

RTCA Special Committee 209 / EUROCAE WG49

ATCRBS / Mode S Transponder MOPS Maintenance

Joint Meeting #11

**RTCA Headquarters, Washington, DC
8 – 10 September 2010**

Initial review of EADS comments on ED-73C

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SUMMARY

This Working Paper reviews the different comments made by EADS on ED-73C and proposes responses or actions for the WG49-SC209 meeting.

This paper contains an initial analysis of the comments made by EADS on ED73C.

ED-73C paragraph	ED-73C Text	EADS comment	Eurocontrol analysis reviewed by WG49 subgroup teleconference	WG49-SC209 agreement
3.6.3	When manually activated, the SPI condition is indicated in the FS field of Mode S replies (DF = 4, 5, 20 and 21)	SPI is also contained in "Surveillance Status Subfield" in GICB#05 (Extended Squitter), GICB#05 is referenced in B.2.1, but the Register Format is not defined (as for all Extended Squitter registers).	<p>True - SPI is also contained in the Surveillance status in ES register 05.</p> <p>Action: to remove 3.6.3, to correct 3.22.2.7 d, to add 20,21 and include text on Extended Squitter to obtain the same text as in DO-181D 2.2.18.2.7 d</p> <p>“When manually selected, the transponder shall transmit the equivalent of the Mode A/C SPI in the FS field of surveillance replies DF=4, 5, 20, 21 and in the Surveillance Status Subfield (see §3.28.8) of Extended Squitter transmissions (DF=17) when they contain the airborne position report. This code shall be transmitted for 18 ±1 seconds (TI timer) after initiation and can be reinitiated at any time.”</p>	
3.7.1	At all RF input levels from MTL+3dB to -21 dBm, the jitter at the leading edge of the first pulse of the reply with respect to P3 shall not exceed 0.1 µs.	A statistical definition for the Jitter measurement is missing as it is given in 3.7.2 for Mode S. Proposal: Adopt the definition for intermode also for Mode A/C (100ns, 99.9 percentile).	<p>Current MOPS in line with Annex 10. 99.9 percent is not defined for Mode A/C</p> <p>Proposed action: Proposal to be discussed in next meeting as it also impacts ICAO Annex 10.</p>	
3.7.2	At all RF input levels from MTL+3dB to -21 dBm, the jitter of the reply delay shall not exceed 0.1 µs peak (99.9 percentile).	A Jitter requirement between MTL and MTL+3dB is missing for Mode A/C and Intermode . Proposal: Allow 200ns (99.9 percentile)	<p>True there is no such no test however it is in line with requirements in Annex 10 and in MOPS which are for MTL +3dB and above for Mode A/C and intermode (more difficult to be measured between MTL and MTL+3dB for Mode A/C)</p> <p>propose no change</p>	

ED-73C paragraph	ED-73C Text	EADS comment	Eurocontrol analysis reviewed by WG49 subgroup teleconference	WG49-SC209 agreement
3.10.3	After recognition of a valid interrogation, the transponder shall not reply to any other interrogation, at least for the duration of the reply pulse train. This dead time shall end no later than 125 µs after the transmission of the last reply pulse of the group.	There is no test in Chapter 5 to check the Mode A/C Dead time.	ED73 test S-S and S-A DO181 2.4.2.6 f tests A-S and S-A Proposed action: A-A and A-S never tested and test different between ED and DO – improvement to be discussed at next meeting	
5.4.11.2 Step 3	Diversity Operation, Delay Selection Test	<p>In 3.16.5 a minimum isolation of 20dB between the antenna ports A and B is required only. The delay selection test requires that an interrogation with a signal power of MTL+3 dB on antenna port A is selected if it is 0.375ns in advance of the same signal on antenna port B with a fixed signal power of -50dBm.</p> <p>It must be recognized that a "receive" isolation that equals the "transmit" isolation of 20 dB only would cause this test to fail, because the stronger but later signal would appear on port A with an interference power of -70dBm. In conclusion, this test defines a minimum "receive" isolation without specifying it explicitly. Furthermore the (hidden) requirement for the "receive" isolation depends on the MTL.</p> <p>Proposals: In chapter 3 the minimum receive channel isolation with respect to the antenna ports should be specified. To be approximately in line with the -50dBm definition for the stronger signal a minimum receive isolation of 30dB is proposed. (For a signal on port A with</p>	<p>In diversity of antenna there are 3 cases</p> <ul style="list-style-type: none"> o less than 125ns - selection of the highest amplitude o greater than 375 – selection of the first o between - not defined <p>therefore in our case the transponder will reply to the first interrogation on A not to the interference from B</p> <p>The 20dB isolation requirement is only on transmission- Although it is not defined on reception (choice of manufacturer) an higher isolation is expected.</p> <p>To verify the point to be tested, the signal injected on B must have an higher amplitude that the signal injected on A to check that the transponder will not reply on the channel with the highest amplitude received. One value is sufficient to demonstrate that the rule used is no more the highest power. However the interference of B on A should remain at a low amplitude e.g. at about 9 dB below the level of the signal on A to ensure 90% response to the first interrogation (see 3.12.5 , 90% reply in presence of pulse pair interference at -9dB). Therefore the amplitude of the signal on B must be chosen at a level</p>	

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		<p>MTL+3dB=-70dBm the -50dBm on port B would result in a S/J ratio of 10dB).</p> <p>Further it is proposed to specify not a fixed value of -50 dBm for the stronger signal but a signal power relative to MTL, i.e., MTL+23dB.</p>	<p>which will not interfere with the acceptance of the interrogation received on A. This maximum amplitude is depending on the isolation between the receiving channel A and the receiving channel B. If the amplitude of the signal on B is specified (-50 dBm) it indirectly specifies a minimum isolation between the receiving channels.</p> <p>Proposed action: The meeting is invited to discuss if -50dBm must be specified therefore indirectly setting a requirement between receiving channels or just given as a typical value.</p>	
<p>3.17.1. (7) and 3.17.1. (8)</p>	<p>If available, the ground speed data input is used to validate airborne/on-the-ground determination in installations that support automatic on-the-ground condition determination as specified in subparagraph 3.22.2.7. The data supports extended squitter airborne/surface format transmission selection and Flight Status (FS), Vertical Status (VS), and Capability (CA) fields as provided in subparagraphs 3.23.1.6, 3.23.1.7, 3.28.5, 3.18.4.5, 3.18.4.12 and 3.18.4.38. If available, the airspeed data input is used to validate airborne/on-the-ground determination in installations that support automatic on-the-ground condition determination as specified in subparagraph 3.22.2.7. The data supports extended squitter airborne/surface format transmission selection and Flight Status (FS),</p>	<p>There is no test in Chapter 5 which checks these requirements.</p>	<p>5.4.12.1 does not contain an associated test and 5.5.8.7. procedure #7 does not contain a section on validation as in DO-181D 2.4.5.7 On-the-Ground Validation Test</p> <p>Action: Add 5.5.8.7.4 with the same text as DO-181D 2.4.5.7 on the ground validation test</p>	

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	Vertical Status (VS), and Capability (CA) fields as provided in subparagraphs 3.23.1.6, 3.23.1.7, 3.28.5, 3.18.4.5, 3.18.4.12 and 3.18.4.38.			
3.17.3.c	(4) Storage Design, Non-Acceptance The transponder may optionally accept a Comm-A interrogation (UF=20, 21) if the data content of that interrogation cannot be processed. (see 'UNABLE TO PROCESS' and 'OPTION TO REPLY', Figure 2-16)	wrong reference to "Figure 2-16"	OK Action: correct 2-16 with 3-15	
3.18.4.5	Transponder Capability CA This 3-bit (6-8) downlink field convey information on the transponder level and the additional information below. It is used in DF=11, the All-Call reply and acquisition squitter, and in DF=17, the Extended Squitter. The codes are: 0 = Reserved	CA = 0 specified in ED-73C = "Reserved" and in ED-73B / ICAO IV / DO260A = "signifies no communications capability (surveillance only), no ability to set CA code 7, either on the ground or airborne".	ED-73C only covers level 2 and above transponders (as European regulation requires level 2 or above) contrary to ED-73B, DO181 and ICAO. This was decided in the last session of WG-49 Action: no change in ED73 DO260 A and B should not authorize CA=0 as an ES squitter transponder is a level 2 transponder. The test procedure in DO-260B 2.4.3.2.1.2.1 does not verify CA=0 however the description has been kept and some tests use CA =0! This should be added to the list of points to improve in DO260B	
3.22.2.6.b	Squitter Rate - Acquisition squitter transmissions shall be emitted at random intervals that are uniformly distributed over the range from 0.8 to 1.2 seconds using a time quantisation of no greater than 15 milliseconds relative to the previous acquisition squitter, with the following exceptions: (1) The scheduled acquisition squitter shall	There is no test in Chapter 5 which checks these requirements.	0.8s tested in 5.4.3.2.3 15ms tested in 5.5.8.6.1 (4) tested in 5.5.8.6.2.2 (j) step10 point (1) could be tested with a suppression lasting 1.17s triggered by the AS transmission. More complex for the other points Proposed action: next meeting to discuss the opportunity to add a test to	

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	<p>be delayed if a mutual suppression interface is active.</p> <p>(2) The scheduled acquisition squitter shall be delayed if the transponder is in a transaction cycle (paragraph 3.22.2.2 k.).</p> <p>(3) The scheduled acquisition squitter shall be delayed if an Extended Squitter is in process.</p> <p>(4) Acquisition squitters shall only be transmitted when in the on-the ground state if the transponder is not reporting the surface type of Mode S Extended Squitter or as specified in subparagraph c.</p>		<p>verify that the transmission of AS is delayed when there is a suppression</p> <p>check at next meeting whether the not tested requirements (2-3) could be removed or changed in a note</p>	
3.23.1.3	The transponder shall be able to transfer information to and from the appropriate data sinks (destinations) and sources (paragraphs 3.17 and 3.2 c and d).	Ref. "3.2 c and d" are not correct.	OK it is 3.23 c and d Action change 3.2 by 3.23 in 3.23.1.3	
3.28.2.f3.29.5.2.2.a	Extended Squitter Types ADS-B Aircraft Trajectory Intent Message	DO-260A chapter 2.2.3.2.7.1 (changed to "Target State and Status"). Event-driven Squitter with GICB #62 (Type 29, Subtype 0).	Action: OK 3.28.2 f and 3.29.5.2.2 a to be corrected in line with DO-260B and future DO-181 2.2.23.1.2 WG49 preference is to have a note in the transponder MOPS to point to DO-260/ED-102 (latest version)	
3.28.2.g	ADS-B Aircraft Operational Coordination Message	according to DO-260A chapter 2.2.3.2.7.9 no longer required	Same as before	
3.28.3.f	(References to DO-260)	The references to "DO-260" seem to be obsolete (with DO-260B)	Same as before	
3.29.5.2.2.a	Register 18 ₁₆ bit 34 shall be set to ONE (1) if the transponder is required to service any part of Register 17 ₁₆ as provided in paragraph 3.29.4.	see following comment		
3.29.5.2.2.b	Once the Register 18 ₁₆ bit 34 has been set to ONE (1) during a particular power-on cycle, then it shall remain set to ONE (1) until power-off of the	see following comment		

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	transponder.			
3.29.5.2.2.c	Register 18 ₁₆ bit 34 shall be set to ZERO (0) if the transponder receives no data from the Aircraft installation that could result in the need to service Register 17 ₁₆ as provided in paragraph 3.29.4. (The corresponding text appears several times.)	Contradiction to previous (2) and the following (1) requirements: In general: All bits of GICB#18 to #1C shall be set to ZERO at power-on and remain ZERO if the corresponding register is not implemented in the transponder or as long as no external data is available for the corresponding register. No reset is required until power-off.	Agreed no reset until power-off. same text than in DO-181D 2.2.24.5.2.2 Action: text to be clarified by the meeting in order to avoid misunderstanding in ED73 and DO181 – Proposal: “ ... shall remain set to zero if the transponder has received no data ...”	
3.29.5.3	The setting of bits in Register 18 ₁₆ - to- 1C ₁₆ is static. If a bit has been set to ONE (1) in one of these registers since power-on of the transponder, then the bit shall remain set to ONE (1) until power off of the transponder.	see previous comment	<u>same as before</u>	
3.30.7.3.c	(c) If a particular data field in Register 5F ₁₆ cannot be updated within 1.0 seconds (e.g., twice the specified minimum update interval of 0.5. seconds, then the data field shall be ZEROed (i.e., binary “00”).	Contradiction to the following requirement 1.0 sec	Action: to be corrected to 2s in ED-73 3.30.7.3 c and in DO-181 2.2.25.7.3	
3.31.3 and B.2.1	If a data-field field cannot be updated with valid data within twice the specified minimum update interval defined for the register or 2 seconds (whichever is the greater), then Status Bit (if specified) of the field will be set to “0” (INVALID) and that data field will be zeroed.	Contradiction to the previous requirement or exception from the general requirement ? 2.0 sec.	no change there - see previous comment	
3.30.8.3 vs TABLE B-2-1	The minimum update interval at which Register 60 ₁₆ shall be reloaded with valid data is 1.0 second. 60 ₁₆ Heading and speed report 1.3s	Corresponding to TABLE B-2-1: 1.3 sec (not 1.0 sec)	1.3s confirmed at the last meeting in June there is already an action to correct it.	
3.30.8.3	If Magnetic Heading data in Register 60 ₁₆ “MB” field bits 2 -through- 12 cannot be updated with valid data	twice .. or 2 sec whichever is greater ??? --> 2.6 sec (2 * 1.3 sec) as defined in TABLE B-2-	OK 2.6s see action in previous comment	

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	<p>within 2.0 seconds (e.g., twice the specified minimum update interval of 1.0 seconds) then Status Bit 1 shall be set to "0" and bits 2 -through-12 shall be set to "0". <i>and following values for Indicated Airspeed, Mach, Baro Altitude Rate, Inertial Vertical Rate</i></p>	1 for GICB#60		
5.4.5.2 a.(2)	<p>STEP 1 - Pulse Level Tolerances, Mode A/C/S All- Call (Paragraph 3.9.2 a.) Using a Mode A interrogation followed by a 1.6-µs P4 pulse at its nominal position, interrogate at the standard rate and at an RF signal level 10 dB above MTL. Vary the level of the P4 pulse between -10 dB and 0 dB with respect to P3. Measure and record : (1) the highest level of P4 relative to P3 at which 90% Mode A replies occur. (2) the lowest level of P4 relative to P3 at which</p>	<p>Mode S acceptance: The Mode S reply rate should be 90% instead of 99% to match with the previous definition of P4 non-acceptance conditions.</p>	<p>OK for 90% as it is defined in 3.9.1 and because it is not an interrogation using P6 for which 99% is defined above MTL+3dB</p> <p>Proposed action:</p> <ol style="list-style-type: none"> 1. in ED-73 5.4.5.2 a (2) replace 99% by 90% 2. DO-181D 2.3.2.5 does not specify the percent – the meeting to consider the addition of the 90% criteria to determine the levels 3. + correct typo error add a t before he in the 2nd paragraph 	
5.4.6.2 . Steps 7A/B/C /D/E/F/ G/H/I/	<p>Set the Master Test Set to generate a standard (i.e., -60 dBm) UF4, UF5, Mode A and Mode C interrogations and verify that the Mode A code and Altitude/ Mode C information provided in the transponder replies is correct. Repeat the procedure given in preceding paragraphs as needed to verify performance of the transponder on both top and bottom channels of diversity transponder.</p>	<p>The Master Test Set is required to be Mode A/ModeC/UF04/UF05 in the second repetition of each test. This is wrong, it shall be the Slave Test Set.</p>	<p>Proposed action: Next meeting to verify and clarify whether it is the master or the slave test set. same question for DO-181D 2.4.2.6 step 7</p>	
5.4.7.2 .f	<p>STEP 6 - Standard Interference Pulse Positioned at Mode A or Mode C Spacing before P1 of a Mode S Interrogation (Paragraphs 3.9.2.b and 3.12.5.d)</p>	<p>Wording: Mode "A/C All-Call" should be replaced by "Mode A/C ONLY All-Call".</p>	<p>it could be A/C All Call or a Mode A/C only All call – A mode S transponder will never reply to a Mode A/C Only All Call.</p> <p>Proposed action:</p>	

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	NOTE: <i>The purpose of this test is to demonstrate that when the interference pulse combines with the P1 pulse of the P1-P2 pair of a Mode S interrogation, that the transponder detects the Mode A/C All-Call . . .</i>		To avoid discussion change the end of the note to say "that the transponder does not reply with a Mode A/C reply." Same proposal for step6 of 2.4.2.7 in DO-181	
5.4.8	Undesired Replies (Paragraph 3.12.7)	Reference to 3.12.7 is wrong. It should be 3.13	Action: replace 3.12.7 by 3.13	
5.5.8.2	references to (Paragraph 3.24.4 - interrogation reply coordination, ELM)	paragraph 3.24.4 does not exist	3.24 level 3 transponder – uplink ELM capability equivalent to DO181 2.2.19.1.4 Action: replace reference 3.24.4 by reference to 3.24	
5.5.8.3	Procedure #3 – CA Verification	CA=7 is not tested on Procedure #2. Therefore the reference to Procedure #2 (interrogation acceptance) is wrong. It should be to Procedure #7 (FS and VS test)	Procedure #2 or #7 seem both a possible option. Proposed action: Meeting to decide what to do. In addition the CA procedure is very light and may need to be more detailed!	
5.5.8.4 .b.(1)	PC Discrimination The interrogation patterns are: UF = 4, 5, 20, 21. PC = 0 and DI≠3 PC = 0 and DI=3 and LSS=1 and SIS=0 PC = 1 and DI=3, PC = 2, 3, 4, 5, 6, 7. Total number of patterns = 36. With the transponder not in non-selective lockout state, interrogate with all of the above patterns consecutively. Verify that, after the sequence, the non-selective lockout state does not exist.	PC=1 and DI=3 condition triggers the non-selective all-call lockout. Therefore it should be removed from the negative test conditions.	same test in DO-181D 2.5.4.4.2 a 3.22.2.4 (Do181 2.2.18.2.4) non selective lockout and Figure 3-11 (Do-181 Fig 2-13) show that PC=1 triggers non-selective lockout whatever the value of DI. HOWEVER 3.18.4.26 (DO-1812.2.14.4.28) PC protocol states that the PC field shall be ignored for the processing of surveillance and Comm A interrogations containing DI=3 Action: Meeting to clarify this inconsistency which could result in different implementations (option 1: only PC≠1 shall be ignored see DI=3 WP option 2: consistent no PC if DI=3 – it implies modifying text and figure)	
5.5.8.1 3	a. Transponder Not Locked Out to All-Calls	Definition of PR checking intervals is statistically wrong. The lower the required reply probability	Proposed action: Improvement to be considered by the meeting (see Appendix A justifying	

ED-73C paragraph	ED-73C Text	EADS comment	Eurocontrol analysis reviewed by WG49 subgroup teleconference	WG49-SC209 agreement
		the higher is the chance for a wrong result with 100 interrogations only. The min-max-intervals could be maintained only by increasing the number of interrogations. Please refer to chapter 3 of this document.	the changes)	
5.7.5.9	PART 9: Register 4016 – Selected Vertical Intention - Data Change Validation –Set 6 (§3.30 –through- 3.30.5)	wrong numbering: Set 8	Action: Typo error, Set 6 to be replaced by Set 8 in the title of 5.7.5.9 (Set 8 Correct in DO181 2.7.5.7)	

Appendix A

EADS rational for changing Procedure #13 PR Tests



3 Analysis of ED73-C Procedure #13 PR Tests

3.1 Theoretical Basis

ED73-C Procedure #13 can be easily identified as a succession of Bernoulli experiences triggered by the transmission of an interrogation.

$$X_i \rightarrow Ber(p) \begin{cases} \text{Reply: } X = 1 \\ \text{No reply: } X = 0 \end{cases}$$

where p represents the reply probability, selected by the PR field of the UF11 interrogation.

Therefore, after n interrogations we have

$$X = \sum_{i=1}^n X_i \rightarrow B(n, p);$$

where the random variable X represents the number of obtained replies after n interrogations.

We can approximate the Binomial distribution to a Gaussian distribution

$$\text{if } \begin{cases} n > 30 \\ np(1-p) > 5 \end{cases} \text{ then } X \rightarrow N(np, np(1-p))$$

Next, we define the Estimator \hat{P} as

$$\hat{P} = \frac{X}{n} ; \text{ then } \hat{P} \rightarrow N\left(p, \frac{p(1-p)}{n}\right)$$

We use \hat{P} to estimate the reply probability p.

We define \hat{z} as a trial of the estimator \hat{P} . As well, we can normalize \hat{P} as:

$$\hat{z} = \frac{\hat{P} - p}{\sqrt{\frac{p(1-p)}{n}}} ; \text{ then } \hat{Z} \rightarrow N(0,1)$$

We can define the confidence interval with confidence level of $1 - \alpha$

$$z_{\frac{\alpha}{2}} \leq \hat{z} \leq z_{1-\frac{\alpha}{2}}$$

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File name: eads comments to ed-73c_sc.doc	Doc. No.: 30163937	TID: 000	DType EDO	Version 01
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$$p + z_{\frac{\alpha}{2}} \cdot \sqrt{\frac{p(1-p)}{n}} \leq \hat{p} \leq p + z_{1-\frac{\alpha}{2}} \cdot \sqrt{\frac{p(1-p)}{n}}$$

$$np + z_{\frac{\alpha}{2}} \cdot \sqrt{np(1-p)} \leq x \leq np + z_{1-\frac{\alpha}{2}} \cdot \sqrt{np(1-p)}$$

Identifying: $x_{\min} \leq x \leq x_{\max}$

where x_{\min} and x_{\max} represents the minimum and maximum number of obtained replies x in order to accept that the transponder is replying with a probability of p .

3.2 Modifications of ED73-C Procedure #13

According with the previous results, the acceptance interval for each value of p depends on the number of samples n and the value of the confidence level $1 - \alpha$.

In ED73-C Procedure #13 there is no reference to the confidence level used to define the acceptance intervals. We assume a confidence level value of 95%.

Using the number of samples stated in ED73-C chapter 5.5.8.13.3, we observe that the size of the acceptance intervals is considerably different to the theoretical value.

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Number of interrogations	PR	p	Replies		Replies ($\alpha=0.05$)	
			No less than	No more than	No less than	No more than
100	0*	1*	99*	100*	99*	100*
100	1	0.5	35	65	40	60
100	2	0.25	18	32	17	33
100	3	0.125	9	15	6	19
100	4	0.0625	4	8	2	11

Table 3-1: ED73-C Procedure #13 Table with original number of samples kept

*: with PR=0, no statistical process is done by the transponder. The requirement for normal operation is reply rate $\geq 99\%$.

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The size of the acceptance intervals would have to be changed if the number of interrogations is kept.

But in order to obtain more precise results it is proposed to keep the size of the acceptance intervals as they are stated in ED73-C chapter 5.5.8.13.3.

In consequence, we observe that the number of interrogations necessary to obtain those values must be much higher for the lower probabilities:

PR	p	Replies (%)		Number of Interrogations ($\alpha=0.05$)
		No less than (%)	No more than (%)	
0	1*	99*	100*	100*
1	0.5	35	65	~ 45
2	0.25	18	32	~ 150
3	0.125	9**	15**	~ 470**
4	0.0625	4**	8**	~ 565**

Table 3-2: ED73-C Procedure #13 Table with original size of intervals kept

*: with PR=0, no statistical process is done by the transponder. The requirement for normal operation is reply rate $\geq 99\%$.

** : interval not centred with respect to p. Number of samples for symmetrical interval with respect to p and rounded to fit to the interval specified.

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3.3 Change Proposal for ED73-C Procedure #13

In order to reach a reasonable compromise between number of interrogations and size of acceptance intervals, we propose to use the following verification table for the obtained replies:

Number of interrogations	PR	p	Replies ($\alpha=0.05$)		% Replies ($\alpha=0.05$)	
			No less than	No more than	No less than (%)	No more than (%)
500	0	1*	495*	500*	99*	100*
500	1	0.5	228	272	45.6	54.4
500	2	0.25	106	144	21.2	28.8
500	3	0.125	48	77	9.6	15.4
500	4	0.0625	21	42	4.2	8.4

Table 3-3: ED73-C Procedure #13 Proposed Table

* : with PR=0, no statistical process is done by the transponder. The requirement for normal operation is reply rate $\geq 99\%$.

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File name: eads comments to ed-73c_sc.doc	Doc. No.: 30163937	TID: 000	DType EDO	Version 01
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Template No. PE-0331-EN, Date: 21.07.2005, (German Source Doc.: No. PE-0176-DE)