ACD 32090/10

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MODE S CPME TEST

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[redacted]

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DOT/FAA/CT-ACD32090/10
CPME Test No. 4 Results

On May 17 and 18, 1989 personnel from Northrup-Wilcox delivered a CPME to the FAA Technical Center for testing. The primary purpose was to verify a correlation between this data and that collected previously by Northrup-Wilcox with their own test equipment. The following people attended:

NAME	COMPANY	PHONE	TITLE
John Stanks	FAATC	609-484-5338	ET
Lynn Blevins	Wilcox	816-453-2600	EE
Leo J. Wapelhorst	FAATC	609-484-5542	EE
John Van Dongen	FAATC	609-484-6949	ET
Jim Mc Loed	UNYSIS	215-648-2981	EE

All tests run during the previous visit, were rerun to verify that no changes had occurred.

PART 1--TEST RESULTS--Standard MTPA Tests

The test numbers indicated are the number assigned to the particular MTPA test. Tests prefixed with an asterisk (ie. *Test 1) indicate a disagreement between the new data and previous data. Test results were compared to both our old data (taken back in 1987) and that furnished by Northrup-Wilcox. Data furnished by Northrup-Wilcox was from three different series of tests (1) Design Qualification tests - figures are labeled DQxx (2)Type Tests - labeled TTxx (3)Production tests - labeled Pxx. Whenever results were available from all types of tests, it is discussed below.

All tests except those which require several levels (ie. dynamic range etc.) were run at the default interrogation level of -30 dbm.

Test 1. ATCRBS Dynamic range test

This test was run in 3 modes (Mode A, C and 2). The new data is shown on figures 1 (Mode A) where the sensitivity is measured at -49dbm, figure 50 (Mode C) where it is -51dbm, and figure 51 (Mode 2) where it is also -51dbm. The data shown for all tests conducted at Northrup-Wilcox indicates a sensitivity of -50dbm. This is factory set at this value. When Mode A was rerun several hours later, the sensitivity was also measured at -51dbm (originally it was the first test conducted after the checkout of the CPME).

***Test 2. ATCRBS Reply Characteristics Test**

See figures 2 and 3 for the test results. The CPME was tested using its high power output amplifier. The measured power output was approximately +52 dbm as shown on figure 2. This compares with the values achieved in the tests conducted in 1987. Data taken manually at Wilcox in May of 1990 indicated an output power of approximately +54dbm. (The required value is +55 dbm).

The delay, power, pulse width, frequency and droop all appear to be well within specification as indicated on figure 3. All values compare favorably with the data furnished by the the Wilcox personnel.

Test 3. ATCRBS Mode Acceptance - Pulse Position

See figure 4 for the test results. The data indicates satisfactory decoding of the ATCRBS Mode A and Mode C interrogations. We neglected to run the same test for Mode 2.

****Test 4. ATCRBS MODE acceptance - pulse width**

See figure 5 for the test results. The data indicates that there is no maximum pulse width rejection (at least not for pulse widths less than 1.5 us). We modified the test and extended the range of testing out to 1.8 us. Test data is shown on figure A-8 and indicates no maximum pulse width discrimination. The specification covering maximum pulse width discrimination is paragraph 2.7.6 of FAA order 1010.51A, which reads: "With the exception of single pulses with amplitude variations approximating an interrogation, any single pulse of a duration more than 1.5 us shall not cause the transponder to initiate reply or suppression action over the signal amplitude range of minimum triggering level (MTL) to 50 db above that level." If this specification is interpreted as the *single pulse being present with another pulse* (which may make it into a mode pair or suppression pair), then *maximum pulse width discrimination is required*. If interpreted that the spec means a *single pulse alone*, then *maximum pulse discrimination is not required*. It was the *consensus of those present* (during the tests of 1987), that the latter interpretation was meant by the spec and *maximum discrimination is not required*.

Test 5. ATCRBS Side Lobe suppression test (Amplitude)

See figure 6 for the test results. The tests showed excellent amplitude SLS characteristics . In the areas where the P1/P2 is 9 db or greater(P1 exceeds P2 by 9 db), the transponder must reply at a rate of at least 90 %. The gray zone, where the ratio is 6 and 3 db, the performance is undefined. The area, however, where P1=P2 (0db) and exceeds it by 3 and 6 db, the transponder must suppress at least 99%. Performance measured was excellent. Figure 7 shows the delay characteristics at the various P1/P2 ratios. This data also matched that of Wilcox.

Test 6. ATCRBS Dead Time .

See figure 8 for the test results. The measured "dead time" was approximately 35 us, compared to 32 us on the Wilcox data, both well within tolerance.

Test 7. ATCRBS Suppression time.

See figure 9 for the test results. The suppression time (approximately 32 us for both Modes A and C, is well within the prescribed 25 to 45 microsecond limits. Their data also indicated 32 us.

Test 12. ATCRBS SLS Mode acceptance - Pulse Position

See figure 10 for the test results. The performance is well centered within the tolerance window. No comparative data was presented by Wilcox.

****Test 13. SLS Characteristics - Pulse Width**

See figure 11 for the test results. The test shows rejection of pulses below .3 us and acceptance of all pulses wider than that to at least 1.5 us. This test was modified to extend the range of pulse widths to 1.8 us. Figure 11 shows that there is no maximum pulse width discrimination up to this value. The following paragraph is lifted from the report of 1987.

The same discussion applies that was cited in the description of test 4 above. In this case, however, another test was performed to determine if the single wide pulse initiated a suppression. A single wide pulse (2 us wide) was followed by a normal mode 3/A interrogation. If a suppression was caused by the single wide pulse, the CPME would not have answered to the Mode 3/A interrogation as it did. Therefore it can be assumed that the wide pulse did not initiate a suppression and meets the consensus interpretation of the specification as described in test 4.

Test 14. ATCRBS Sensitivity Test

See figure 12 for the test results. This test is a successive approximation search for the MTL of the CPME and shows approximately the same sensitivity as the dynamic range test of test 1. This also agrees with all the data from Wilcox, which showed the sensitivity to be -50dbm for all modes.

Test 20. ATCRBS ONLY ALL CALL Test

The test results are shown on figure 13. The CPME, as specified, does not respond to the ATCRBS ONLY All Call interrogations. The recovery interrogation, however, should produce a response (100% as indicated).

Test 31. ATCRBS/Mode S All Call Dynamic Range test

See figure 14 for the test results. This data shows the sensitivity to be the same as the Mode A ATCRBS sensitivity (-49dbm).

Test 32 Mode S All Call Dynamic Range

See figure 15 for the test results. The measured sensitivity in this test was -49dbm.

Test 33 Mode S Roll Call Reply Pulse Characteristics Test

See figures 16 and 17 for the test results. The reply power, power difference between the first and last reply pulse, the reply frequency are all acceptable. An error in the MTPA measurement because of the rise time of the first pulse. When a correction is applied for this, the data correlates very well with that furnished by Wilcox. Figures 67 to 69 show the performance at various power levels.

Test 34 Mode S All Call Reply Characteristics Test

See figures 18 and 19 for the test results. This reply type shows the same characteristics as those described in Test 33 above.

***Test 35 ATCRBS / Mode S Acceptance---P4 Level**

See figure 20 and 61 to 66 for the test results. This test was rerun on the second day as figure 20 showed a problem at high signal levels. Reference to the first CPME test report (CT-150-86-63) shows that originally, the CPME had a problem at high signal levels in Mode C. This problem was corrected in later models. We were unable to duplicate the performance on the second day of testing as indicated in figures 61 to 66.

Test 36 ATCRBS/Mode S Acceptance---- P4 position

See figure 21 for the test results for Mode A. This test fixes either the lead or trail edge of P4 and varies the other in time. The point at a lead edge position of 2.0 us is the nominal position for this interrogation type. The acceptance window should be centered about this value. This data compares favorably with that furnished by Wilcox. They apparently did not keep the edges fixed, but maintained a constant pulse width of 1.6 us for their test.

Test 37 ATCRBS / Mode S Acceptance Test --- P1/P3 width

See figure 22 for the test results on Mode A (we forgot to run Mode C). No data was furnished by Wilcox for comparison.

Test 38 Mode S Acceptance --- Sync Phase Position

See figure 23 for the test results. This data correlates very well with that furnished for all the tests (Mode S sync phase reversal Position test Number 38).

Test 39 Mode S Acceptance -- Pulse combination

See figure 24 for the test results. As indicated on the sketch, the stray pulse combines with P1 and P2 of the Mode S interrogation to form an ATCRBS ONLY ALL CALL (because the pulse seen as P4--really P2 of the Mode S interrogation is .8 us wide). Mode S transponders reject this interrogation.

Test 40 Mode S Dead Time Test (Reply requested)

See figure 25 for the test results. The dead time is specified to be measured from the last reply pulse of the previous reply to the position of P1 of the succeeding interrogation. The dead time appears to be less than 5 us. The data furnished by Wilcox measures it at 2us.

***Test 41 Mode S Dead Time Test (Bad Parity)**

See figure 26 for the test results. Dead time is approximately 25 us as a result of handling an interrogation with incorrect parity. This is well within the allowed 128us. A slight discrepancy exists here, apparently an interpretation of the specification. The data furnished by Wilcox indicates a recovery time of 1us. This approximately the time from the trail edge of the first interrogation to P1 of the second. The MTPA test reference is sync phase to sync phase. The first tested point is 20us (which correlates to .75us when using the reference apparently used by Wilcox). The reply rate is approximately 30%. This is really irrelavant as the performance is well within specified limits.

Test 42 Mode S Dead Time Test (Broadcast)

See figure 27 for the test results. The dead time from a broadcast interrogation is approximately 25 us.

Test 43 Mode S Dead Time Test (Comm C)

See figure 28 for test results. This tests exhibits the same interpretation as test 41 discussed above. Performance is well within limits.

***Test 44 Mode S Dead Time Test (Suppression Pair)**

See figure 29 for the test results. Data submitted by Wilcox for this test shows a time of 20us. The data from all the different test groups (design qualification, type test, production test etc all agrees). It lists a specification limit of 36us. This is also a possible misinterpretation of the specification. The CPME should not suppress because of a suppression pair as the Mode S decoding and suppression logic are supposed to be independent.

Test 47 Mode S Roll Call Interrogation Dynamic Range Test

See figure 30 for the test results.

Test 50 Non-Selective All Call Lockout Tests (Required Negative Tests -- MOPS Procedure #4-Par. 2.5.4.4.2

See figures 31 to 34 for the test results. This test, which uses all illegal methods to attempt to lock out the CPME to non-selective all call interrogations, showed that the CPME responded properly in all cases. The failure to reach a 100% reply rate on the Mode S All Call interrogations in the UF = 20 rows is a MTPA problem. The duty cycle of the interrogation pattern is such the the local oscillator is sometimes pulled out of phase lock resulting in "off frequency" interrogations which are not seen by the CPME.

Test 51 Non-Selective All Call Lockout Tests (Required Negative Tests -- MOPS Procedure #4-Par. 2.5.4.4.2 continued

See figure 35 (figure 36 is a duplicate) for the test results. This test sends a UF=4 interrogation which puts the CPME in the non-selective lockout state. It then interrogates with all Interrogator Identifier (IIs) codes from 1 to 15 to see that they are not locked out.

Test 55 Mode S Multisite Lockout (Negative Test) -- MOPS Procedure #5 (Insensitivity to all invalid Signals)

This test tries to initiate the lockout state for all invalid combinations of the DI field, the IIs field, and the LOS field for interrogation types UF=4,5,20 and 21. The CPME should ignore all the illegal requests. On the last trip, the responses to the UF=4,5,20 and 21 all contained parity errors, so the all call interrogations to check the multisite timers were never made. Figures 37 and 38 show the test results. As indicated, the CPME does not initiate any of the multisite timers on the illegal combinations of the DI and LOS fields (Note the absence of DI=1 and 7 on sheet A-46 as these are legal combinations to initiate the multisite timers).

Test 56 Mode S Side Lobe Suppression test

The test results are shown on figure 39. The suppression characteristics of Mode S interrogations appear to be no problem. Figures 70 to 72 show the data for other levels as indicated on the data supplied by Wilcox. This data also correlates.

Test 57 Standard Interfering Pulse During P6

This test (which was developed during this session) moves a "standard interfering pulse" (a 0.8 us pulse from an asynchronous RF source) in 1 us increments across the entire P6 data block. The initial insertion point is 1 us after the occurrence of the sync phase reversal. The level of the pulse is 3 and 6 db below P6 for the two halves of the test.

This test uses Mode S interrogation content of all "1's" to provide the CPME the maximum number of phase reversals. The performance is indicated on figure 40. Excellent correlation exists between this data and that furnished by Wilcox.

Test 58 ATCRBS ONLY ALL CALL WITH SYNC PHASE 100 NS EARLY

This is not a standard MTPA test. It was developed on the first trip during the investigation of the position of the sync phase acceptance window (see test 38). Since the problem is now fixed, the response is properly 0% to this test as indicated on sheet figure 41.

****Test 65 Mode S All Call Protocol and Lockout-- MOPS Procedure #4 (Positive Tests) Par. 2.5.4.4.1**

This test consists of all the legal interrogation types and combinations of the PC, DI, LOS and IIs fields of those interrogations which should be able to activate the non-selective lockout timer. The data on the results of the test are shown on figure 42. On the last trip, replies to all the interrogations which should activate the timer contained incorrect parity. The test was aborted as a result. As indicated, the timer is now activated only in the non-multisite mode (PC = 1). The activation of the non-selective timer with the multisite protocol (DI = 1 or 7, LOS = 1 and IIs = 0) was a part of "Change 2 to the MOPS" and apparently the CPME is not required to meet this requirement.

Test 66 Mode S Multisite Timer Uniqueness Test -- MOPS Procedure #5 (IIs discrimination)

This test insures that only the multisite timer which matches the IIs which initiated the lockout is locked out. A site issues a lockout and then all other IIs values are issued to insure that none of them are also locked out. The data is shown on figure 43. The timer values of this test are the actual values of the timers as one of the intents of this test is to measure the actual value of them.

The following exerpt is from the last report when an investigation of the timer accuracy was performed as a result of the difference between the first timer and the others.

An analysis of the MTPA test was done when timer 1 showed a time of 16.5 seconds and all the rest were 17.9 seconds as the Wilcox personnel indicated that there was no difference between them. The sketch on sheet A-52 will explain what happened. The CPME was implemented with a 2 second clock to control the timers. Thus, the initiation of the first timer is an asynchronous event which can happen at any time between the two clock ticks as shown. The timer will time out, however, when a clock tick occurs. Thus the time for timer 1 must be somewhere between 16 and 18 seconds depending on the time of initiation with respect to the 2 second clocks. Immediately upon timeout of timer 1, timer 2 is activated and the MTPA is in sync with the 2 second clock. Thus all timers after this will show approximately 18 seconds. In actual use, however, all timers will act like timer 1 and give a value of 16 to 18 seconds. Change 2 of the MOPS changed the multisite timer specification to 18 plus or minus 1 second, but the CPME is required to meet only the plus or minus 2 second requirement of the Mode S National Standard.

Test 67 Mode S Multisite Timer Protocol--MOPS Procedure #5 (Positive Tests)

Figure 44 shows the results of this test. The multisite timers are tested for each of the UF=4,5,20 and 21 interrogation types. The reset logic of the multisite timers is also tested for all the surveillance interrogation types and IIs values. The timer values are not to be interpreted as the actual values as it was decided to forgo accuracy in this test for run time of the test. Test 66 should be used as the true value of the timers.

Test 68 Mode S Stochastic All Call Test

The test results are shown on figure 45. The MTPA makes 100 interrogations with each value of the PR field and compares the reply rate to the expected rate. A non-selective lockout is then issued and the interrogations are repeated. There is no spec for the accuracy of the stochastic process but the reply probabilities seem to be approximately those requested. Excellent correlation is also achieved between this data and that furnished by Wilcox.

Test 70 Mode S Short Message Protocol

Test 70 issues all short interrogations with all UF code values from 0 to 24 with three different Mode S ID's (all 0's, all 1's and the correct ID). Following each interrogation is another spaced at 128 us from the first to check the recovery from each. If the CPME answers the first interrogation it will not answer the recovery one. If it does not answer the first, however, it should always answer the recovery. Figure 46 shows that the CPME did properly handle the Short Message Mode S Protocol.

Test 71 Mode S Long Message Protocol

This test is the same as test 70 but uses long interrogations instead of short ones. The results are shown on figure 47.

Test 72 Mode S Broadcast Effect on Multisite Timers

This test issues lockout commands for each of the multisite timers in a broadcast message. It then verifies that the commands were ignored. Also checked is the recovery from a broadcast interrogation. The test results are shown on figure 48. Previously the site with IIs = 7 was locked out by a broadcast every time.

^Test 73 Mode S Address Test

This test changes the Mode S address to 552 different values via the MTPA interface and then verifies that the transponder responds to that address, reports that address in UF = 11 replies and does not respond to a different address. The address of the CPME cannot be changed in this manner, so this test was not run.

Test 108 Reply Rate Capability Test ---MOPS Procedure

Test 108, the MOPS burst reply rate capability test produced the data shown on figure 49 which shows no problems.

***MISCELLANEOUS TESTS**

(1.0) Comm B Multisite Protocol

An attempt to run the multisite Comm B MOPS test was unsuccessful. This test is MOPS Procedure #18 outlined in paragraph 2.5.4.18 of the MOPS. The test consists of a matrix of 7 transponder states and 24 interrogation types. In the first transponder state, there is no "message waiting" which in the CPME"s case means that there was no previous Comm A message. Interrogation type 12 attempted to make a Comm B reservation for site 1. The MOPS states that a transponder must not accept this reservation, but a value of "5" in the UM field indicates that the CPME did accept the reservation. This looks like another case of MOPS requirement vs. the CPME requirement. Appendix 8 of FAA-E-2716 in paragraph 80.3.4.1 indicates that the sensor will not request the data until it has received a message from the CPME containing a "B bit". This requirement would make the interrogation of state Number 12 illegal as no prior message was sent to the transponder. It is puzzling, however, why the unit would accept a reservation if it had nothing to send down.

Rather than use up a lot of time trying to continue on the Comm B protocol, a series of tests using several utility MTPA programs were conducted to investigate problems and also to learn as much as possible about the CPME performance. The tests will be discussed individually along with the reasons for running them.

(1.1) Wilcox test 202

This test checks the special ATCRBS ONLY LOCKOUT PROTOCOL of the CPME. We did not have an existing MTPA test which would adequately check this function, so we could not verify the data submitted by Wilcox.

(1.2) Wilcox test 203

This test gives the CPME delay and jitter performance at several signal strengths throughout the dynamic range. We do not have an equivalent test, but the data correlates very well with that obtained during the various dynamic range tests which collect data on delay and jitter.

(1.3) Wilcox test 204

This test checks that the CPME will not reply to various inputs. We do not have tests which specifically check for this, but we generated the interrogations via several utility programs and verified via the oscilloscope that the CPME did not respond to any of them. The four interrogations were:

1. ATCRBS Mode 3/A with P2 - This is only one point of the data collected during the SLS tests.

2. A single 0.8us pulse - no replies were seen.
3. A single 16us pulse - we could not test this one.
4. CW - this was created by removing the PAM Drive Line which makes the interrogator go into the CW mode. No replies were seen.

(1.4) Wilcox test 205

This test gives the delay and jitter performance when interrogated with an ATCRBS/Mode S All Call interrogation. As stated above in test 203, this data is collected during all the MTPA dynamic range tests. It compares with the data presented by Wilcox.

(1.5) Wilcox test 206

This test checks the ATCRBS reply format in response to Modes 2, 3/A and C. We used MTPA test #2 to check the reply content. This data is shown on figures 52 (Mode C) and 56 for Mode 2. Reference back to figure 2 verifies the code for Mode 3/A.

(1.6) Wilcox test 207

This test checks various reply fields in the Mode S reply. Fields checked are the Address, Capability, Altitude, Call Sign, ATCRBS Identity and Extended Capability report. A LFT (Leo's Format Test) file was created (W1), which generated the scenario of test 207. The data was then checked manually for proper content. The results are shown on figure 55.

(1.7) Wilcox test 208

This test interactively checks the CPME status reply bits. Figures 80 and 81 show the results of this test which was run by using a LFT file. The status bits were controlled by switches on a test box furnished with the CPME. Part of the test also checks the status bits which can be set via the interrogations. All the results were as expected.

(1.8) Wilcox test 210

This test verifies proper operation of the standard message interface of the CPME. This test was simulated by another LFT file (W210). Figure 58 shows the interrogations issued along with the reply content. All replies contained the expected data.

(1.9) Wilcox test 211

This test verifies proper operation of the ELM interface of the CPME. This test was simulated by LFT files (W211I and W211R). W211I instructs the CPME to expect a 16 segment ELM and loads the CPME by sending up 4 at a time. After each group of 4 interrogations, the status of the CPME is checked via the final segment interrogation (of the group of 4). Each time, the CPME acknowledged receipt of another 4 segments as specified. When all the segments (16) were finally issued, the CPME acknowledged receipt of all and then issued a request to send down a 16 segment 'downlink ELM'. Figure 59 shows this scenario and the last reply does contain a request to send down a 16 segment 'downlink ELM'. The LFT utility can only handle one reply at a time. Therefore file W211R extracts the downlink ELM replies in that manner. The results of this scenario are shown on figure 60. The data is correctly echoed down via the downlink ELM as specified.

(1.10) Wilcox test 212

This test which tests the Comm B protocol of the CPME.

(1.11) Wilcox test 213

This test which tests the Comm C protocol of the CPME.

(1.12) Wilcox test 214

This test which tests the Comm D protocol of the CPME.

The CPME protocol is slightly different than that of a transponder, so Comm B, Comm C and Comm D protocols could not be adequately checked by existing MTPA tests. At this time, no effort exists to write software to perform these tests. When the new DATAS (Data Link Test and Analysis System) is completed, it will be able to conduct these tests.

SUMMARY

1. SENSITIVITY MEASUREMENTS :The sensitivity of the CPME was measured to be within 1 db of the specified value (-50 dbm).

2. REPLY DELAY: The reply delay measurements all correlate with the data submitted by Wilcox.

3. REPLY POWER MEASUREMENTS: Automated data was not submitted by Wilcox on their measurements of reply power. The only data submitted, was manually collected using a detector and an oscilloscope. This data showed the output power to be approximately +54dbm (the specification calls for +55dbm). All the MTPA data indicates a power of approximately +52dbm, or approximately 3db below the specified value. It is not known, why the reply power data from the AUTOMATED TEST UNIT was not submitted, as it is collected on the majority of the tests.

4. TIMING MEASUREMENTS: All the measurements in which time is the variable, (ie. interrogation acceptance/rejection) agreed with the data submitted by Wilcox.

5. PROTOCOL MEASUREMENTS: Most of the protocol tests could not be totally verified as the MTPA tests are written for Mode S transponders and the protocol is slightly different. Whenever possible, utility programs of MTPA were used to simulate the tests which produced the Wilcox data. In all these cases, the data matched that submitted by Wilcox. It is important, however, that the protocol be thoroughly checked out in order to prevent the occurrence of system problems later. When the DATAS is completed, it will be capable of performing these tests if desired.