

RTCA Special Committee 209

Working Group #1

Mode S Transponder MOPS Development/Maintenance

Meeting #1

RTCA, Washington DC

3 – 5 April 2007

**Proposed Changes to the Comm-B Protocol
Test Procedure (#18) in the draft of DO-181D**

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SUMMARY

This Working Paper contains recommended changes to §2.5.4.18 Procedure #18 Comm-B Protocol in the working draft of DO-181D.

This Working Paper contains recommended changes to §2.5.4.18 Procedure #18 Comm-B Protocol in the working draft of DO-181D. The purposes of these changes are to correct errors with the current test procedure and to reduce the test complexity by removing some unnecessary test steps. The following text describes the changes.

Test Complexity

The current test procedure calls for 18,522 interrogation pattern/transponder state combinations. This large number comes from multiplying the number of transponder states by the number of interrogation patterns. The reason that this number is so large is because a subset of the transponder states and interrogation patterns are multiplied by 15 or 16 in order to test with all applicable IIS codes. The 18,522 total is incorrect because it is an over-simplification to multiply the number of transponder states by the number of interrogation patterns that are derived this way. For example, with transponder states 6 and 7, the IIS code in the interrogation pattern must match the IIS of the transponder state. Therefore, even with interrogation patterns that are IIS sensitive, there is only one IIS value to use with each state 6 and 7. Also, with interrogation patterns that are IIS sensitive, it is only necessary to use all IIS codes with those transponder states that might logically be affected by the IIS code. The proposed test procedure identifies specific combinations of transponder state and interrogation patterns that require the use of multiple IIS codes. In many cases it is sufficient to test with the correct IIS and one incorrect IIS value.

Transponder States

The proposed changes include altering the transponder states that are identified in the current test procedure. A new state is added with the Comm-B message inserted at the interface (B-bit set) but not yet extracted. The current test procedure does not include this state, and it is important to verify that the transponder behaves properly with the various interrogation patterns when in this state. A message may not be closed out until it has been extracted at least once.

The current test procedure uses whether the IIS field in an interrogation matches the stored value as a transponder state (condition H in figure 2-19). The proposed test procedure does not use this as a transponder state condition. The status of the multisite timer is a transponder state, but the IIS code is an interrogation field. Instead of using the IIS code as transponder state criteria, the IIS code is varied as part of the interrogation patterns used. The transponder states have been changed accordingly.

The current test uses a total of 63 transponder states derived from the 7 basic states with states 4 through 7 multiplied by the 15 IIS codes. The proposed test procedure uses 6 basic states with just one (in multisite) used for all 15 IIS codes. The total number of transponder states is reduced to 20.

Interrogation Patterns

The current test uses 294 interrogation patterns that are derived from the 24 basic interrogation patterns with 18 of them (4 through 12, and 16 through 24) multiplied by 16 IIS codes. The proposed test procedure reduces this total by only requiring multiple IIS codes when IIS value could directly affect the transponder's response to an interrogation.

The proposed test reduces the total number of transponder states and interrogation patterns to 1435.

Expected Test Results

The current test procedure identifies thousands of transponder state/interrogation pattern combinations but it does not provide any information on the expected status of the transponder as these combinations are tested. The proposed test procedure provides a table that identifies the expected transponder status for all combinations of transponder states and interrogation patterns.

The Proposed Procedure #18:

2.5.4.18 Procedure #18 Comm-B Protocol

(§2.2.19.1.12 through §2.2.19.1.12.4)
(§2.2.19.2.2 through §2.2.19.2.3.1)
(§2.2.19.2.3.3 through §2.2.19.2.3.5)
(§2.2.19.2.1.2 – UM)
(Figure 2-19 – Flowchart)

This test procedure verifies that the Comm-B protocol is carried out correctly.

The test procedure follows the notation of transponder states and of interrogation patterns as shown in the flowchart.

Transponder States

The transponder states are defined by the combinations of conditions E through I, where:

E	=	B-register set: B-bit inserted.
F	=	T-register set: Message has been transmitted.
G	=	Timer runs: For multisite only.
H	=	HS is correct (in next interrogation).
I	=	Next message waiting.

There are seven possible states as shown below:

#	E	F	G	I	
1	0	0	0	0	No B-bit, others impossible or inconsequential.
2	1	0	0	0	B-register set, message not extracted
23	1	1	0	0	Message extraction, not multisite protocol.
43	1	1	0	1	As above, next message waiting.
54	1	1	1	0	In multisite, interrogation with wrong IIS can not close out.
5	1	1	1	1	As above with next message waiting.
6	1	1	1	0	In multisite, interrogation with correct IIS can close out.
67	1	1	1	1	As above <u>In multisite, next message waiting but after closeout B-bit will show again.</u>

States 54 must be tested with all 15 IIS codes.

It is not necessary to test state 6 with all IIS codes with all interrogation patterns. However, the IIS used in the multisite reservation should be changed each time the transponder has to be returned to state 6 after a previous interrogation pattern that changed it to another state.

through 7 must be used with all 15 IIS codes.

Total: $4 \times 15 + 3 = 63$ transponder states to be used.

Interrogation Patterns

#	A	B	C	D	K	L	
1	0	0	0	0	0	0	Ordinary interrogation, asking for short reply.
2	0	0	0	0	0	1	Ground-initiated Comm-B extraction (FIS etc).
3	0	0	0	0	1	0	Air-initiated Comm-B extraction, not multisite.
4	0	1	0	0	0	0	Multisite, but not for Comm-B. <u>(IIS sensitive: state 5 use one incorrect IIS and the correct IIS)</u>
5	0	1	0	0	0	1	Ground-initiated Comm-B extraction, multisite not for Comm-B. <u>(IIS sensitive: state 5 use one incorrect IIS and the correct IIS)</u>
6	0	1	0	0	1	0	Air-initiated Comm-B extraction, multisite not for Comm-B. <u>(IIS sensitive: state 5 use one incorrect IIS and the correct IIS)</u>
7	0	1	0	1	0	0	Multisite closeout for Comm-B. <u>(IIS sensitive: states 2-4 use IIS=0 and IIS≠0, state 5 use all 16 IIS codes)</u>
8	0	1	0	1	0	1	Multisite closeout for Comm-B and ground initiated Comm-B extraction. <u>(IIS sensitive: states 2-4 use IIS=0 and IIS≠0, state 5 use one incorrect IIS and the correct IIS)</u>
9	0	1	0	1	1	0	Multisite closeout for Comm-B and attempt to extract a possible message still waiting at the air-initiation interface. <u>(IIS sensitive: states 2-4 use IIS=0 and IIS≠0, state 5 use one incorrect IIS and the correct IIS)</u>
10	0	1	1	0	0	0	Multisite reservation with wrong RR, see next line. <u>(IIS sensitive: state 5 use one incorrect IIS and the correct IIS)</u>
11	0	1	1	0	0	1	Attempt at multisite reservation with wrong RR. Transponder must not accept reservation. <u>(IIS sensitive: state 5 use one incorrect IIS and the correct IIS)</u>
12	0	1	1	0	1	0	Multisite reservation, correct. <u>(IIS sensitive: states 2-4 use all 16 IIS codes, state 5 use one incorrect IIS and the correct IIS)</u>
13	1	0	0	0	0	0	Non-selective cancellation.
14	1	0	0	0	0	1	Non-selective cancellation and ground initiated Comm-B extraction.
15	1	0	0	0	1	0	Non-selective cancellation and attempt to extract possible message still waiting at the air-initiation interface.

16	1	1	0	0	0	0	Non-selective cancellation, multisite not for Comm-B. <u>(IIS Sensitive: state 5 use all 16 IIS codes)</u>
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#	A	B	C	D	K	L	
17	1	1	0	0	0	1	Non-selective cancellation with ground initiated Comm-B extraction, multisite not for Comm-B. <u>(IIS Sensitive: state 5 use one incorrect IIS and the correct IIS)</u>
18	1	1	0	0	1	0	Non-selective cancellation and attempt to extract possible message still waiting at air-initiation interface, multisite not for Comm-B. <u>(IIS Sensitive: state 5 use one incorrect IIS and the correct IIS)</u>
19	1	1	0	1	0	0	Non-selective cancellation and multisite closeout, cancel non-selective message and close out multisite message if IIS is correct. <u>(IIS Sensitive: state 5 use all 16 IIS codes)</u>
20	1	1	0	1	0	1	Non-selective cancellation and multisite close-out and ground-initiated Comm-B extraction. Will cancel non-selective message and will close out multisite message if IIS is correct. Will extract Comm-B. <u>(IIS Sensitive: state 5 use one incorrect IIS and the correct IIS)</u>
21	1	1	0	1	1	0	Same as above, except with air-initiated extraction. <u>(IIS Sensitive: state 5 use one incorrect IIS and the correct IIS)</u>
22	1	1	1	0	0	0	Non-selective cancellation and reservation with wrong RR. Cancel but make no reservation. <u>(IIS sensitive: state 5 use one incorrect IIS and the correct IIS)</u>
23	1	1	1	0	0	1	Non-selective cancellation and reservation with wrong RR. Cancel but make no reservation. <u>(IIS sensitive: state 5 use one incorrect IIS and the correct IIS)</u>
24	1	1	1	0	1	0	Non-selective cancellation and reservation. Cancel and make reservation. <u>(IIS sensitive: states 5 & 6 use one incorrect IIS and the correct IIS)</u>

A =	PC=4:	Cancellation
B =	DI=1:	Multisite in effect
C =	MBS=1:	Multisite reservation
D =	MBS=2	Multisite closeout
K =	RR=16 with DI ≠ 7 or with DI=7 and RRS=0	Air initiated MB extraction
L =	RR larger than 15 but not according to code K above	Ground MB extraction

The symbols A, B, C, etc., correspond to the symbols on the flowchart (Figure 2-19).

For IIS sensitive interrogation patterns use IIS≠0 unless otherwise stated in the table.

For state 6 always use the correct IIS code with the exception of interrogation pattern 24 where an incorrect IIS code is also used.

When the IIS code must not equal 0 or must be incorrect, the value used should be varied with different interrogation patterns.

~~Interrogation patterns 4 through 12 and 16 through 24 of the 24 patterns shown are IIS sensitive; each of them must be used with each of the 16 IIS codes.~~

Interrogation patterns 10, 11, 22, 23 are forbidden to the sensor. They must be used to verify that the transponder makes reservations only when the reservation is accompanied by extraction of the message.

~~There are $18 \times 16 + 6 = 294$ interrogation patterns to be used.~~

Test Sequence.

All ~~143518,522~~ combinations of the ~~63~~ transponder states and ~~294~~ valid interrogation patterns must be used. Additional interrogations may be needed to set transponder states. The test sequence may be set up Interrogate soe that when the transponder enters a given state, and then use all interrogation patterns are used that will not change the state, followed by patterns that will. The test then proceeds. Repeat with the newlyw acquired state.

~~—This must be done until all 18,522 combinations have been exhausted. Some combinations must be repeated because more than one interrogation pattern can change the state.~~

To ‘set the B-bit’, use DR=1 and DR=3 commands alternately during the test sequence.

UM Field Verification

During the test sequence when the DI is required to be 1, alternately use RSS = 0 and 1, and when DI is not required to be 1, alternately use DI=0 and 7 so that the reply will contain IIS and IDS in the UM field according to §2.2.19.1.9. These fields are used to verify the Comm-B reservation status and associated IIS as a result of each interrogation pattern and transponder state.

Required Negative Tests

Concurrent tests are part of the sequence above.

If PC is not required to be 4, use all other codes. ~~If DI is not required to be 1, use all other codes.~~ If MBS is not required to be 1 or 2, use codes 30 and 43. If RR is required to be less than 16, use all codes less than 16.

Inserted tests must be interspersed within the sequence.

Insert interrogations of formats other than UF=4, 5, 20, 21 and verify that they have no effect on the protocol.

Such interrogations should constitute one percent of the total number of interrogations used.

The interrogation patterns ~~2, 5, 8, 11, and 14, 17, 20 and 23~~ must include, when RR=16 is used, the combinations of RR=16 with DI=7 and RRS Codes 1 through 15. It must be verified that these combinations do not cause the air-initiated Comm-B message to be transmitted.

UM Field Verification

~~During the test sequence when a multisite reservation is made (column C), the following reply will contain IIS and IDS in the UM field according to §2.2.19.2.1.2. Verify that these patterns are correct.~~

Timer Duration and Automatic Closeout Test

Arrange the sequence so that the timer runs out occasionally. Verify timer duration and closeout.

Either during the test sequence or in a separate test, verify that interrogation patterns 10, 11, and 12 do not restart the timer when the transponder is in state 5 and the IIS is incorrect. Verify that interrogation patterns 10 and 11 do not restart the timer when the transponder is in state 5 and the IIS is correct. Verify that interrogation pattern 12 does restart the timer when the transponder is in state 5 and the IIS is correct.

Simultaneous Tests

While the transponder is undergoing the verification of the B-protocol, the number of interrogations and replies can be used to make tests for interface action, message content, etc. Such tests are described in Procedures 19 through 23.

Expected Transponder States as a Function of Interrogation Pattern and Prior Transponder State:

Interrogation Pattern	<u>Transponder State</u>						
	1	2	3	4	5 (IIS incorrect)	5 (IIS correct)	6
<u>1</u>	<u>1 a,c,e</u>	<u>2 a,d,e</u>	<u>3 a,d,e</u>	<u>4 a,d,e</u>	<u>5 a,d,f</u>	<u>6 a,d,f</u>	<u>7 a,d,f</u>
<u>2</u>	<u>1 b,c,e,i</u>	<u>2 b,d,e,i</u>	<u>3 b,d,e,i</u>	<u>4 b,d,e,i</u>	<u>5 b,d,f,i</u>	<u>6 b,d,f,i</u>	<u>7 b,d,f,i</u>
<u>3</u>	<u>1 b,c,e,h</u>	<u>3 b,d,e,j</u>	<u>3 b,d,e,j</u>	<u>4 b,d,e,j</u>	<u>5 b,d,f,j</u>	<u>6 b,d,f,j</u>	<u>7 b,d,f,j</u>
<u>4</u>	<u>1 a,c,e</u>	<u>2 a,d,e</u>	<u>3 a,d,e</u>	<u>4 a,d,e</u>	<u>5 a,d,f</u>	<u>6 a,d,f</u>	<u>7 a,d,f</u>
<u>5</u>	<u>1 b,c,e,i</u>	<u>2 b,d,e,i</u>	<u>3 b,d,e,i</u>	<u>4 b,d,e,i</u>	<u>5 b,d,f,i</u>	<u>6 b,d,f,i</u>	<u>7 b,d,f,i</u>
<u>6</u>	<u>1 b,c,e,h</u>	<u>3 b,d,e,j</u>	<u>3 b,d,e,j</u>	<u>4 b,d,e,j</u>	<u>5 b,d,f,j</u>	<u>6 b,d,f,j</u>	<u>7 b,d,f,j</u>
<u>7</u>	<u>1 a,c,e</u>	<u>2 a,d,e</u>	<u>3 a,d,e</u>	<u>4 a,d,e</u>	<u>5 a,d,f</u>	<u>1 a,c,e</u>	<u>2 a,d,e</u>
<u>8</u>	<u>1 b,c,e,i</u>	<u>2 b,d,e,i</u>	<u>3 b,d,e,i</u>	<u>4 b,d,e,i</u>	<u>5 b,d,f,i</u>	<u>1 b,c,e,i</u>	<u>2 b,d,e,i</u>
<u>9</u>	<u>1 b,c,e,h</u>	<u>3 b,d,e,j</u>	<u>3 b,d,e,j</u>	<u>4 b,d,e,j</u>	<u>5 b,d,f,j</u>	<u>1 b,c,e,h</u>	<u>3 b,d,e,k</u>
<u>10</u>	<u>1 a,c,e</u>	<u>2 a,d,e</u>	<u>3 a,d,e</u>	<u>4 a,d,e</u>	<u>5 a,d,f,l</u>	<u>6 a,d,f,l</u>	<u>7 a,d,f</u>
<u>11</u>	<u>1 b,c,e,i</u>	<u>2 b,d,e,i</u>	<u>3 b,d,e,i</u>	<u>4 b,d,e,i</u>	<u>5 b,d,f,i,l</u>	<u>6 b,d,f,i,l</u>	<u>7 b,d,f,i</u>
<u>12</u>	<u>1 b,c,e,h</u>	<u>6 b,d,g,j</u> or <u>3 b,d,e,j¹</u>	<u>6 b,d,g,j</u> or <u>3 b,d,e,j¹</u>	<u>7 b,d,g,j</u> or <u>4 b,d,e,j¹</u>	<u>5 b,d,f,j,l</u>	<u>6 b,d,f,j,m</u>	<u>7 b,d,f,j</u>
<u>13</u>	<u>1 a,c,e</u>	<u>2 a,d,e</u>	<u>1 a,c,e</u>	<u>2 a,d,e</u>	<u>5 a,d,f</u>	<u>1 a,c,e</u>	<u>2 a,d,e</u>
<u>14</u>	<u>1 b,c,e,i</u>	<u>2 b,d,e,i</u>	<u>1 b,c,e,i</u>	<u>2 b,d,e,i</u>	<u>5 b,d,f,i</u>	<u>1 b,c,e,i</u>	<u>2 b,d,e,i</u>
<u>15</u>	<u>1 b,c,e,h</u>	<u>3 b,d,e,j</u>	<u>1 b,c,e,h</u>	<u>3 b,d,e,k</u>	<u>5 b,d,f,j</u>	<u>1 b,c,e,h</u>	<u>3 b,d,e,k</u>
<u>16</u>	<u>1 a,c,e</u>	<u>2 a,d,e</u>	<u>1 a,c,e</u>	<u>2 a,d,e</u>	<u>5 a,d,f</u>	<u>1 a,c,e</u>	<u>2 a,d,e</u>
<u>17</u>	<u>1 b,c,e,i</u>	<u>2 b,d,e,i</u>	<u>1 b,c,e,i</u>	<u>2 b,d,e,i</u>	<u>5 b,d,f,i</u>	<u>1 b,c,e,i</u>	<u>2 b,d,e,i</u>
<u>18</u>	<u>1 b,c,e,h</u>	<u>3 b,d,e,j</u>	<u>1 b,c,e,h</u>	<u>3 b,d,e,k</u>	<u>5 b,d,f,j</u>	<u>1 b,c,e,h</u>	<u>3 b,d,e,k</u>
<u>19</u>	<u>1 a,c,e</u>	<u>2 a,d,e</u>	<u>1 a,c,e</u>	<u>2 a,d,e</u>	<u>5 a,d,f</u>	<u>1 a,c,e</u>	<u>2 a,d,e</u>
<u>20</u>	<u>1 b,c,e,i</u>	<u>2 b,d,e,i</u>	<u>1 b,c,e,i</u>	<u>2 b,d,e,i</u>	<u>5 b,d,f,i</u>	<u>1 b,c,e,i</u>	<u>2 b,d,e,i</u>
<u>21</u>	<u>1 b,c,e,h</u>	<u>3 b,d,e,j</u>	<u>1 b,c,e,h</u>	<u>3 b,d,e,k</u>	<u>5 b,d,f,j</u>	<u>1 b,c,e,h</u>	<u>3 b,d,e,k</u>
<u>22</u>	<u>1 a,c,e</u>	<u>2 a,d,e</u>	<u>1 a,c,e</u>	<u>2 a,d,e</u>	<u>5 a,d,f</u>	<u>1 a,c,e</u>	<u>2 a,d,e</u>
<u>23</u>	<u>1 b,c,e,i</u>	<u>2 b,d,e,i</u>	<u>1 b,c,e,i</u>	<u>2 b,d,e,i</u>	<u>5 b,d,f,i</u>	<u>1 b,c,e,i</u>	<u>2 b,d,e,i</u>
<u>24</u>	<u>1 b,c,e,h</u>	<u>6 b,d,g,j</u>	<u>1 b,c,e,h</u>	<u>6 b,d,g,k</u>	<u>5 b,d,f,j</u>	<u>1 b,c,e,h</u>	<u>6 b,d,f,k,m</u> or <u>7 b,d,f,j,l²</u>

¹ If IIS = 0.

² If IIS is incorrect.

Verification Required:

<u>a</u>	<u>Short Reply (DF=4, 5)</u>
<u>b</u>	<u>Long Reply (DF=20, 21)</u>
<u>c</u>	<u>DR = 0, No Downlink Request</u>
<u>d</u>	<u>DR = 1 or 3, Request to Send Comm-B</u>
<u>e</u>	<u>UM = No Comm-B reservation</u>
<u>f</u>	<u>UM = IDS = 1, Comm-B Reservation Active, IIS = Value Set with Transponder State</u>
<u>g</u>	<u>UM = IDS = 1, Comm-B Reservation Active, IIS = Value in Interrogation</u>
<u>h</u>	<u>MB = All 0's</u>
<u>i</u>	<u>MB per RR</u>
<u>j</u>	<u>MB Contains 1st Comm-B Message Inserted</u>
<u>k</u>	<u>MB Contains 2nd Comm-B Message Inserted</u>
<u>l</u>	<u>Verify Multisite Timer is not Restarted</u>
<u>m</u>	<u>Verify Multisite Timer is Restarted</u>