall** have the following capabilities:

a. Ability to handle the following formats:

Format Number	**Format Name**
UF=16	Long Special Surveillance Interrogation
DF=16	Long Special Surveillance Reply

b. Ability to receive long Mode S interrogations (UF=16) and generate long Mode S replies (DF=16) at a continuous rate of 16.6 milliseconds (60 per second).

Note: *Although item "b" above states the minimum requirement, in certain high density traffic situations, the transponder could receive "bursts" of UF=16 interrogations at a much higher rate. The theoretical upper limit for a burst is 120 UF=16 interrogations received in a 100-millisecond interval, with no more than 10 unique UF=16 interrogations in any 1-second interval and no more than 120 total UF=16 interrogations in any 1-second interval.*

c. Means for delivering the TCAS data content of all accepted interrogations addressed to the TCAS equipment.

d. Antenna diversity (see §2.2.12).

e. Mutual suppression capability

f. RF performance compatibility with own aircraft's TCAS. Specifically, when the Mode S transponder transmitter is in the inactive state, the RF power at 1090 MHz at the terminals of the Mode S transponder antenna **shall** not exceed -70 dBm.

Note: *This unwanted power restriction is necessary to insure that the Mode S transponder does not prevent TCAS from meeting its requirements. It assumes that the isolation between the transponder antenna and the TCAS antenna exceeds 20 dB. The resultant interference level at the TCAS RF port will then be below -90 dBm.*

g. Reply rate limiting for Mode S replies. The reply rate limiting device **shall** protect the transponder from over-interrogation while permitting at least the reply rates required in §2.2.13.3.1.c and §2.2.22.b above.

h. The ability to interface with both FAA TSO-C119A (for compatibility with RTCA/DO-185) and RTCA/DO-185A/B compatible units.

An RTCA/DO-185A/B compatible transponder **shall** annunciate its capability to the on-board TCAS via the transponder/TCAS interface. Likewise, an RTCA/DO-185A/B compatible TCAS annunciates its capability to the on-board transponder via the transponder/TCAS interface. The capability of the transponder/TCAS system is then limited to the capability of either the transponder or the TCAS unit having the least capability.

The transponder **shall** consider the transponder/TCAS system to be compatible with RTCA/DO-185A/B if and only if both the TCAS and the transponder are compatible with RTCA/DO-185A/B.

2.2.22.1 Message Fields and Protocols

2.2.22.1.1 MA Message, Comm-A Used by TCAS

Note: *Control of the TCAS sensitivity level can be accomplished by one or more ground-based Mode S sensors through the transmission of Comm-A interrogations, UF=20 or 21, containing TCAS Sensitivity Level Command Messages to the TCAS aircraft. The interrogator identification information required to correlate the sensitivity level command with a particular originating ground-based Mode S sensor site is contained in the IIS subfield (see §2.2.19.2.1.1) of SD of the same Comm-A.*

Subfields in MA for a TCAS Sensitivity Level Command Message

ADS: A-Definition Subfield – This 8-bit (bits 33 – 40) uplink subfield in MA defines the data contained in the remainder of MA. For convenience in coding, ADS is expressed in two groups of 4 bits each, ADS1, 33 through 36, and ADS2, 37 through 40. A TCAS Sensitivity Level Command Message **shall** use ADS1=0 and ADS2=5.

SLC: TCAS Sensitivity Level Command – This 4-bit (bits 41 – 44) subfield contains a sensitivity level command for the TCAS aircraft.

The transponder **shall** monitor the TMS (see §2.2.19.2.1.1.c) and ADS subfields of Comm-A interrogations UF=20 and 21. If ADS1=0 and ADS2=5 and TMS=0, the IIS subfield of SD and the SLC subfield of MA **shall** be provided to the TCAS unit.

2.2.22.1.2 MB Message, Comm-B Used by TCAS

Airborne equipment **shall** use the MB field (see §2.2.14.4.20) of Comm-B replies to transmit a Resolution Advisories Report and a Data Link Capability Report to Mode S sensors.

2.2.22.1.2.1 Air-Initiated Downlink of RA Report

2.2.22.1.2.1.1 Air-Initiated Downlink of RA Report for All Transponder/TCAS Systems

The following requirements apply to all transponder/TCAS systems, i.e., both those that are compatible with RTCA/DO-185A/B, and those that are **NOT** compatible with RTCA/DO-185A/B.

Whenever TCAS reports that it has an active Resolution Advisory (RA), the transponder **shall** indicate that it has an RA Report awaiting downlink by setting the DR field in DF=4, 5, 20, 21 replies to DR=2, 3, 6, or 7 as appropriate.

Upon receipt of a DF=4, 5, 20, or 21 reply, with DR=2, 3, 6 or 7, a Mode S sensor may request downlink of the RA Report by setting RR=19 and DI≠7, or RR=19, DI=7 and RRS=0 in a surveillance or Comm-A interrogation (UF=4, 5, 20, or 21) to the TCAS aircraft. When this request is received by own Mode S transponder, own transponder **shall** reply with a Comm B reply, DF=20, 21, whose MB field contains an RA Report with information previously provided to the transponder by the TCAS equipment.

While an RA is active, the content of the MB field in the RA Report **shall** be updated at least once every second. DR=2, 3, 6 or 7 **shall** remain set for 18 ±1 seconds following the end of the RA. In addition, the RA Report **shall** remain "frozen," i.e., **shall** retain the last ARA and the corresponding RAC, for 18 ±1 seconds following the end of the RA, unless superseded by a new ARA.

Subfields in MB for RA Report

BDS: B-Definition Subfield – This 8-bit (bits 33 – 40) subfield indicates that a RA Report is contained in MB by BDS1=3 and BDS2=0, the combination of which is equivalent to BDS=48.

ARA: Active Resolution Advisories – This 14-bit (bits 41 – 54) subfield indicates the currently active Ras (if any) generated by own TCAS unit against one or more threat aircraft.

RAC: Resolution Advisory Complements – This 4-bit (bits 55 – 58) subfield indicates the currently active RA complements (if any) received from other TCAS aircraft equipped with on-board resolution capability.

2.2.22.1.2.1.2 Air-Initiated Downlink of RA Report for FAA TSO-C119A Compatible Systems

The following requirements apply to all FAA TSO-C119A compatible transponder/TCAS systems in addition to the requirements provided in §2.2.22.1.2.1.1.

An active RA is identified as being any NON-ZERO ARA.

2.2.22.1.2.1.3 Air-Initiated Downlink of RA Report for RTCA/DO-185A/B Compatible Systems

The following requirements apply to all RTCA/DO-185A/B compatible transponder/ TCAS systems in addition to the requirements provided in §2.2.22.1.2.1.1.

Subfields in MB for RA Report

BDS: B-Definition Subfield – Additional Information

When BDS1=3 and BDS2 =0, the subfields indicated below are contained in MB. For 18 ±1 seconds following the end of an RA, all MB subfields in the RA report with the exception of bit 59 (RAT) **shall** retain the information reported at the time the RA was last active.

Except for the RAT bit, the following subfields are provided to the transponder by the TCAS for application in the RA Report.

RAT: Resolution Advisory Terminated Indicator – This 1-bit (bit 59) subfield **shall** be set by the transponder to indicate when an RA previously generated by TCAS has ceased being generated. RAT **shall** be set in accordance with the following:

0 = The RA indicated by the ARA subfield is currently active. The transponder **shall** set RAT to ZERO at all times except those defined for RAT =1.

1 = The RA indicated by the ARA subfield has been terminated. RAT **shall** be set to ONE for 18 ±1 seconds following termination of a previously reported RA. Termination of the RA may result from any of the following:

a. Notification of termination of the RA received from own on-board TCAS.

b. Notification of loss of capability received from own on-board TCAS, i.e., TCAS declaration of interface failure.

c. Transponder declaration of interface failure.

The transponder **shall** monitor the 1-bit RA Indicator (RAI) from TCAS to determine whether there is an active RA. RAI is set to ZERO by TCAS to indicate that there is an active RA. Otherwise, RAI is set to ONE by TCAS. Termination of the RA is indicated by the transition of RAI from ZERO to ONE.

Note: *The RAT bit is used to indicate that the RA has been terminated. It may be used, for example, to permit removal of an RA indication from an Air Traffic Control display, or for assessment of RA duration within a particular airspace.*

MTE: Multiple Threat Encounter – This 1-bit (bit 60) subfield indicates whether two or more simultaneous threats are currently being processed by the TCAS threat resolution logic.

TTI: Threat Type Indicator – This 2-bit (bit 61 – 62) subfield defines the type of identity data contained in the TID subfield (see §2.2.22.1.2.1.3).

TID: Threat Identity Data – This 26-bit subfield (bit 63 – 88) contains the Mode S address of the threat if the threat is equipped with a Mode S transponder. If the threat is not equipped with a Mode S transponder, then this subfield contains the altitude, range, and bearing of the threat.

If two or more threats are simultaneously being processed by the TCAS threat resolution logic, the TID subfield contains the identity or position data for the most recently declared threat.

If TTI=1, the TID subfield contains the Mode S address of the threat in bits 63 through 86, and bits 87 through 88 are set to ZERO.

If TTI=2, the TID subfield contains the following three subfields.

TIDA: Threat Identity Data, Altitude – This 13-bit subfield (bits 63 – 75) contains the most recently reported Mode-C altitude code of the threat. Coding of the TIDA subfield is consistent with the coding of the Mode-C Altitude reply.

TIDR: Threat Identity Data, Range – This 7-bit subfield (bits 76 – 82) contains the most recent range of the threat estimated by TCAS.

TIDB: Threat Identity Data, Bearing – This 6-bit subfield (bits 83 – 88) contains the most recent bearing of the threat estimated by TCAS, relative to the TCAS aircraft heading.

2.2.22.1.2.2 Data Link Capability Codes in MB

2.2.22.1.2.2.1 Data Link Capability Codes in MB for All Transponder/TCAS Systems

Notes:

1 The ground-based Mode S sensor learns of the specific data link capabilities on board the aircraft by using the data link capability report protocol specified in §2.2.19.1.12.5, §2.2.19.1.12.6, §2.2.19.1.12.7, and §2.2.19.1.12.8.

2. The data bits discussed in the following subparagraphs are modified in the MB field of the Data Link Capability Report by the Mode S transponder such that the data appears appropriately in response to a request for Data Link Capability Report when BDS1=1 and BDS2=0. As such, these data bits comprise only a small fraction of the entire Data Link Capability Report which may collate data from multiple sources for transfer in the downlink. Care must be taken to ensure that the data fields discussed in the following subparagraphs are not compromised when other sources attempt to update the Data Link Capability Report, and that updating of these bits does not compromise other parts of the Data Link Capability Report.

2.2.22.1.2.2.2 Data Link Capability Codes in MB for FAA TSO-C119A Compatible Systems

The following requirements apply to all FAA TSO-C119A compatible transponder/TCAS systems.

The Mode S transponder **shall** process the TCAS-supplied capability information (RI) for inclusion in the Data Link Capability Report. This capability information **shall** cause the transponder to set the following codes in a Data Link Capability Report:

Bit Codes in MB for Data Link Capability Report

The following codes **shall** appear in the MB field for a Data Link Capability Report when BDS1=1 and BDS2=0.

Bit 48 equals 1 indicates that the transponder/TCAS interface is operational and the transponder is receiving TCAS RI=2, 3 or 4.

Bits 69 and 70 form a capability code subfield which indicates the aircraft's on-board resolution advisory generation capability.

The codes are:

Bit 69	Bit 70	Meaning
0	0	No on-board resolution advisory generation capability (TCAS RI not equal to 3 or 4, or no operational interface.)
0	1	An on-board vertical-only resolution advisory generation capability exists (TCAS RI=3)
1	0	An on-board vertical and horizontal resolution advisory generation capability exists (TCAS RI=4)
1	1	Not assigned

2.2.22.1.2.2.3 Data Link Capability Codes in MB for RTCA/DO-185A Compatible Systems

The following requirements apply to all RTCA/DO-185A compatible transponder/TCAS systems.

Bits 48, 69, 70, 71, and 72 are provided to the transponder by the TCAS and **shall** appear in the MB field for a Data Link Capability Report when BDS1=1 and BDS2=0.

Notes:

1. *Bit 71 set to ONE indicates that the transponder/TCAS system is compatible with RTCA/DO- 185A.*

2. *Bit 72 is "Reserved" for future use by TCAS and/or the transponder. Until appropriate coding of this bit has been defined, it should be set to ZERO (0) by the TCAS.*

If the transponder detects a failure of the transponder/TCAS interface, then the transponder **shall** ensure that Bits 48, 69, 70, 71, and 72 are set to ZERO in the Data Link Capability Report.

2.2.22.1.2.2.4 Data Link Capability Codes in MB for RTCA/DO-185B Compatible Systems

The following requirements apply to all RTCA/DO-185B compatible transponder/TCAS systems.

Bits 48, 69, 70, 71, and 72 are provided to the transponder by the TCAS and **shall** appear in the MB field for a Data Link Capability Report when BDS1=1 and BDS2=0.

Notes:

1. *Bit 48 ("MB" bit 16) set to ONE (1) indicates that the transponder TCAS interface is operational and the transponder is receiving TCAS RI=2, 3 or 4.*

2. *Bit 69 ("MB" bit 37) set to ONE (1) indicates capability of Hybrid Surveillance, and set to ZERO (0) indicates that there is no Hybrid Surveillance capability.*

3. *Bit 70 ("MB" bit 38) set to ONE (1) indicates that TCAS is generating both TAs and RAs, and set to ZERO (0) indicates the generation of TAs only.*

4. *Bits 71, 72 ("MB" bits 39, 40) are encoded in accordance with the following table:*

Bit 72	***Bit 71***	***Meaning***
"MB" Bit 40	***"MB" Bit 39***	
0	*0*	*DO-185 (6.04A)(TSO-C119a)*
0	*1*	*DO-185A (TSO-C119b)*
1	*0*	*DO-185B*
1	*1*	*For future versions or enhancements*

If the transponder detects a failure of the transponder/TCAS interface, then the transponder **shall** ensure that Bits 48, 69, 70, 71, and 72 are set to ZERO in the Data Link Capability Report.

2.2.22.1.2.3 Additional MB Message Reserved for RTCA/DO-185A/B Compatible Systems

An RCTA/DO-185A/B compatible TCAS has the capability of sending the transponder a 56-bit message for storage into one of the Ground-Initiated Comm-B (GICB) registers. When operating in an RTCA/DO-185A/B compatible system, the transponder shall store the TCAS-supplied 56-bit message into the specified transponder GICB register. The GICB register specified for this purpose is Register $0F_{16}$.

Notes:

1. *The actual structure and coding of the TCAS MB Message is not specified in this document and may be defined in the future. It is the intent of RTCA/DO-185A/B compatible systems that the transponder/TCAS interface be implemented in a manner such that the TCAS can directly format the designated MB message and thereby alleviate the need for the transponder to know the exact structure and coding of the message.*

2. *Transponders designed for use in RTCA/DO-185A/B compatible systems should allow for future use of other MB messages sent by TCAS.*

2.2.22.1.3 MU Message, Comm-U Used by TCAS

The Mode S transponder **shall** supply the MU field (see §2.2.14.4.25) of a long special surveillance interrogation, UF=16, to TCAS only under the following conditions:

a. The interrogation contains the transponder's discrete address and UDS=48.

b. The interrogation contains the broadcast address (all ONES) and UDS=50

Notes:

1. *The MU field is used by TCAS to transmit a TCAS Broadcast Interrogation Message containing own transponder's address for the purpose of controlling interference caused by TCAS interrogations, or to transmit a TCAS Resolution Message for air-to-air resolution advisory coordination.*

2. *Ideally the transponder should serve as a modem for TCAS and supply the entire MU field to TCAS (including the UDS Field) of any received UF=16 interrogation. Currently implemented transponder/TCAS interface protocols do not provide the UDS Field information to TCAS so it is necessary for these transponders to select the UDS messages that are passed to TCAS. If this*

interface limitation is removed in the future, then all UDS messages would be passed to TCAS.

Subfield in MU for a TCAS Resolution Message

UDS: U-Definition Subfield – This 8-bit (bits 33 – 40) subfield defines the data content and coding in the remainder of the MU field. For convenience in coding, UDS is expressed in two groups of 4 bits each; UDS1, 33 through 36, and UDS2, 37 through 40. TCAS Resolution Messages **shall** be identified by UDS1=3 and UDS2=0, the combination of which is equivalent to UDS=48.

Subfield in MU for a TCAS Broadcast Message

UDS: U-Definition Subfield – A TCAS Broadcast Interrogation Message is identified by UDS1=3 and UDS2=2, the combination of which is equivalent to UDS=50.

2.2.22.1.4 MV Message, Comm-V Used by TCAS

2.2.22.1.4.1 MV Message, Comm-V Used by FAA TSO-C119A Compatible Systems

Upon acceptance of a UF=16 containing a TCAS Resolution Message from a threat TCAS aircraft, the Mode S transponder **shall** transmit a long special surveillance reply, DF=16, to the requesting aircraft. The MV field of this reply **shall** contain a Coordination Reply Message with information previously provided by own TCAS.

Subfields in MV for a Coordination Reply Message

ARA: Active Resolution Advisories – This 14-bit (bits 41 – 54) subfield as described in §2.2.22.1.2.1.1.

RAC: Resolution Advisory Complements – This 4-bit (bits 55 – 58) subfield as described in §2.2.22.1.2.1.1.

VDS: V-Definition Subfield – This 8-bit (bits 33 – 40) subfield defines the content and coding in the remainder of MV. For convenience in coding, VDS is expressed in two groups of 4 bits each; VDS1, bits 33 through 36, and VDS2, bits 37 through 40. The airborne TCAS equipment is a source of long special reply MV messages containing the VDS1=3 code. A Coordination Reply Message is identified by VDS1=3 and VDS2=0, the combination of which is equivalent to VDS=48.

2.2.22.1.4.2 MV Message, Comm-V Used by RTCA/DO-185A/B Compatible Systems

In addition to the requirements provided in §2.2.22.1.4.1, a RTCA/DO-185A/B compatible system **shall** provide the following:

Subfields in MV for a Coordination Reply Message

RAT: Resolution Advisory Terminated Indicator – This 1-bit (bit 59) subfield as described in §2.2.22.1.2.1.3.

MTE: Multiple Threat Encounter – This 1-bit (bit 60) subfield as described in §2.2.22.1.2.1.3.

2.2.22.1.5 RI Air-to-Air Reply Information

This 4-bit (bits 14 – 17) downlink field **shall** be included in special surveillance formats DF=0, 16. This field **shall** contain information pertaining to replying aircraft. Where airspeed is reported (see §2.2.14.4.33), the maximum true airspeed flown in normal operations **shall** be given using the coding shown below.

In addition to the RI coding in §2.2.14.4.33, a TCAS-Compatible Mode S transponder **shall** be capable of receiving additional RI codes from own TCAS for inclusion in special surveillance formats DF=0, 16 for replies to non-acquisition interrogations.

The codes are:

Code	Meaning
0	No on-board TCAS
1	Not assigned
2	On-board TCAS with resolution capability inhibited
3	On-board TCAS with vertical-only resolution capability
4	On-board TCAS with vertical and horizontal resolution capability
5 – 7	Not assigned
8	No maximum airspeed data available
9	Airspeed is less than or equal to 75 knots
10	Airspeed is greater than 75 and less than or equal to 150 knots
11	Airspeed is greater than 150 and less than or equal to 300 knots
12	Airspeed is greater than 300 and less than or equal to 600 knots
13	Airspeed is greater than 600 and less than or equal to 1200 knots
14	Airspeed is greater than 1200 knots
15	Not assigned

The following protocol **shall** apply:

On receipt of a short special interrogation, UF=0, or a long special interrogation, UF=16, the interrogated Mode S transponder **shall** reply with a short special reply, DF=0, or a long special reply, DF=16, depending on the code contained in the RL field of the interrogation. In this reply, the sensitivity level and the air-to-air reply information **shall** be supplied in the SL and RI fields. The Mode S transponder **shall** transmit the SL field supplied by TCAS to indicate the sensitivity level at which TCAS is currently operating.

Bit 14 of the RI field replicates the AQ bit (see §2.2.14.4.5) of the interrogation. That is, codes 0 – 7 are supplied by TCAS for use in the reply to an air-to-air non-acquisition interrogation; codes 8 – 15 (indicating aircraft maximum airspeed) **shall** be supplied by the Mode S transponder for use in the reply to an acquisition interrogation. For a reply to a non-acquisition interrogation, the Mode S transponder **shall** set the RI field to ZERO (0) to indicate a non-operational TCAS if the conditions for setting bit 48 to ONE (1) (see §2.2.22.1.2.2) are not satisfied. If RI=0, the SL field has no meaning.

2.2.22.2 General Requirements of the Mode S Interface to the TCAS Equipment

2.2.22.2.1 Delivery of Messages

The transponder **shall** transmit a valid Coordination Reply Message in response to an incoming TCAS Resolution Message if, and only if, current transponder indications show

that the incoming message can be delivered to the TCAS unit. If the transponder recognizes a valid incoming TCAS Resolution Message but does not send a valid Coordination Reply Message, all data in the incoming message **shall** be discarded.

Note: *This requirement implies that the manufacturer must determine the rate at which incoming interrogations can actually be accepted by the transponder (generally a rate much greater than §2.2.22.b) and the rate at which these interrogations can be passed to the TCAS unit and, if necessary, provide a queuing mechanism to ensure that accepted interrogations are not lost. The transponder must be able to monitor the status of the queue and the status of any other relevant internal structures or pathways so as not to accept new TCAS Resolution Messages if the queue is full or if there is some other condition that would prevent delivery to the TCAS unit (e.g., the transponder/TCAS interface is not established or has failed or TCAS is indicating no resolution capability).*

If the transponder cannot accept the incoming TCAS Resolution Message contained in the MU field of a long special surveillance interrogation UF=16, the transponder **shall** either (a) not reply to this interrogation, or (b) reply with a long special surveillance reply DF=16 with all 56 bits of the MV field equal to ZERO (0).

2.2.22.2.2 Data Integrity

The interface between TCAS and the transponder **shall** be designed to provide communication in the normal operational aircraft environment for that class of TCAS equipment while assuring error rates of less than one detected error in 10^5 bit transmissions and less than one undetected error in 10^9 bit transmissions for transfers in either direction. Compliance with this requirement **shall** be demonstrated either by direct test in a simulated operational environment or by analysis based on the known characteristics of proven interface techniques.

The Mode S transponder **shall** monitor the status of the communications interface with own TCAS. A detected failure in the interface **shall** be recognized by the transponder as a loss of integrity and **shall** be treated as a TCAS failure (see §2.2.22.1.5 and §2.2.19.1.12.5).

Note: *Incomplete data transmission can result in erroneous execution of the TCAS logic algorithms*

2.2.22.2.3 TCAS Failure Data Handling

When a TCAS failure is detected, the transponder **shall** set all areas for storage of TCAS data to ZERO.

2.2.22.2.4 Communication Timing

TCAS Resolution Messages that are received by the transponder **shall** be delivered to the TCAS unit (received by TCAS from the TCAS/transponder interface) within 0.01 second of receipt by the transponder.

Note: *This requirement assumes the transponder input message rate of one message every 16.6 milliseconds (60 per second).*

2.2.22.3 Data Provided by TCAS Equipment to the Mode S Transponder

2.2.22.3.1 Data Contained in the Special Surveillance Replies (DF=0, 16)

a. Contents of the SL Field

The Mode S transponder **shall** report a changed value of the sensitivity level in the SL field in any special surveillance reply, DF=0, 16 generated no later than 250 milliseconds after receipt of the changed SL value from TCAS.

b. Contents of the RI Field

The TCAS equipment provides a value for downlink transmission by the transponder in the RI field whenever the corresponding UF=0 or 16 interrogation contains AQ=0 (tracking interrogation). The Mode S transponder **shall** report a changed resolution capability in any special surveillance reply, DF=0, 16 generated no later than one second after receipt of the changed RI value from TCAS.

2.2.22.3.2 Data Contained in the Long Special Surveillance Reply (DF=16)

When the Mode S transponder receives a long special surveillance interrogation (UF=16) with RL=1 and UDS=48 in the MU field, the transponder **shall** reply with a long special surveillance reply, DF=16. This reply **shall** contain a Coordination Reply Message (see §2.2.22.1.4), the contents of which were provided previously by the TCAS equipment.

2.2.22.3.3 Data Contained in Altitude and Identity Surveillance and Comm-B Replies (DF=4, 5, 20, 21)

Contents of the DR Field

The TCAS equipment provides a continuous indication to the Mode S transponder whenever a TCAS resolution advisory exists. This **shall** cause the transponder to set either code 2, 3, 6 or 7 in the DR field (see §2.2.14.4.12) within one second of first receipt of this indication.

2.2.22.3.4 Data Contained in the Altitude and Identity Comm-B Reply (DF=20, 21)

a. Resolution Advisories Report

When the Mode S transponder receives an altitude or identity surveillance or Comm-A interrogation, UF=4, 5, 20 or 21 with RR=19, the transponder **shall** reply with a Comm-B, DF=20, 21. This reply **shall** contain a Resolution Advisories Report (§2.2.22.1.2.1).

b. Data Link Capability Report

The TCAS equipment indicates to the Mode S transponder its resolution capabilities, which the transponder **shall** include in the Data Link Capability Report (see §2.2.22.1.2.2).

Note: *§2.2.19.1.12.8 specifies that the transponder will recognize a change in on-board data link capability and will automatically set DR=4, 5, 6 or 7,*

causing the ground system to read out a new Data Link Capability Report.

2.2.22.4 Data Provided by the Mode S Transponder to the TCAS Equipment

The transponder **shall** provide the following data to the TCAS equipment:

a. The aircraft discrete address,

b. The aircraft pressure altitude from the source that is the basis for own altitude in Mode S replies,

c. Quantization for pressure altitude (fine or coarse, where fine is defined to be 10 feet or less, and coarse is defined to be greater than 10 feet).

When selecting the altitude source used for Mode S replies and for TCAS, the transponder **shall** use the source that is valid and provides the finest quantization. The altitude data **shall** be provided to TCAS at the finest quantization available.

2.2.22.5 TCAS-Compatible Transponder Automatic Performance Monitoring

The transponder **shall** be capable of detecting malfunctions in the Mode S transponder system that would degrade TCAS functioning and upon detection **shall** make this information available to TCAS.

2.5.4.31 Procedure #31 Transmission of RA Report to Mode S Sensor (§2.2.22.h and §2.2.22.1.2.1)

This test verifies that the transponder correctly determines the transponder/TCAS system capability (either FAA TSO-C119A or RTCA/DO-185A/B compatibility) based on communication with the on-board TCAS unit and then reports RA information in the appropriate format. This test requires that the transponder demonstrate proper operation with both FAA TSO-C119A and RTCA/DO-185A/B compatible transponder/TCAS interfaces.

This test verifies that the transponder correctly (1) receives RA information from the TCAS unit, (2) indicates to the ground (DR field in DF=4, 5, 20, and 21 replies) that it has information awaiting downlink, (3) transmits this information in DF=20, 21 replies, (4) retains RA information for 18 ±1 seconds following the end of the RA, and (5) (for RTCA/DO-185A/B compatible transponder/TCAS systems) properly indicates the end of the RA via the RA Terminated indicator.

Note: *The tests refer to a "TCAS bit" in the DR field of DF=4, 5, 20, and 21 replies. The TCAS bit is interpreted herein as bit 12 of the 5-bit (bits 9-13) DR field. That is, if DR=2, 3, 6, or 7, then the "TCAS bit" is set, and the transponder is therefore indicating that it has TCAS information available.*

2.5.4.31.1 Procedure #31 Transmission of RA Report for a Transponder Operating with an FAA TSO-C119A Compatible TCAS (§2.2.22.h, §2.2.22.1.2.1, §2.2.22.1.2.1.1, and §2.2.22.1.2.1.2)

a. ARA=0 and RAC=0:

Interrogate the transponder with UF=4, 5, 20, and 21 interrogations when no RA information has been received via the transponder/TCAS interface.

Show that the TCAS bit in the DR field is not set in the DF=4, 5, 20, and 21 replies.

b. ARA≠0 and RAC≠0:

Send ARA=‘10000000000000’ and RAC=‘1000’ to the transponder via the transponder/TCAS interface.

Interrogate the transponder with UF=4, 5, 20, and 21 interrogations.

Show that the ‘TCAS bit’ in the DR field is set in the DF=4, 5, 20, and 21 replies.

Interrogate the transponder with UF=4, 5, 20, and 21 interrogations with RR=19.

Show that the TCAS bit in the DR field is set in the DF=20 and 21 replies. Show that the ARA and RAC information is correctly reported in the DF=20 and 21 replies.

Send ARA=0 and RAC=0 to the transponder via the transponder/TCAS interface.

Interrogate the transponder once per second for the next 20 seconds with a UF=4 interrogation with RR=19.

Show that for 18 ±1 seconds after the end of the RA, the TCAS bit in the DR field in the reply remains set and that ARA=1000000000000 and RAC=1000 are reported. Show that after 18 ±1 seconds, the TCAS bit in the DR field in the reply is not set and that ARA=0 and RAC=0 are reported.

c. ARA≠0 and RAC=0:

Repeat all portions of step b replacing every instance of RAC=1000 with RAC=0.

d. ARA=0 and RAC≠0:

Send ARA=0 and RAC=‘1000’ to the transponder via the transponder/TCAS interface.

Interrogate the transponder with UF=4, 5, 20, and 21 interrogations.

Show that the TCAS bit in the DR field is not set in the DF=4, 5, 20, and 21 replies.

Interrogate the transponder with UF=4, 5, 20, and 21 interrogations with RR=19.

Show that the ‘TCAS bit’ in the DR field is not set in the DF=20 and 21 replies.

Send ARA=0 and RAC=0 to the transponder via the transponder/TCAS interface.

Interrogate the transponder once per second for the next 20 seconds with a UF=4 interrogation with RR=19.

Show that the TCAS bit in the DR field in the replies is not set.

e. ARA≠0, RAC≠0, new ARA and RAC values received during 18-second time-out:

Send ARA=‘00000100000000’ and RAC=‘0100’ to the transponder via the transponder/TCAS interface.

Interrogate the transponder with UF=4, 5, 20, and 21 interrogations.

Show that the TCAS bit in the DR field is set in the DF=4, 5, 20, and 21 replies.

Interrogate the transponder with UF=4, 5, 20, and 21 interrogations with RR=19.

Show that the TCAS bit in the DR field is set in the DF=20 and 21 replies. Show that the ARA and RAC information is correctly reported in the DF=20 and 21 replies.

Send the following sequence (60 seconds total) of ARA and RAC data to the transponder via the transponder/TCAS interface.

For 5 seconds, ARA=0 and RAC=0;

For the next 5 seconds, ARA=‘10000000000000’ and RAC=‘1000’;

For the next 5 seconds, ARA=‘01000000000000’ and RAC=0;

For the next 5 seconds, ARA=0 and RAC=0;

For the next 5 seconds, ARA=0 and RAC=‘0100’;

For the next 5 seconds, ARA=‘01000000000000’ and RAC=0;

For the next 30 seconds, ARA=0 and RAC=0.

Interrogate the transponder once per second during the 60 seconds described above with UF=4 interrogations with RR=19.

Show that the TCAS bit in the DR field in the replies remains set for the first 48 ±1 seconds and is set to ZERO thereafter. Show that in the replies:

For the first 5 seconds, ARA=‘00000100000000’ and RAC=‘0100’;

For the next 5 seconds, ARA=‘10000000000000’ and RAC=‘1000’;

For the next 38 ±1 seconds, ARA=‘01000000000000’ and RAC=0;

For the next 12 ±1 seconds, ARA=0 and RAC=0.

RAT=1 from 16 seconds to 25 seconds and from 31 seconds to 48 seconds, and that RAT=0 at other times.

2.5.4.31.2 Procedure #31 Transmission of RA Report for a Transponder Operating with an RTCA/DO-185A/B Compatible TCAS (§2.2.22.h, §2.2.22.1.2.1, §2.2.22.1.2.1.1, and §2.2.22.1.2.1.3)

a. ARA=0 and RAC=0:

Interrogate the transponder with UF=4, 5, 20, and 21 interrogations when no RA information has been received via the transponder/TCAS interface.

Show that the 'TCAS bit' in the DR field is not set in the DF=4, 5, 20, and 21 replies.

b. ARA≠0 and RAC≠0:

Send ARA='10000000000000', RAC='1000', RAI=0, MTE=0, TTI=1, and TID='AAAAAA' {HEX} to the transponder via the transponder/TCAS interface.

Interrogate the transponder with UF=4, 5, 20, and 21 interrogations.

Show that the 'TCAS bit' in the DR field is set in the DF=4, 5, 20, and 21 replies.

Interrogate the transponder with UF=4, 5, 20, and 21 interrogations with RR=19.

Show that the 'TCAS bit' in the DR field is set in the DF=20 and 21 replies.

Show that the ARA, RAC, RAT(=0), MTE, TTI, and TID are correctly reported in the DF=20 and 21 replies.

Send ARA=0, RAC=0, RAI=1, and MTE=0 to the transponder via the transponder/TCAS interface.

Interrogate the transponder once per second for the next 20 seconds with a UF=4 interrogation with RR=19.

Show that for 18 ±1 seconds after the end of the RA, the 'TCAS bit' in the DR field in the reply remains set, and that RAT=1, ARA='10000000000000', RAC='1000', MTE=0, TTI=1, and TID='AAAAAA' {HEX} are reported. Show that after 18 ±1 seconds, the 'TCAS bit' in the DR field in the reply is not set and that RAT, ARA, RAC, MTE, TTI, and TID are all set to ZERO.

c. ARA≠0 and RAC=0:

Repeat all portions of step b replacing every instance of RAC='1000' with RAC=0, and replacing TTI=1, TID='AAAAAA' {HEX} with TTI=2, TIDA='0101010101010', TIDR='1010101', TIDB='010101'.

d. ARA=0 and RAC≠0:

Send ARA=0, RAC='1000', RAI=1, and MTE=0 to the transponder via the transponder/TCAS interface.

Interrogate the transponder with UF=4, 5, 20, and 21 interrogations.

Show that the 'TCAS bit' in the DR field is not set in the DF=4, 5, 20, and 21 replies.

Interrogate the transponder with UF=4, 5, 20, and 21 interrogations with RR=19.

Show that the 'TCAS bit' in the DR field is not set in the DF=20 and 21 replies.

Send ARA=0, RAC=0, RAI=1, and MTE=0 to the transponder via the transponder/TCAS interface.

Interrogate the transponder once per second for the next 20 seconds with a UF=4 interrogation with RR=19.

Show that the 'TCAS bit' in the DR field in the replies is not set.

e. ARA≠0, RAC≠0, new ARA and RAC values received during 18-second time-out:

Send ARA='00000100000000', RAC='0100', RAI=0, MTE=0, TTI=1, and TID='555555' {HEX} to the transponder via the transponder/TCAS interface.

Interrogate the transponder with UF=4, 5, 20, and 21 interrogations.

Show that the 'TCAS bit' in the DR field is set in the DF=4, 5, 20, and 21 replies.

Interrogate the transponder with UF=4, 5, 20, and 21 interrogations with RR=19.

Show that the 'TCAS bit' in the DR field is set in the DF=20 and 21 replies. Show that the ARA, RAC, RAT(=0), MTE, TTI, and TID are correctly reported in the DF=20 and 21 replies.

Send the following sequence (60 seconds total) of ARA and RAC data to the transponder via the transponder/TCAS interface.

For 5 seconds, ARA=0, RAC=0, RAI=1, MTE=0;

For the next 5 seconds, ARA='10000000000000', RAC='1000', RAI=0, MTE=0, TTI=1, and TID='AAAAAA' {HEX};

For the next 5 seconds, ARA='01000000000000', RAC=0, RAI=0, MTE=0, TTI=1, and TID='555555' {HEX};

For the next 5 seconds, ARA=0, RAC=0, RAI=1, and MTE=0;

For the next 5 seconds, ARA=0, RAC='0100', RAI=1, and MTE=0;

For the next 5 seconds, ARA='01000000000000', RAC=0, RAI=0, MTE=0, TTI=1, and TID='555555' {HEX};

For the next 30 seconds, ARA=0, RAC=0, RAI=1, and MTE=0.Interrogate the transponder once per second during the 60 seconds described above with UF=4 interrogations with RR=19.

Show that the 'TCAS bit' in the DR field in the replies remains set for the first 48 ±1 seconds and is set to ZERO thereafter. Show that in the replies:

For the first 5 seconds, ARA='00000100000000', RAC='0100', RAT=1, MTE=0, TTI=1, and TID='555555' {HEX};

For the next 5 seconds, ARA='10000000000000', RAC='1000', RAT=0, MTE=0, TTI=1, and TID='AAAAAA' {HEX};

For the next 5 seconds, ARA='01000000000000', RAC=0, RAT=0, MTE=0, TTI=1, and TID='555555' {HEX};

For the next 10 seconds, ARA='01000000000000', RAC=0, RAT=1, MTE=0, TTI=1, and TID='555555' {HEX};

For the next 5 seconds, ARA='01000000000000', RAC=0, RAT=0, MTE=0, TTI=1, and TID='555555' {HEX};

For the next 18 ±1 seconds, ARA='01000000000000', RAC=0, RAT=1, MTE=0, TTI=1, and TID='555555' {HEX};

For the next 12 ±1 seconds, ARA=0, RAC=0, RAT=0, and MTE=0.

2.5.4.32 Procedure #32 Transmission of TCAS Capability Information to a Mode S Sensor (§2.2.22.h and §2.2.22.1.2.2) and to other TCAS Aircraft (§2.2.22.1.5)

This test verifies that the transponder receives operational information from its associated TCAS unit and correctly reports this information in Data Link Capability Reports to a Mode S sensor and in special surveillance replies to another TCAS aircraft. This test requires that the transponder demonstrate proper operation with both FAA TSO-C119A and RTCA/DO-185A/B compatible transponder/TCAS interfaces.

2.5.4.32.1 Procedure #32 Transmission of TCAS Capability Information to a Mode S Sensor (§2.2.22.h , §2.2.22.1.2.2, §2.2.22.1.2.2.1, and §2.2.22.1.2.2.2) and to other TCAS Aircraft (§2.2.22.1.5) for a Transponder Operating with an FAA TSO-C119A Compatible TCAS

a. Enable the transponder only (i.e., establish the state where the transponder/TCAS interface is not operational).

b. Interrogate the transponder with a non-acquisition UF=0 interrogation.

   Show that the transponder replies with the correct capability information in the DF=0 reply (i.e., RI=0).

c. Interrogate the transponder with the following four interrogations:

   UF=4 with RR=17 and DI≠7;

   UF=5 with RR=17 and DI≠7;

   UF=20 with RR=17, DI=7, and RRS=0;

UF=21 with RR=17, DI=7, and RRS=0.

Show, in each of the four cases, that the transponder replies with the correct capability information in the DF=20, 21 replies (i.e., BDS1=1, BDS2=0, bit 48=0, and bits 69, 70, 71, and 72 = 0000).

d. Repeat the procedures in steps b and c above for each of the following 16 cases:

(1) TCAS reports "on-board TCAS with resolution capability inhibited" (RI=2) to the transponder via the transponder/TCAS interface.

Show that the transponder replies with RI=2 in the DF=0 reply.

Show that the transponder replies with bit 48=1 and bits 69, 70, 71, and 72 = '0000' in the DF=20, 21 replies.

(2) TCAS reports "on-board TCAS with vertical-only resolution capability" (RI=3) to the transponder via the transponder/TCAS interface.

Show that the transponder replies with RI=3 in the DF=0 reply.

Show that the transponder replies with bit 48=1 and bits 69, 70, 71, and 72 = '0100' in the DF=20, 21 replies.

(3) TCAS reports "on-board TCAS with vertical and horizontal resolution capability" (RI=4) to the transponder via the transponder/TCAS interface.

Show that the transponder replies with RI=4 in the DF=0 reply.

Show that the transponder replies with bit 48=1 and bits 69, 70, 71, and 72 = '1000' in the DF=20, 21 replies.

(4)-(16) TCAS reports RI=0, 1, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, and 15 to the transponder via the transponder/TCAS interface.

Show that for each case, the transponder replies with RI=0 in the DF=0 reply.

Show that for each case, the transponder replies with bit 48=0 and bits 69, 70, 71, and 72 = '0000' in the DF=20, 21 replies.

2.5.4.32.2 Procedure #32 Transmission of TCAS Capability Information to a Mode S Sensor (§2.2.22.h , §2.2.22.1.2.2, §2.2.22.1.2.2.1, and §2.2.22.1.2.2.3) and to other TCAS Aircraft (§2.2.22.1.5) for a Transponder Operating with an RTCA/DO-185A Compatible TCAS

Repeat the procedures provided in Steps "a" through "d" of §2.5.4.32.1 for an RTCA/DO-185A compatible transponder/TCAS interface.

Show that the transponder properly reports with the RI field in DF=0 replies set exactly as provided in Steps "a" through "d" of §2.5.4.32.1.

Show that the transponder properly reports with DF=20, 21 replies that are exactly the same as those specified in Steps "b" through "d" of §2.5.4.32.1 with the exception that bits 70 and 71 = "don't care" for the four cases in Step "c" and bit 71 = 1 for cases 1 – 3.

2.5.4.32.3 Procedure #32 Transmission of TCAS Capability Information to a Mode S Sensor (§2.2.22.h , §2.2.22.1.2.2, §2.2.22.1.2.2.1, and §2.2.22.1.2.2.3) and to other TCAS Aircraft (§2.2.22.1.5) for a Transponder Operating with an RTCA/DO-185B Compatible TCAS

a. Repeat the procedure provided in Step "a" of §2.5.4.32.1 for an RTCA/DO-185B compatible transponder/TCAS interface.

b. Repeat the procedure provided in Step "b" of §2.5.4.32.1 for an RTCA/DO-185B compatible transponder/TCAS interface.

c. Repeat the procedure provided in Step "c" of §2.5.4.32.1 for an RTCA/DO-185B compatible transponder/TCAS interface.

d. Repeat the procedures in steps b and c above for each of the following 16 cases:

(1) TCAS reports "on-board TCAS with resolution capability inhibited" (RI=2) to the transponder via the transponder/TCAS interface.

TCAS reports that there is no "Hybrid Surveillance" capability to the transponder via the transponder/TCAS interface.

Show that the transponder replies with RI=2 in the DF=0 reply.

Show that the transponder replies with bit 48=1 and bits 69, 70, 71, and 72 = '0001' in the DF=20, 21 replies.

(2) TCAS reports "on-board TCAS with vertical-only resolution capability" (RI=3) to the transponder via the transponder/TCAS interface.

TCAS reports that there is "Hybrid Surveillance" capability to the transponder via the transponder/TCAS interface.

Show that the transponder replies with RI=3 in the DF=0 reply.

Show that the transponder replies with bit 48=1 and bits 69, 70, 71, and 72 = '1101' in the DF=20, 21 replies.

(3) TCAS reports "on-board TCAS with vertical-only resolution capability" (RI=3) to the transponder via the transponder/TCAS interface.

TCAS reports that there is no "Hybrid Surveillance" capability to the transponder via the transponder/TCAS interface.

Show that the transponder replies with RI=4 in the DF=0 reply.

Show that the transponder replies with bit 48=1 and bits 69, 70, 71, and 72 = '0101' in the DF=20, 21 replies.

(4)-(16) TCAS reports RI=0, 1, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, and 15 to the transponder via the transponder/TCAS interface.

Show that for each case, the transponder replies with RI=0 in the DF=0 reply.

Show that for each case, the transponder replies with bit 48=0 and bits 69, 70, 71, and 72 = '0000' in the DF=20, 21 replies.

2.5.4.33 Procedure #33 TCAS or transponder/TCAS Interface Failure During Transmission of RA Report and Data Link Capability Report to a Mode S Sensor (§2.2.22.1.2.1.3 and §2.2.22.1.2.2.3)

This test applies to RTCA/DO-185A/B compatible systems.

a. Send ARA='10000000000000', RAC='1000', RAI=0, MTE=0, TTI=1, and TID='AAAAAA' {HEX} to the transponder via the transponder/TCAS interface once per second for 5 seconds.

During the 5th second, cause the TCAS unit to report a TCAS failure to the transponder (i.e., RI=0 and SL 1).

Interrogate the transponder once per second during the 5 seconds described above and for an additional 25 seconds (30 seconds total) with UF=4 interrogations with RR=19 and DI 7.

Show that in the DF=20 replies:

For the first 23 ±1 seconds, the 'TCAS bit' is set in the DR field. Thereafter, it is cleared.

For the first 5 seconds, ARA='10000000000000', RAC='1000', RAT=0, MTE=0, TTI=1, and TID='AAAAAA' {HEX}.

For the next 18 ±1 seconds, ARA='10000000000000', RAC='1000', RAT=1, MTE=0, TTI=1, and TID='AAAAAA' {HEX}.

For the remaining 7 ±1 seconds, ARA, RAC, MTE, TTI, and TID all = 0.

b. Repeat the steps in test a, except during the 5th second, cause the transponder to recognize a failure on the transponder/TCAS interface (i.e., disconnect or otherwise interrupt the interface).

The results should be the same as in test a.

c. Send "on-board TCAS with vertical-only resolution capability" (RI=3) to the transponder via the transponder/TCAS interface for 5 seconds.

During the 5th second, cause the transponder to recognize a failure on the transponder/TCAS interface (i.e., disconnect or otherwise interrupt the interface).

Interrogate the transponder once per second for 30 seconds with UF=4 interrogations with RR=17 and DI 7.

Show that in the DF=20 replies:

For the first 5 seconds, bit 48=1, and bits 69, 70, 71, and 72 = ‘0110’.

For the next 25 seconds, bits 48, 69, 70, 71, and 72 all = 0.

2.5.4.34 Procedure #34 Coordination (§2.2.22.1.3 and §2.2.22.1.4)

This test verifies that the transponder (1) accepts incoming UF=16 interrogations containing a TCAS Resolution Message and passes all necessary information to the TCAS unit, and (2) receives coordination information from the TCAS unit and correctly reports this information in outgoing DF=16 replies. This test requires that the transponder demonstrate proper operation with both FAA TSO-C119A and RTCA/DO-185A/B compatible transponder/TCAS interfaces.

2.5.4.34.1 Procedure #34 Coordination (§2.2.22.1.3 and §2.2.22.1.4.1) for a Transponder Operating with an FAA TSO-C119A Compatible TCAS

a. Interrogate the transponder with a UF=16 interrogation with UDS=48, MTB=0, CVC=0, VRC=2, CHC=0, HRC=0, VSB=7 when no resolution advisory information has been received from the TCAS unit.

   Show that the transponder sends a DF=16 reply with VDS=48, ARA=0, and RAC=0.

   Show that the coordination information in the MU field is correctly output on the transponder/TCAS interface.

b. Send ARA=0 and RAC='0100' to the transponder from the TCAS unit.

   Interrogate the transponder with a UF=16 interrogation with UDS=48, MTB=0, CVC=0, VRC=2, CHC=0, HRC=0, VSB=7.

   Show that the transponder sends a DF=16 reply with VDS=48.

   Show that the coordination information in the MU field is correctly output on the transponder/TCAS interface.

c. Send ARA='00000100000000' and RAC='0100' to the transponder from the TCAS unit.

   Interrogate the transponder with a UF=16 interrogation with UDS=48, MTB=0, CVC=2, VRC=0, CHC=0, HRC=0, VSB=13.

   Show that the transponder sends a DF=16 reply with VDS=48, ARA='00000100000000', and RAC='0100'.

   Show that the coordination information in the MU field is correctly output on the transponder/TCAS interface.

d. Send ARA='00000100000000' and RAC=0 to the transponder from the TCAS unit.

Interrogate the transponder with a UF=16 interrogation with UDS=48, MTB=0, CVC=2, VRC=0, CHC=0, HRC=0, VSB=13.

Show that the transponder sends a DF=16 reply with VDS=48.

Show that the coordination information in the MU field is correctly output on the transponder/TCAS interface.

e. Send ARA=0 and RAC=0 to the transponder from the TCAS unit.

Interrogate the transponder with a UF=16 interrogation with UDS=48, MTB=0, CVC=0, VRC=1, CHC=0, HRC=0, VSB=14.

Show that the transponder sends a DF=16 reply with VDS=48, ARA=0, and RAC=0.

Show that the coordination information in the MU field is correctly output on the transponder/TCAS interface.

2.5.4.34.2 Procedure #34 Coordination (§2.2.22.1.3 and §2.2.22.1.4.2) for a Transponder Operating with an RTCA/DO-185A/B Compatible TCAS

a. Interrogate the transponder with a UF=16 interrogation with UDS=48, MTB=0, CVC=0, VRC=2, CHC=0, HRC=0, VSB=7 when no resolution advisory information has been received from the TCAS unit.

Show that the transponder sends a DF=16 reply with VDS=48, ARA=0, RAC=0, RAT=0, and MTE=0.

Show that the coordination information in the MU field is correctly output on the transponder/TCAS interface.

b. Send ARA=0, RAC='0100', RAI=1, and MTE=0 to the transponder from the TCAS unit.

Interrogate the transponder with a UF=16 interrogation with UDS=48, MTB=0, CVC=0, VRC=2, CHC=0, HRC=0, VSB=7.

Show that the transponder sends a DF=16 reply with VDS=48.

Show that the coordination information in the MU field is correctly output on the transponder/TCAS interface.

c. Send ARA='11100000000000', RAC='0100', RAI=0, and MTE=0 to the transponder from the TCAS unit.

Interrogate the transponder with a UF=16 interrogation with UDS=48, MTB=0, CVC=2, VRC=0, CHC=0, HRC=0, VSB=13.

Show that the transponder sends a DF=16 reply with VDS=48, ARA='11100000000000', RAC='0100', RAT=0, and MTE=0.

Show that the coordination information in the MU field is correctly output on the transponder/TCAS interface.

d. Send ARA='11100000000000', RAC=0, RAI=0, and MTE=1 to the transponder from the TCAS unit.

Interrogate the transponder with a UF=16 interrogation with UDS=48, MTB=0, CVC=2, VRC=0, CHC=0, HRC=0, VSB=13.

Show that the transponder sends a DF=16 reply with VDS=48, ARA='11100000000000', RAC=0, RAT=0, and MTE=1.

Show that the coordination information in the MU field is correctly output on the transponder/TCAS interface.

e. Send ARA=0, RAC=0, RAI=1, MTE=0 to the transponder from the TCAS unit. This RAI=1 is intended to represent the transition from RAI=0 to RAI=1 indicating the end of ARA='11100000000000' in d, above.

Interrogate the transponder with a UF=16 interrogation with UDS=48, MTB=0, CVC=0, VRC=1, CHC=0, HRC=0, VSB=14.

Show that the transponder sends a DF=16 reply with VDS=48.

Show that the coordination information in the MU field is correctly output on the transponder/TCAS interface.

2.5.4.35 Procedure #35 MU Messages To TCAS (§2.2.22.1.3)

This test verifies that the transponder correctly: 1) accepts UF=16 interrogations with MU data containing a TCAS Resolution Message (UDS=48) and passes all necessary information to the TCAS unit; 2) accepts UF=16 broadcast interrogations with MU data containing a TCAS Broadcast Message (UDS=50) and passes all necessary information to the TCAS unit; 3) does not transfer the MU data of UF=16 discrete interrogations with UDS≠48 and broadcast interrogations with UDS≠50 to the TCAS unit.

a. Interrogate the transponder with a valid UF=16 TCAS Coordination Message (UDS1=3, UDS2=0). Verify that the transponder replies with a valid DF=16 Coordination Reply Message and the data content of the MU field is correctly output on the transponder/TCAS interface.

b. In one second, interrogate the transponder with ten UF=16 interrogations, each containing a TCAS Broadcast Message (UDS1=3, UDS2=2, and interrogation address all ONEs), each containing a unique “own” Mode S address (i.e., ten different Mode S addresses). Verify that the MU data for each interrogation is correctly output on the transponder/TCAS interface.

c. Interrogate the transponder at the rate of 10 per second or less with 255 UF=16 interrogations addressed to the transponder with UDS values from 0 to 255 except for UDS=48. Verify that the transponder does not output the messages over the transponder/TCAS interface.

d. Interrogate the transponder at the rate of 10 per second or less with 255 UF=16 broadcast interrogations with UDS values from 0 to 255 except for UDS=50. Verify that the transponder does not output the messages over the transponder/TCAS interface.

2.5.4.36 Procedure #36 Transponder Replies to Incoming TCAS Resolution Messages (§2.2.22.2.1)

This test verifies that (1) whenever the transponder replies with a valid Coordination Reply Message to an incoming TCAS Resolution Message, the incoming message is successfully delivered to the TCAS unit; and (2) whenever the transponder's internal queue is full or some other condition is present which would prevent delivery of the message to TCAS, the transponder does not reply with a valid Coordination Reply Message to an incoming TCAS Resolution Message and does not pass the incoming data to TCAS.

a. Interrogate the transponder with a UF=16 interrogation containing a valid TCAS Resolution Message when all of the following conditions are true: the transponder is reporting that it has an operational TCAS; no transponder queues are full; and no TCAS failure conditions exist.

   Demonstrate that the transponder transmits a valid Coordination Reply Message and that the incoming coordination information is correctly output on the transponder/TCAS interface.

b. Interrogate the transponder with a UF=16 interrogation containing a valid TCAS Resolution Message when the transponder queue is full. Demonstrate that the transponder does not send a valid Coordination Reply Message and does not output the incoming coordination information on the transponder/TCAS interface.

   Demonstrate that when the queue is full the transponder still replies to interrogations that do not contain information directed to the transponder/TCAS interface.

c. Interrogate the transponder with a UF=16 interrogation containing a valid TCAS Resolution Message when a TCAS failure condition is present (the transponder is reporting no resolution advisory capability).

   Demonstrate that the transponder does not send a valid Coordination Reply Message and does not output the incoming coordination information on the transponder/TCAS interface.

   Demonstrate that when a TCAS failure is present the transponder still replies to interrogations that do not contain information directed to the transponder/TCAS interface.

   Note: *When the transponder does not send a valid reply, it may either send no reply or send a DF=16 interrogation with all 56 bits of the MV field equal to ZERO.*

2.5.4.37 Procedure #37 Transponder/TCAS Throughput (§2.2.22 b and g)

This test verifies that the interrogation input rate requirement and the reply rate limiting requirement referenced above are met by the transponder. In addition, this test is important for demonstrating that the transponder's internal structures (e.g., queues, timing) have been designed in such a way that they are compatible with any TCAS unit with which the transponder is paired.

a. Interrogate the transponder with UF=16 interrogations for 5 seconds at a continuous rate of 16.6 milliseconds, i.e., 60 interrogations per second.

   Demonstrate that the transponder accepts all interrogations, transmits a valid reply to each interrogation, and correctly outputs the information on the transponder/TCAS interface in the order that it was received by the transponder.

b. Interrogate the transponder with UF=16 interrogations for 5 seconds at a rate greater than that at which the transponder can accept all interrogations.

Note: *In some installations, interrogating at a high rate with all UF=16 interrogations causes the transponder's internal queue to fill, thus stopping the transponder's acceptance of and reply to interrogations because of the full queue, rather than because of the reply rate limiting. If this is the case, it is necessary to interrogate the transponder with a mix of short and long interrogations; this mix should include the largest number of UF=16 interrogations that is possible while at the same time avoiding any queue overflow. This will allow the reply rate limiting feature to be tested.*

   Demonstrate that the reply rate limiting feature is exercised (i.e., there is a mechanism which recognizes the high interrogation rate and stops the transponder from accepting and replying to replies before the transponder overheats or otherwise becomes adversely affected).

   Demonstrate that the transponder can accept and reply to at least the number of interrogations specified in §2.2.13.3.1.c.

   Demonstrate that for each accepted interrogation, and only for each accepted interrogation, the transponder transmits a valid reply and correctly outputs the information on the transponder/TCAS interface in the order that it was received by the transponder.

c. Interrogate the transponder with UF=16 interrogations at a burst rate greater than that which the transponder can accept. Maintain the burst scenario for at least 5 seconds.

Note: *Burst interrogations must be used to insure that the TCAS interface has not failed due to lack of periodic data updates.*

   Cause the TCAS test unit to accept information from the transponder at the slowest rate possible including a retry while still conforming to the transponder/TCAS interface protocols.

   Demonstrate that for each accepted interrogation, and only for each accepted interrogation, the transponder transmits a valid reply and correctly outputs the

information on the transponder/TCAS interface in the order that it was received by the transponder.

2.5.4.38 Procedure #38 Transponder Communication Timing (§2.2.22.2.4)

This test verifies that the communications timing requirement specified in §2.2.22.2.4 is met.

a. Demonstrate that the elapsed time from the transponder's receipt of an incoming UF=16 interrogation containing a TCAS Resolution Message to the receipt by the TCAS test unit from the TCAS/transponder interface is less than or equal to 0.01 second.

Note: *This assumes an interrogation rate less than or equal to 60 interrogations per second.*

2.5.4.39 Procedure #39 TCAS Crosslink (§2.2.14.4.13, §2.2.14.4.7, and §2.2.18.2.10)

This test verifies that the transponder (1) correctly reports the Crosslink Capability (CC) in DF=0 replies, and (2) decodes the DS field in UF=0 interrogations and correctly responds with the contents of the ground initiated Comm-B register in the MV field of the corresponding DF=16 reply.

a. Interrogate the transponder with UF=0, RL=0 interrogations. Verify that the CC field (bit 7) is a one in each DF=0 reply requested.

b. Generate data for each defined ground-initiated Comm-B message for each of the Comm-B registers that can be controlled via an interface or are internal to the transponder. The data content for each register should be unique so that it can be distinguished from all others. Interrogate the transponder with UF=0, RL=1, and all combinations of DS (1-255). Verify that the contents of the MV field of each DF=16 reply (whose register could be loaded with a test message) matches the contents of the corresponding Comm-B register requested.

During the Comm-B protocol test procedure (Procedure #18) or as an extension of the above test, use a TCAS Crosslink type interrogation to extract the ground-initiated Comm-B registers in order to verify the Crosslink protocol operates and correctly reports the proper ground-initiated Comm-B data as the transponder changes Comm-B protocol state (if done as part of Procedure #18, interrogate with UF=0, RL=1, DS = 1 -255 when interrogating with ground MB extraction).

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