Test Report for the Coexistence of PMSE with Aeronautical Services in the Band 960-1164 MHz

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Approved and released by:

Oliver Parker

List of Acronyms

Acronym	Meaning
ADS-B	Automatic Dependant Surveillance –Broadcast
APIS	Any Point In Space
ASOP	Acquire Stable Operating Point
BSOP	Break Stable Operating Point
CAA	Civil Aviation Authority
CNS	Communications, Navigation and Surveillance
DME	Distance Measuring Equipment
DUT	Device Under Test
FCA	Frequency Clearance Agreement
FIR	Flight Information Region
FRUIT	False Replies Uncorrelated with Interrogation Transmission *or*
	False Replies Uncorrelated In Time
GA	Geographic Area
GNSS	Global Navigation Satellite System
ICAO	International Civil Aviation Organization
MOD	Ministry of Defence
Mode A	A code identifying an aircraft and set for the duration of a flight.
Mode C	A code identifying the current altitude of an aircraft.
Mode S	A message addressed to or from a ‘Selected’ aircraft.
PMSE	Programme Making and Special Events
RF	Radio Frequency
SMR	Successful Message Rate
SSR	Secondary Surveillance Radar
TSDF	Time Slot Duty Factor

Contents

1 BACKGROUND

1.1 Ofcom would like to determine the impact of the coexistence of Programme Making and Special Events (PMSE) low power systems with incumbent aeronautical Communications, Navigation and Surveillance (CNS) systems operating in the band 960-1164 MHz. There are a number of CNS systems operating in this band including Distance Measuring Equipment (DME), Secondary Surveillance Radar (SSR) as well as the Military Tactical Data Link system known as Link-16.

1.2 JCSys have been contracted by Ofcom under contract no. 1358 to test the impact of PMSE on the existing systems operating in the 960-1164 MHz frequency range and well as the impact of those systems on PMSE. JCSys have been testing the compatibility of Link-16 with CNS systems for a number of years and as such have access to a wide range of in service CNS equipment in support of this test programme.

2 OBJECTIVES

2.1 The objective of this test report is to present the results of the testing carried out by JCSys to determine the compatibility of PMSE with the existing CNS system operating in the 960-1164 MHz frequency range.

3 APPROACH

3.1 A simulated PMSE transmission signal will be used to determine if there are any changes to the performance characteristics of various CNS equipment receivers in the presence of PMSE signals. To ensure an accurate representation of the real Radio Frequency (RF) environment is used, a complex RF signal environment will be simulated which includes the presence of Link-16 as detailed below in Test Configuration Sections of this document.

3.2 The PMSE equipment performance will also be measured using an audio quality measurement system supplied by Ofcom. The audio recording system will be used to determine any changes to PMSE audio quality and performance while operating in the simulated CNS RF signal environment.

4 DME GROUND BEACON TEST CONFIGURATION

4.1 Overview

4.1.1 In accordance with the requirement JCSys has tested a range of DME Ground Beacons for coexistence with PMSE signals.

4.1.2 It has been agreed that testing of DME beacons will be used to read across to Military Tactical Air Navigation (TACAN) systems, that are for the purposes of testing identical in their operation (reference email from Clive Beamish (MoD) to Ofcom, 25 February 2015 12:29, Subject: Compatibility of new TACANS).

4.1.3 In accordance with the agreed Test Specification DME Ground Beacons were tested in a representative RF pulse environment, which includes DME and Link 16 pulses. PMSE signals were introduced into the RF environment to determine the effect on DME Ground Beacon performance.

4.1.4 All testing has been carried out under controlled laboratory conditions with the raw data recorded and stored so that all elements of the testing can be re-visited and repeated at a later stage if required.

4.2 DME Pulse Environment

4.2.1 DME Ground Beacon testing was carried out on both X and Y channel.

4.2.2 The following DME pulse environments were used:

- For a Y mode DME beacon 1200 pulse pairs per second (ppps) on-code load (36us spacing) + 300ppps off-code load (12us spacing).
- For an X mode DME beacon 2200ppps on-code load (12us spacing) + 300ppps off-code load (36us spacing).

4.2.3 Testing was carried out on both the Co and Adjacent channels.

4.3 Link-16 Pulse Environment

4.3.1 The link-16 pulse environment used in the testing represents the UK Any Point In Space (APIS) 70NM radius Geo Area at 60% Time Slot Duty Factor (TSDF), known as 70/60. This represents the pseudo random frequency hopping Link-16 pulse environment as approved to operate in the UK FIR.

4.4 PMSE Signals for Interference Testing

4.4.1 Four independent PMSE channels, with frequencies defined by Ofcom (Table 4-1), were simulated using CW carriers with no modulation.

PMSE Frequency Set for 1125MHz Channel: 101X/Y	
Co-channel	**Adjacent Channel**
1124.6	1123.975
1124.9	1124.35
1125	**1125**
1125.25	1125.6
1125.7	1126.025

Table 4-1 – PMSE Test Frequencies

4.4.2 Each of the four channels has the same transmission power to represent being part of a single PMSE system, as shown in Figure 4-1 below. The common parameters are varied as follows:-

- Signal Power, as measured at the receiver of the DUT, from -127 dBm in 1 dB steps.
- Offset frequency from nominal operating frequency of DUT, from 0 MHz in 200 kHz steps.

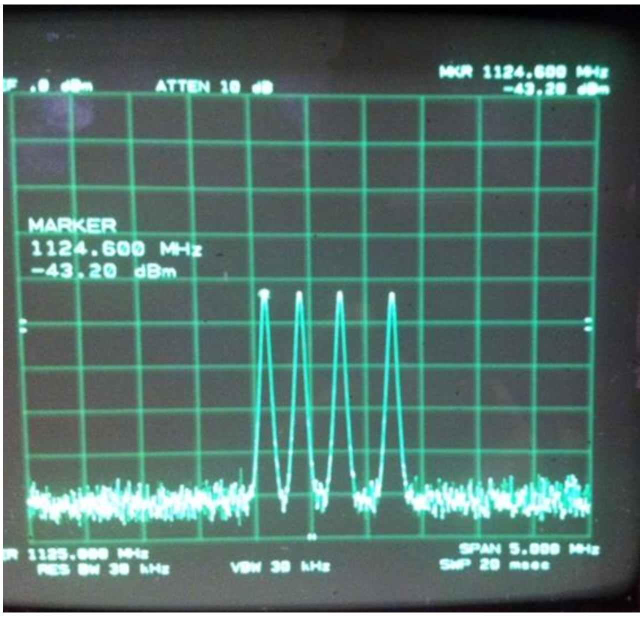


Figure 4-1 – Four PMSE Channels used for testing

4.5 Measurement Approach

4.5.1 Testing was undertaken on DME Channel 101X (1125MHz) using a Desired Signal of 150 ppps and then repeated on DME Channel 101Y.

4.5.2 Testing was also undertaken with the PMSE signals on the Adjacent Channel to measure the effect.

4.5.3 In order to produce a Beacon Reply Efficiency (BRE) curve, 20 Desired Signal Levels were used:

- -50,-60,-70,-80,-82,-84,-85,-86,-87,-88,-89-90,-91,-92,-93,-94,-95,-96,-97,-98. (dBm)

4.5.4 Testing was initially carried out using the full pulse environment as specified above. JCSys then undertook an additional set of tests without the presence of the Link-16 signal. This was done in order to comply with a request from Ofcom, for the purposes of comparison, and to allow a more complete analysis of the results.

5 DME GROUND BEACON TESTING RESULTS

5.1 Introduction

5.1.1 DME Ground Beacons are an air radio navigation technology that transmits reply signals in response to received interrogation signals. Aircraft use DME airborne interrogators to determine their slant range from DME Ground Beacons by sending and receiving pulse pairs, of specific spacing. A typical DME Ground Beacon system for en-route or terminal navigation will have a 1 kW or 100W respectively peak pulse output on the assigned UHF channel.

5.1.2 Three DME Ground Beacon types were used by JCSys as part of the PMSE test programme, these are:

- Fernau 2020 (Used extensively within the UK Flight Information Region, NATS Enroute)
- Thales 415 (Used for military ILS and civil applications)
- Fernau 1117 (Used for civil applications)

5.2 Pass/Fail Criteria

5.2.1 The performance requirements of a DME Ground Beacon are defined in ICAO Annex 10.

5.2.2 The specific test parameter to be measured is Beacon Reply Efficiency (BRE). BRE performance is the measurement of a known number of interrogations resulting in a processed number of replies normally expressed as a percentage (a BRE of 100% means all interrogations are processed successfully into replies).

5.2.3 ICAO Annex 10 states that a DME beacon must maintain 70% beacon reply efficiency and that it must be able to achieve this at a power density of -103dBW/m2 for Enroute and -93dBW/m2 for Aerodrome approach.

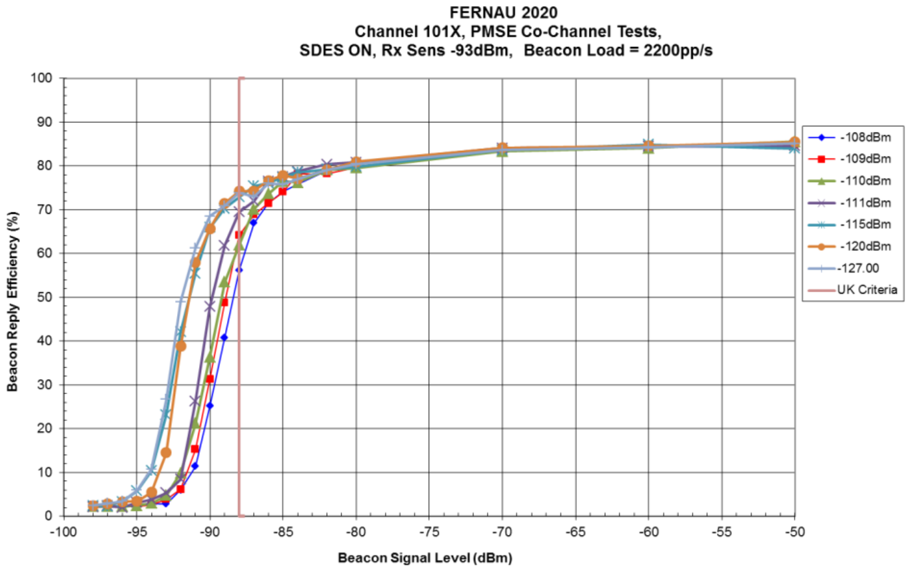
5.2.4 A UK criteria for DME Ground Beacons has been derived from ICAO Annex 10 using a typical antenna gain and cable loss to determine a signal level of -88dBm for Enroute and -78dBm for Aerodrome DME’s. These levels had been previously agreed between the UK CAA and UK MOD.

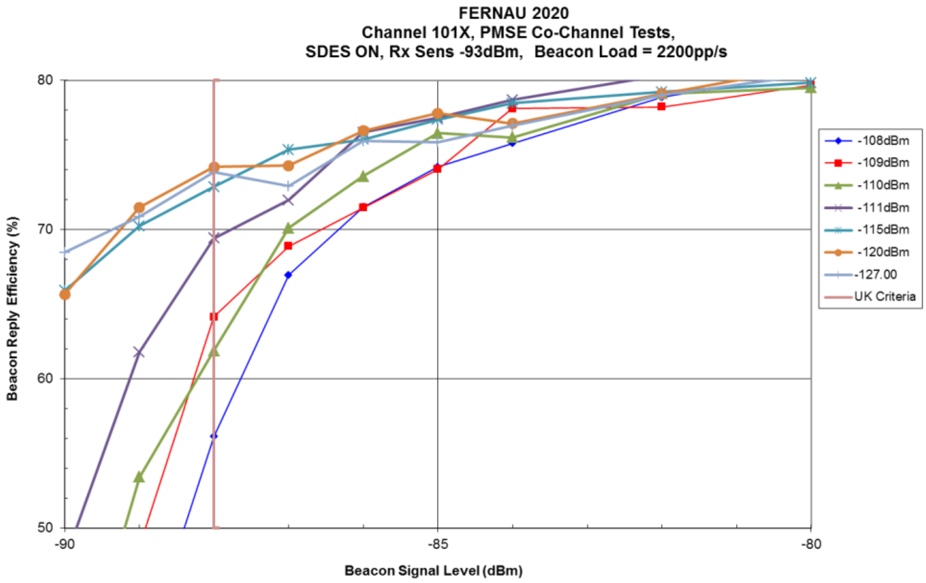
5.3 Fernau 2020 Test Results

5.3.1 Fernau 2020 Full Pulse Environment Testing, Co-Channel

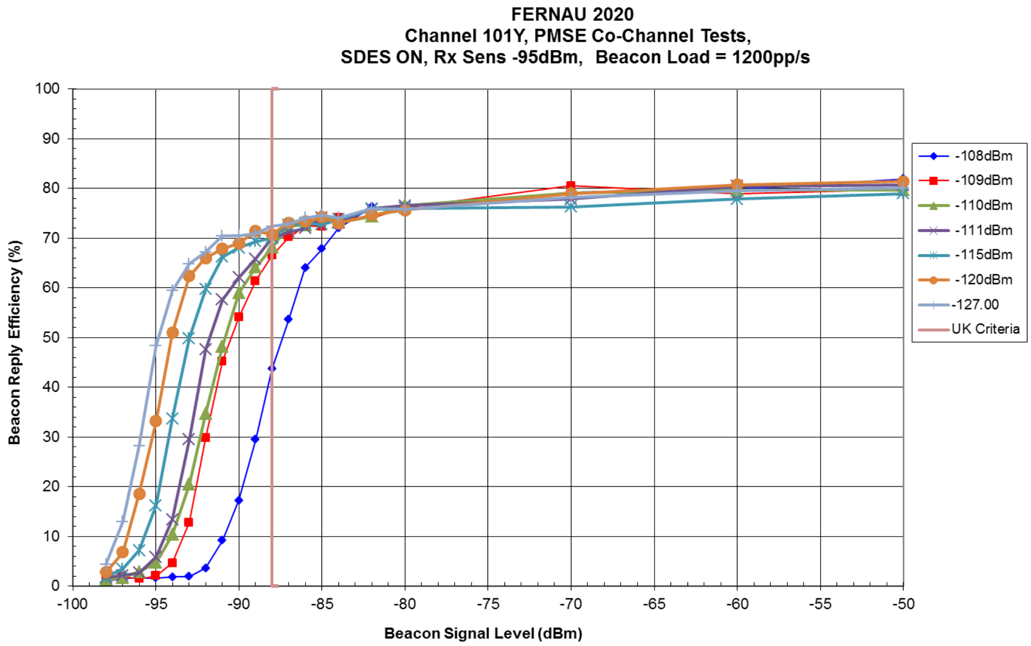
5.3.1.1 The following charts shows a number of reply efficiency curves for a Fernau 2020 ground beacon operating in X and Y mode when tested with the full pulse environment as specified in section 4 above.

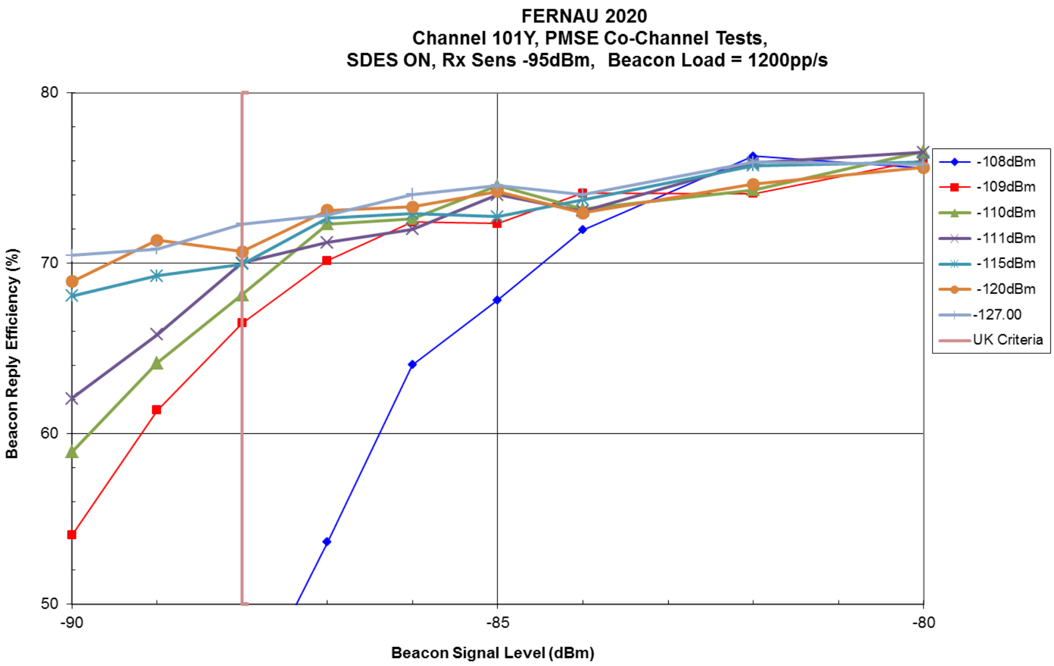
5.3.1.2 The PMSE signal level is measured at the receiver input of the beacon. Expanded views are also provided in each case.





Figures 5-1 & 5-2 – Fernau 2020, 101X, Co-Channel Test, Full Pulse Environment



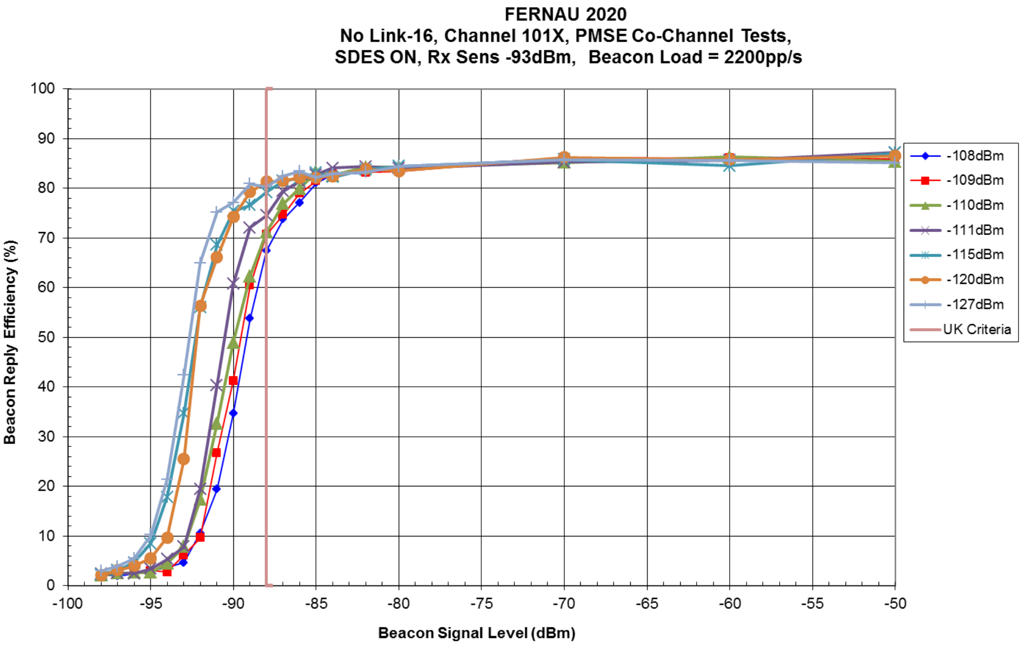


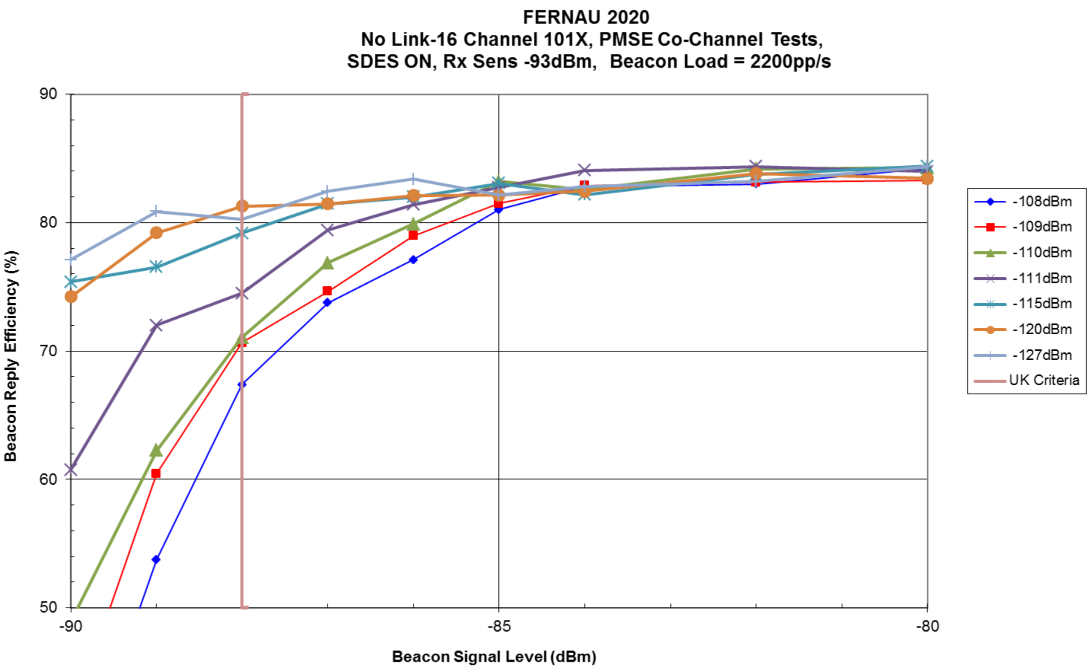
Figures 5-3 & 5-4 – Fernau 2020, 101Y, Co-Channel Test, Full Pulse Environment

5.3.1.3 The test data indicates that a PMSE signal level of -111dBm should not be exceeded for the co-channel case for Y mode. A signal level of -111dBm just causes a fail of the criteria for X mode.

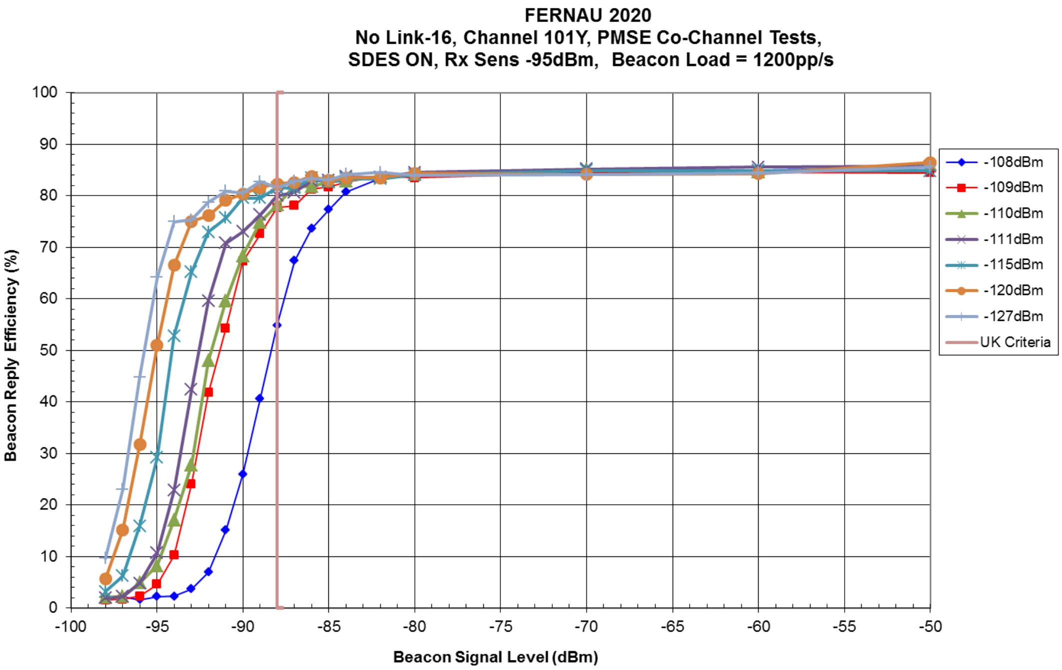
5.3.2 Fernau 2020 No Link 16 Testing, Co-Channel

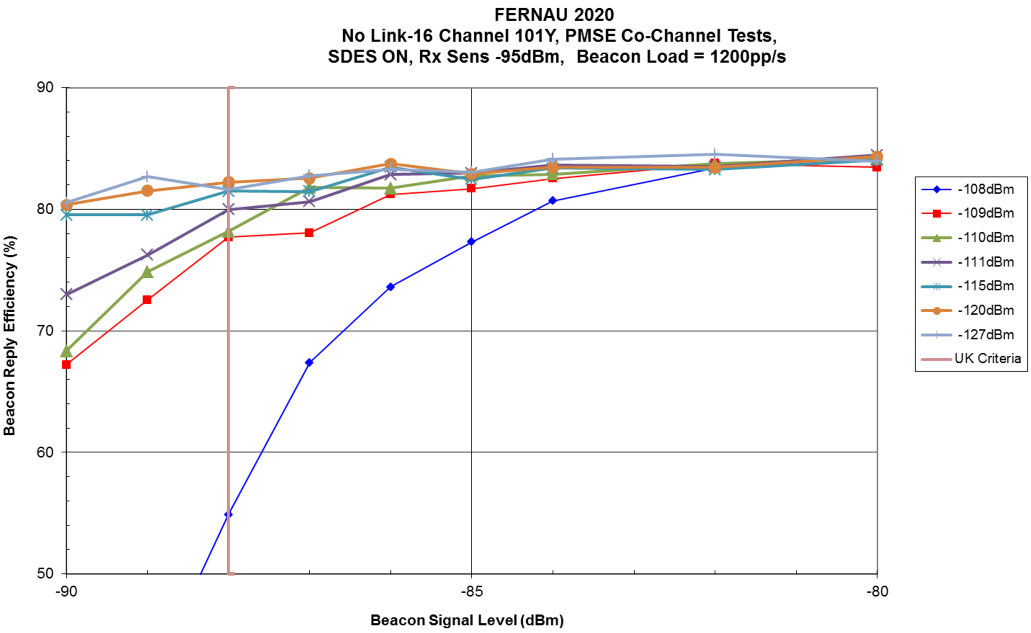
5.3.2.1 Testing was also carried without the presence of the specified Link-16 pulse environment for the purposes of completeness, the results were as follows:





Figures 5-5 & 5-6 – Fernau 2020, 101X, Co-Channel Test, No Link 16

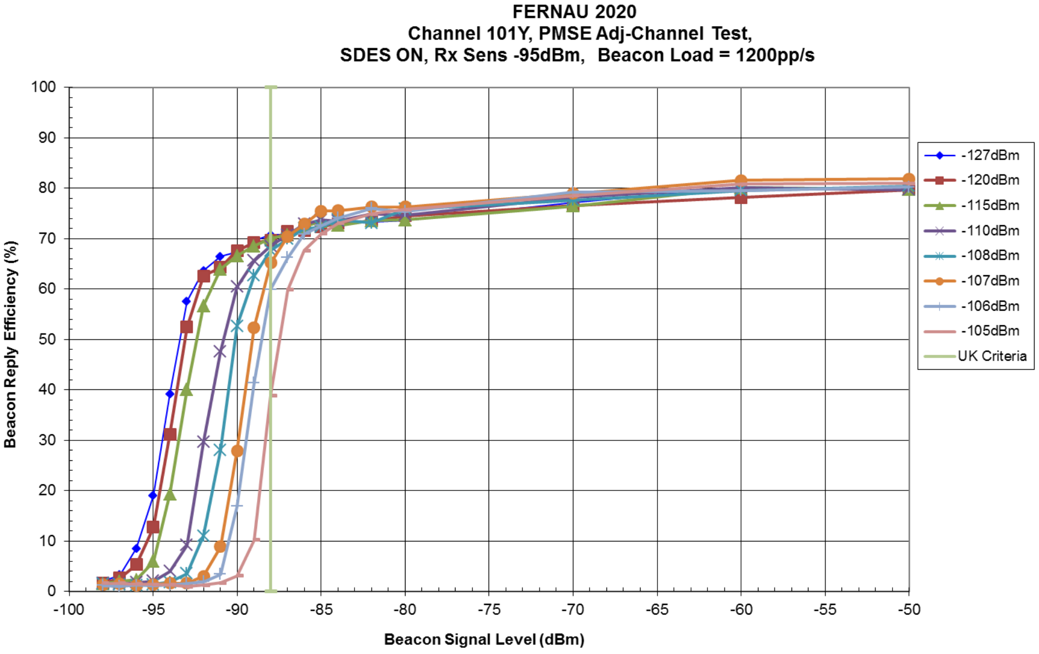


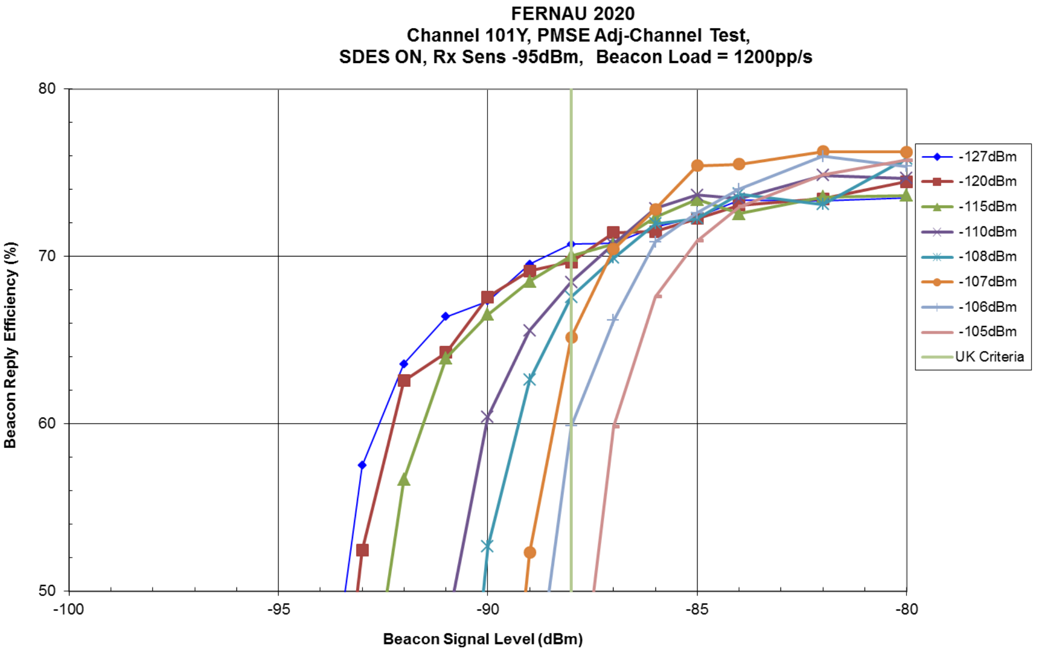


Figures 5-7 & 5-8 – Fernau 2020, 101Y, Co-Channel Test, No Link 16

5.3.2.2 The test data indicates that a PMSE signal of -109dBm should not be exceeded for both X and Y mode.

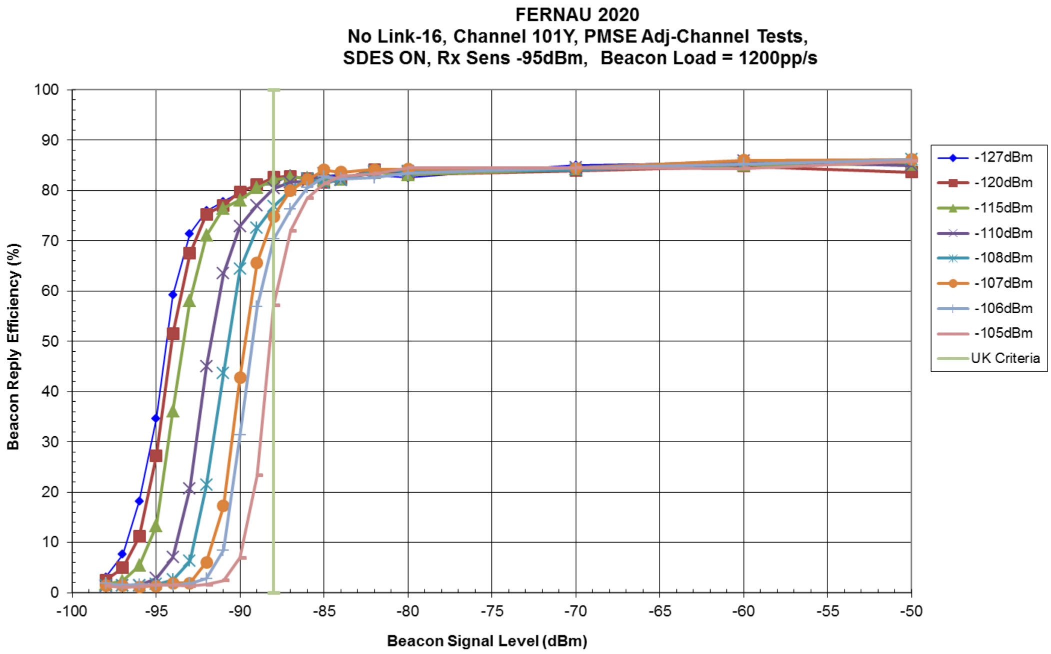
5.3.3 Fernau 2020, Full Pulse Environment, Adjacent Channel Testing

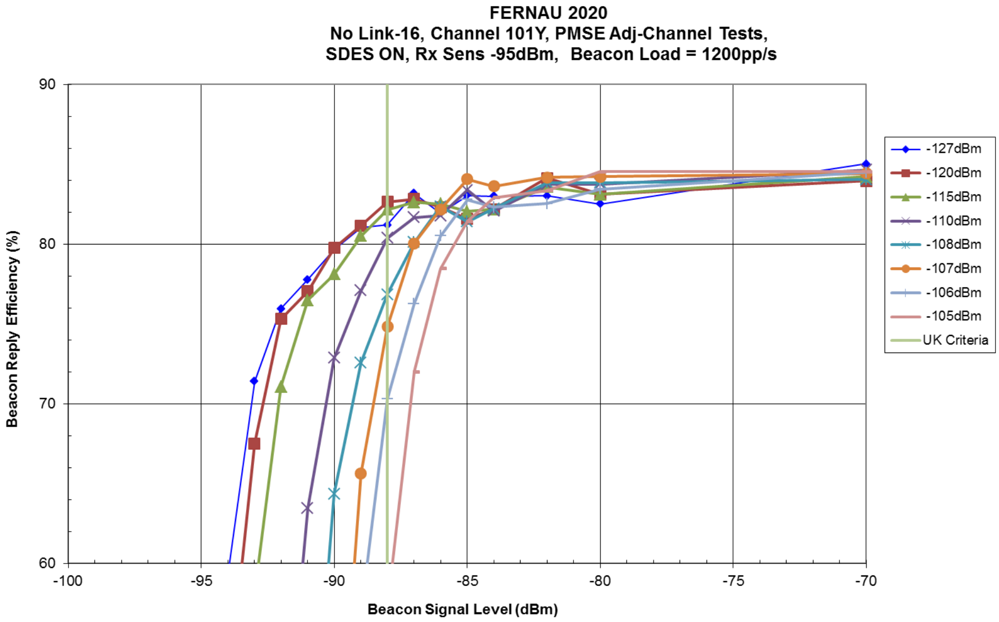




Figures 5-9 & 5-10 - Fernau 2020, 101Y, Adjacent Channel Test, Full Pulse Environment

5.3.3.1 Results show that with the PMSE signal on an Adjacent Channel it still causes the reply efficiency of the DME to drop below 70% when the signals were applied. The results indicate that signal level of -115dBm should not be exceeded.





Figures 5-11 & 5-12 - Fernau 2020, 101Y, Adjacent Channel Test, No Link 16

5.3.3.2 With the same test undertaken without the presence of Link 16 signals test data indicates that a PMSE signal level of -106dBm should not be exceeded.

5.3.4 Fernau 2020 Results Summary

5.3.4.1 The Fernau 2020 is used for enroute and aerodrome and typically has a fixed sensitivity of -95dBm.

5.3.4.2 The test results for the Fernau 2020 indicate that the beacon is susceptible to the PMSE signal with the resulting effect of causing the reply efficiency to drop below 70% with the beacon operating in either X or Y mode.

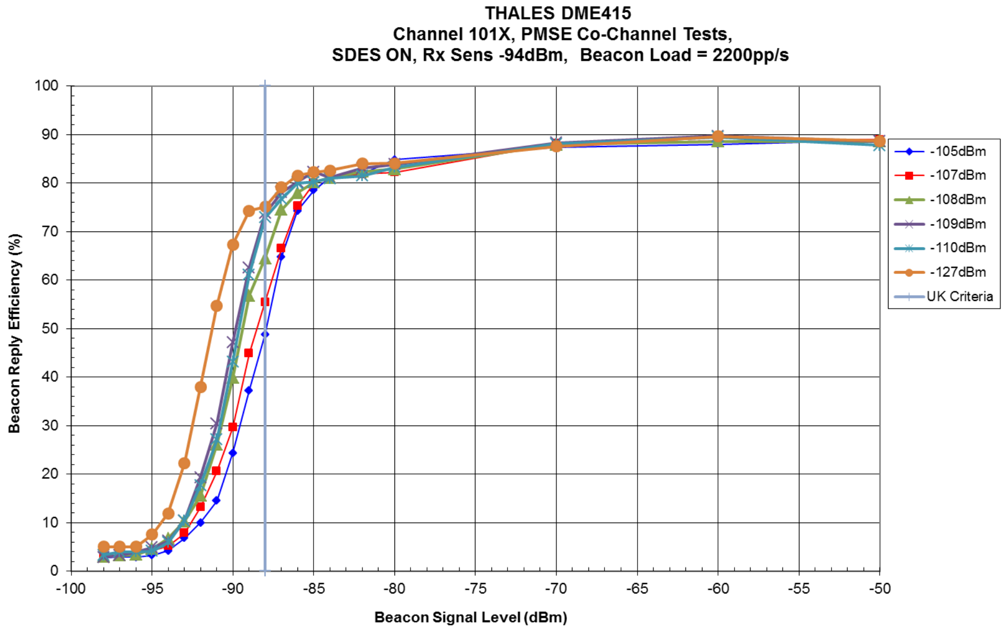
5.3.4.3 The test data indicates that a PMSE signal level of -111dBm should not be exceeded for the co-channel case for Y mode. A signal level of -111dBm just causes a fail of the criteria for X mode.

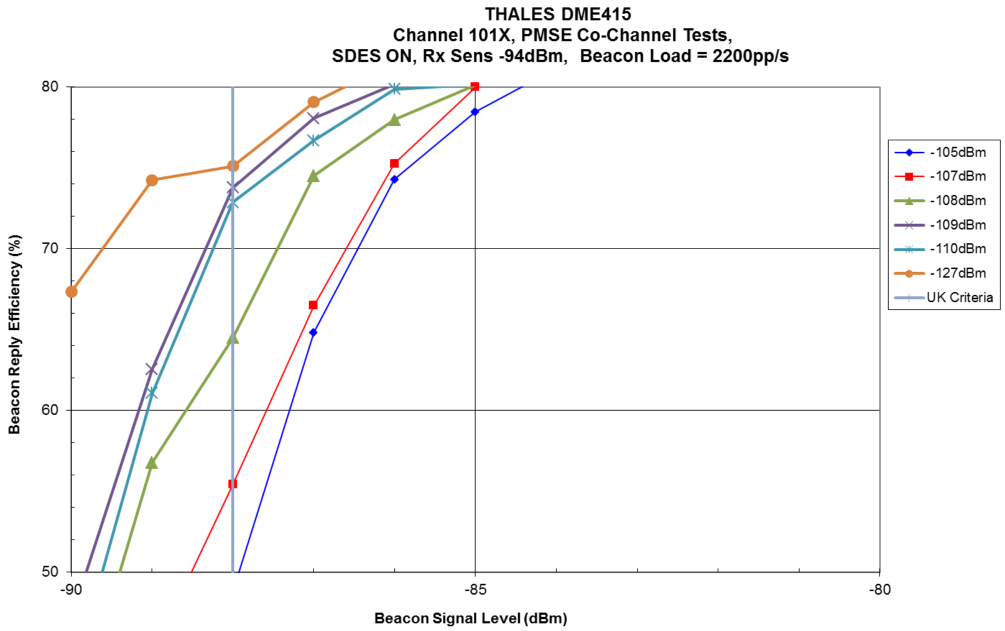
5.3.4.4 Without the presence of Link 16, the test data indicates that -109dBm should not be exceeded for both X and Y mode in the co-channel case.

5.3.4.5 The PMSE adjacent channel test data indicates that with no Link-16 a PMSE signal level of -106dBm should not be exceeded. When Link-16 is applied a PMSE signal level of -115dBm should not be exceeded.

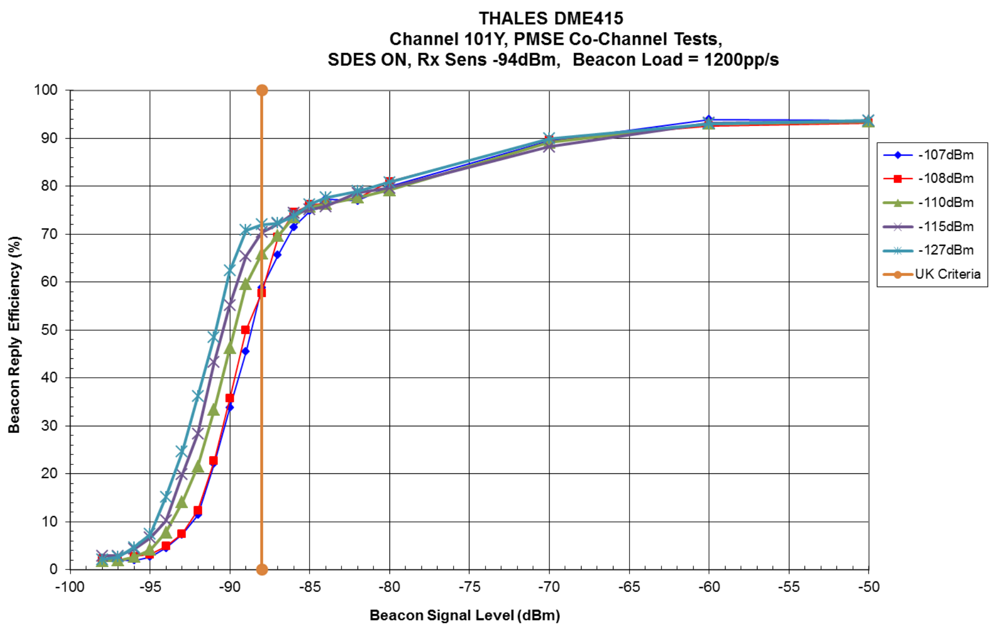
5.4 Thales DME 415 Test Results

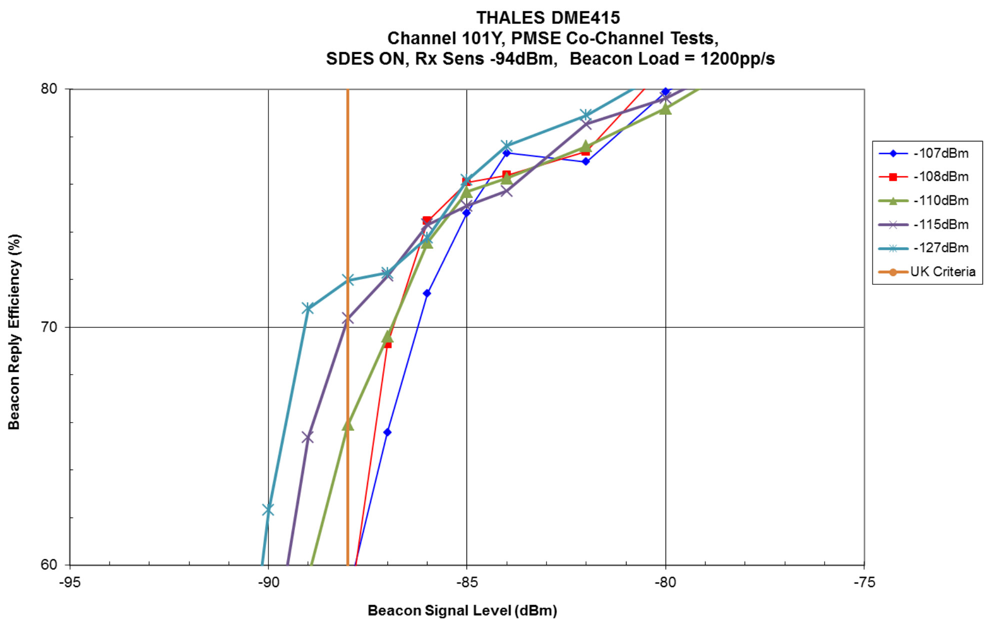
5.4.1 Thales DME415, Full Pulse Environment Testing, Co-Channel





Figures 5-13 & 5-14 – Thales 415, 101X, Co-Channel Test, Full Pulse Environment

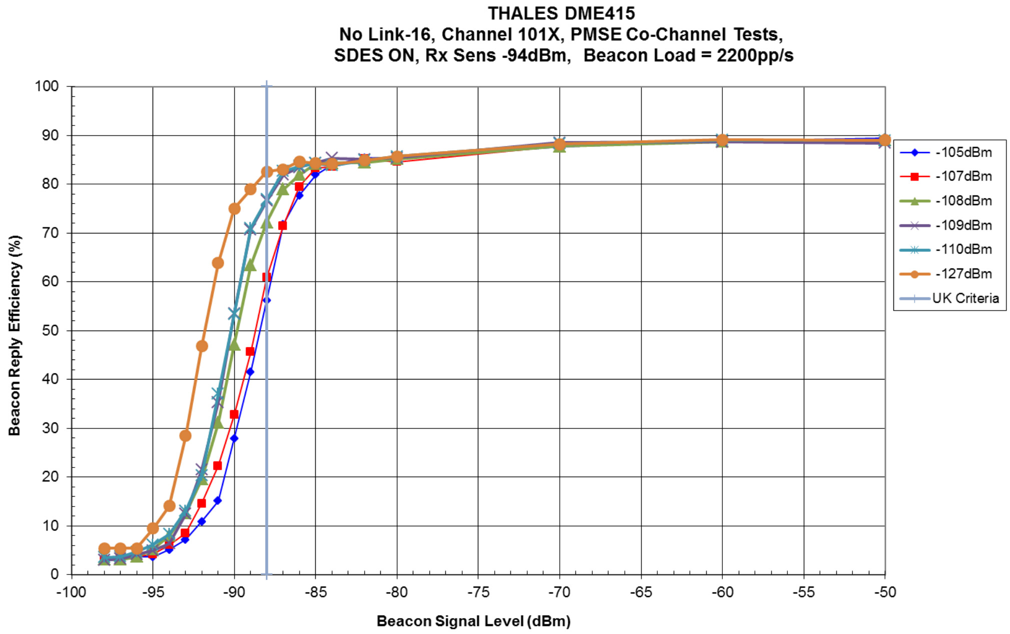


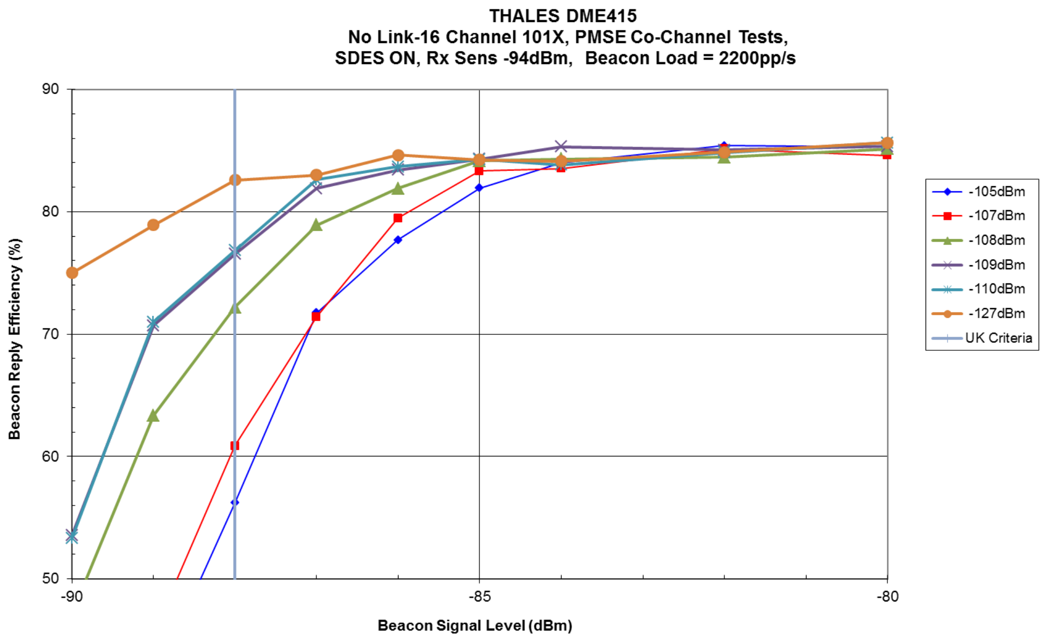


Figures 5-15 & 5-16 – Thales 415, 101Y, Co-Channel Test, Full Pulse Environment

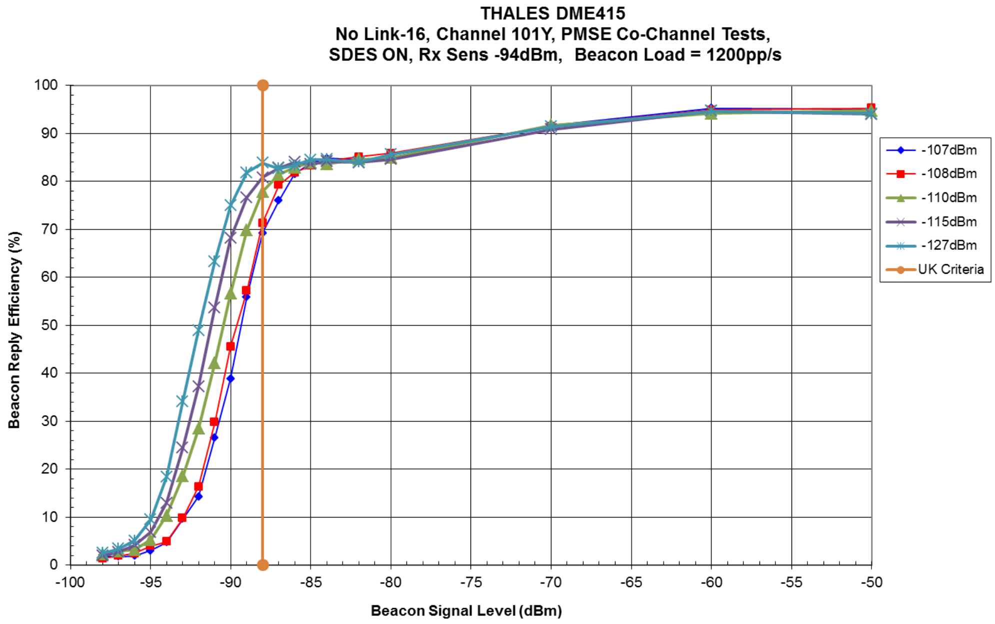
5.4.1.1 The PMSE Co-Channel test data indicates a PMSE signal level greater than -108dBm in X mode will cause the Thales DME415 to drop below the -88dBm criteria. For Y mode a signal level greater than -115dBm also cause a drop below -88dBm.

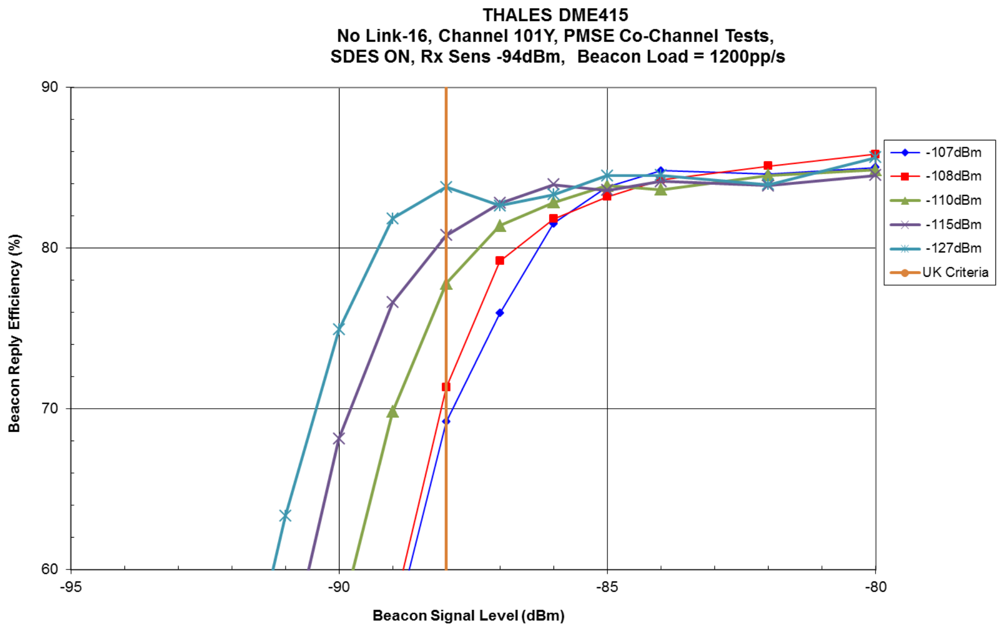
5.4.2 Thales DME415, No Link 16 Testing, Co-Channel





Figures 5-17 & 5-18 – Thales 415, 101X, Co-Channel Test, No Link 16





Figures 5-19 & 5-20 – Thales 415, 101Y, Co-Channel Test, No Link 16

5.4.2.1 With no Link-16 signals applied the test data indicates that a PMSE signal greater than -108dBm will cause it to fall below the -88dBm criteria.

5.4.3 Thales DME415 Results Summary

5.4.3.1 Testing of the Thales DME415 Beacon gave similar results to the Fernau 2020 and in all cases caused the reply efficiency to drop to below 70%.

5.4.3.2 The PMSE Co-Channel test data indicates a PMSE signal level greater than -108dBm in X mode will cause the Thales DME415 to fail the criteria. For Y mode a signal level greater than -115dBm will cause a fail.

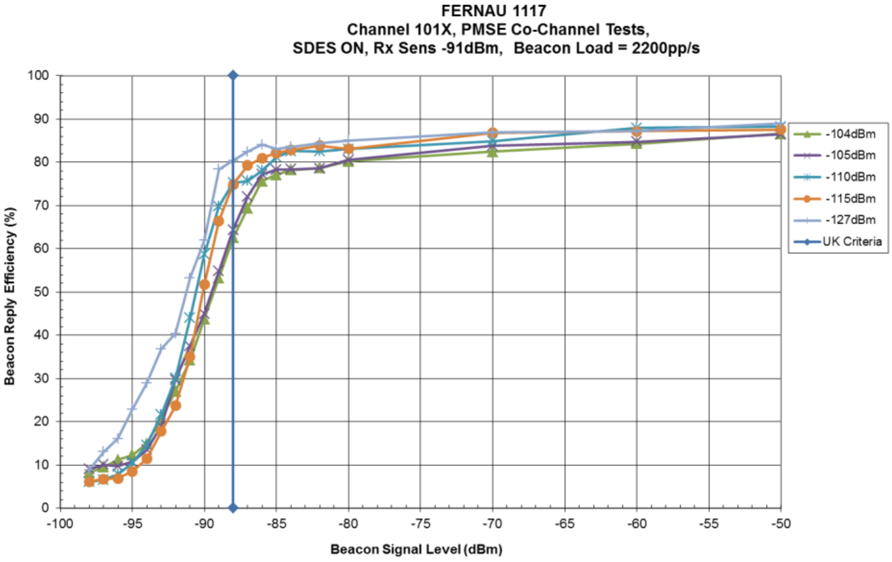
5.4.3.3 With no Link-16 signals applied the test data indicates that a PMSE signal of greater than -108dBm will also result in a fail.

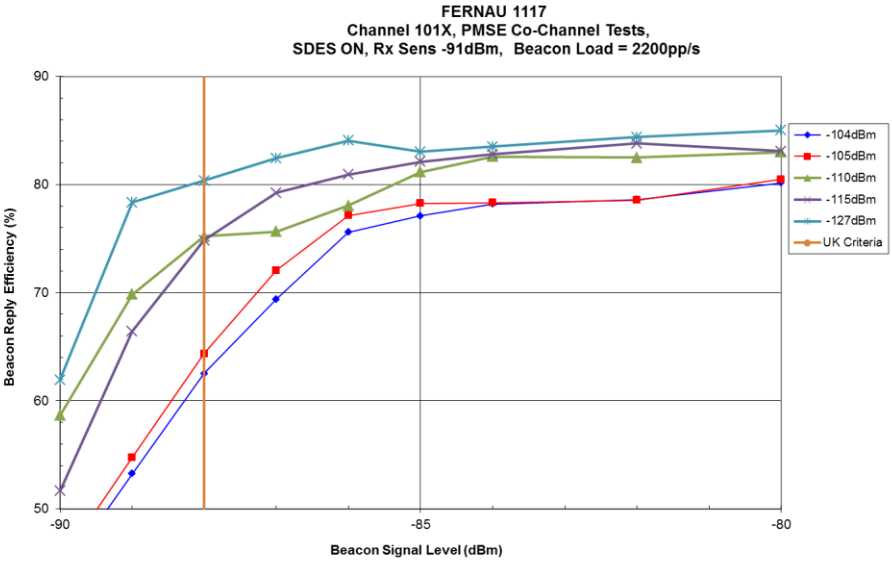
5.4.3.4 One of the reason for the above results is that the Thales DME415 has an automatic circuit that causes the beacon to de-sensitise in the presence of any CW Signals.

5.5 Fernau 1117 Test Results

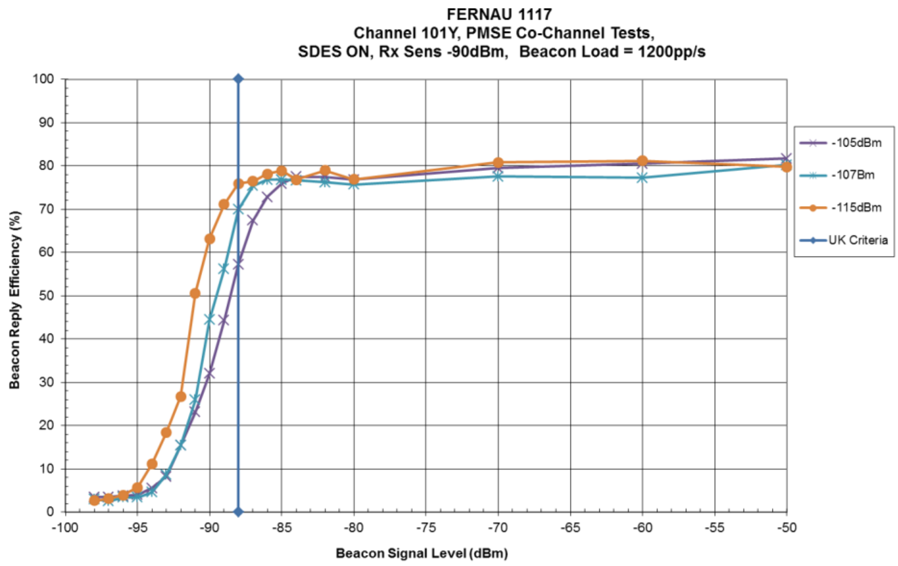
5.5.1 Summary

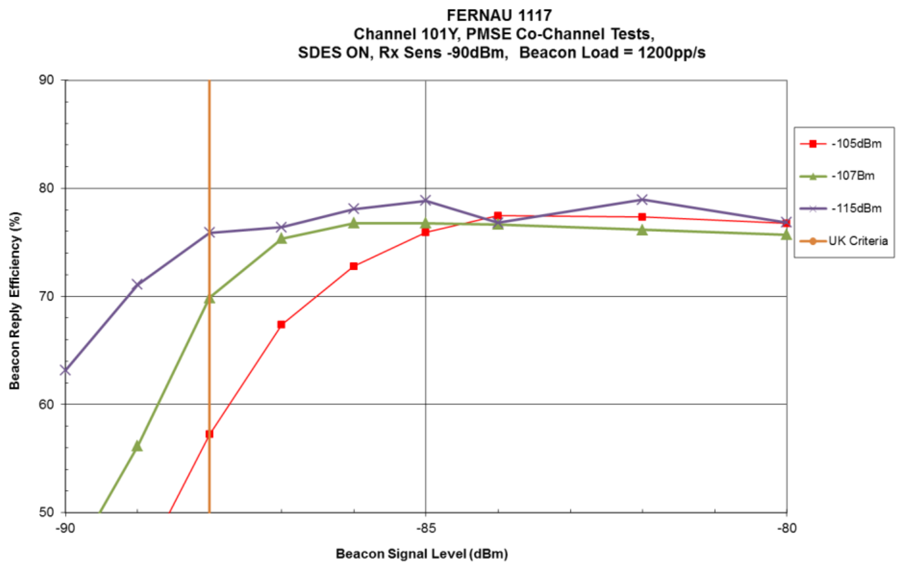
5.5.1.1 Testing of the Fernau 1117 Beacon against the standard test configuration gave similar results to the Fernau 2020 and the Thales 415 and caused the reply efficiency to drop to below 70%.



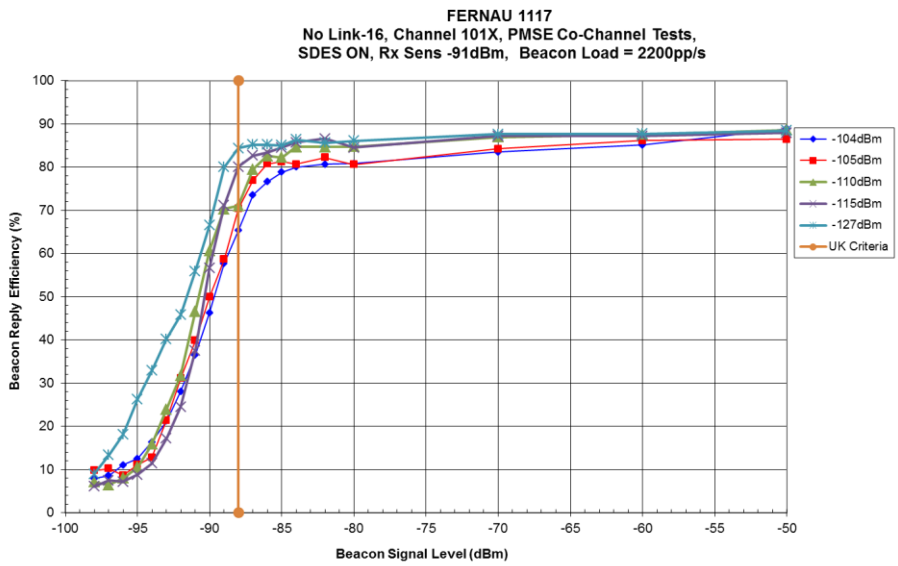


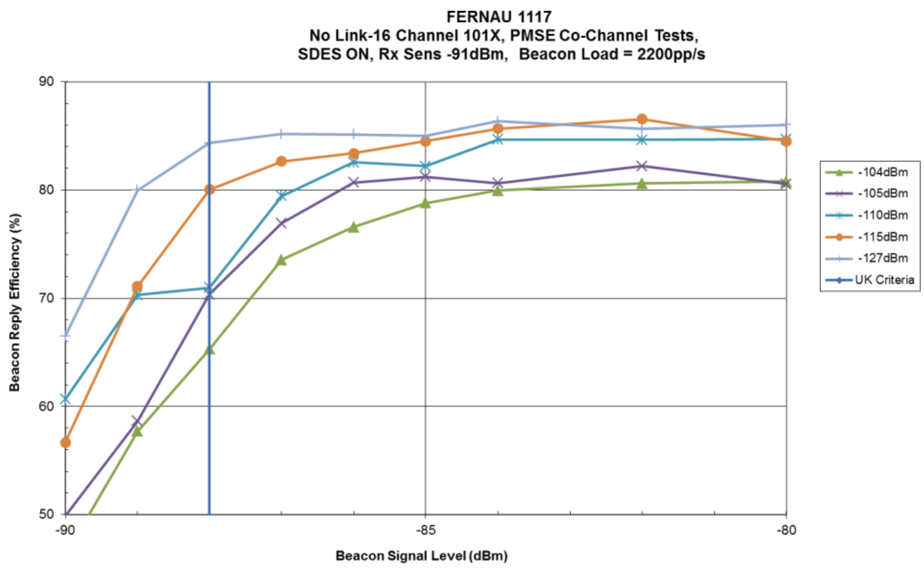
Figures 5-21 & 5-22 – Fernau 1117, 101X, Co-Channel Test, Full Pulse Environment



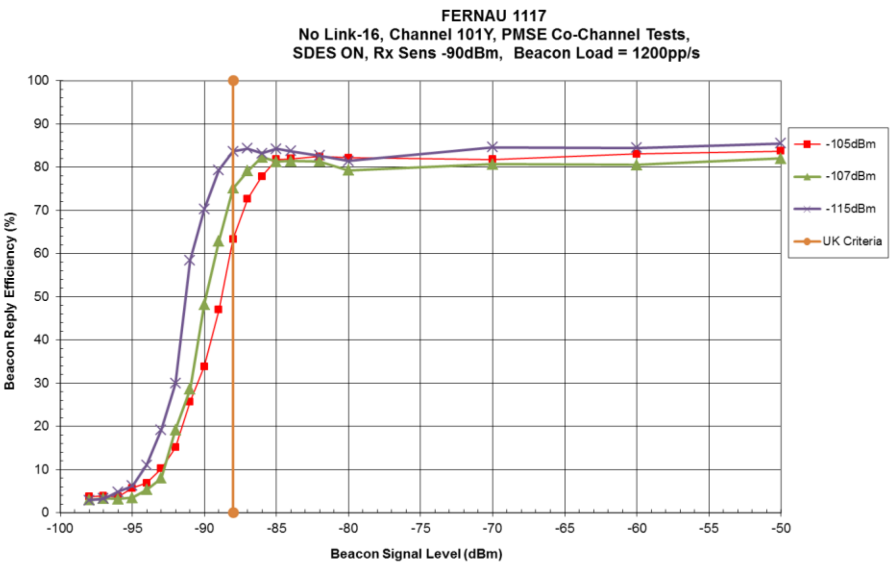


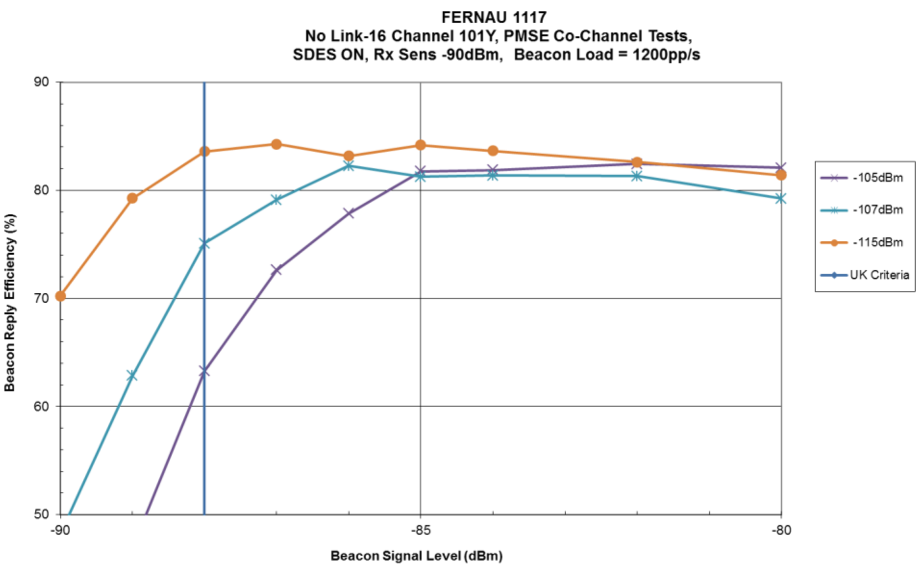
Figures 5-23 & 5-24 – Fernau 1117, 101Y, Co-Channel Test, Full Pulse Environment





Figures 5-25 & 5-26 – Fernau 1117, 101X, Co-Channel Test, No Link-16





Figures 5-27 & 5-28 – Fernau 1117, 101Y, Co-Channel Test, No Link-16

5.5.2 When tested the Fernau 1117 was not able to maintain a 70% reply efficiency at -88dBm at all the tested PMSE signal levels. Both with and without the presence of Link 16, a PMSE signal level of greater than -110dBm can cause the reply efficiency to drop below 70% at -88dBm.

5.6 Frequency Selectivity Testing

5.6.1 Introduction

5.6.1.1 With all beacons under test showing similar results and failing to pass the test criteria, JCSys in consultation with Ofcom decided to amend the test parameters and attempt to determine what level of frequency separation is required in order for the PMSE signal to have no effect on the beacon under test.

5.6.1.2 This test produces selectivity curves for each type of beacon, on both X and Y Mode. The results of the tests are shown below. In addition an representative X/Y channel selectivity curve, without the presence of Link 16, are included (Figures 5-30, 5-32 and 5-34) to verify/validate the PMSE Off frequency rejection (OFR) curves.

5.6.2 Fernau 2020 Selectivity and Offset Curves

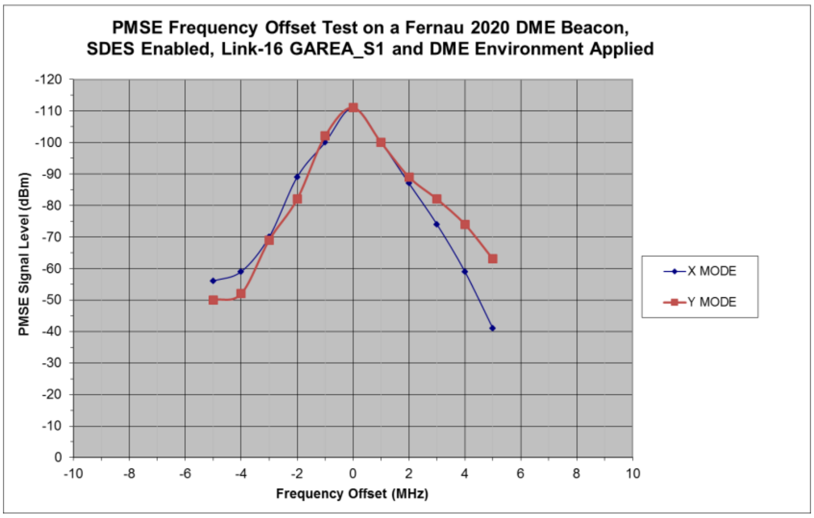


Figure 5-29 – Fernau 2020 X and Y Channel Selectivity Curves

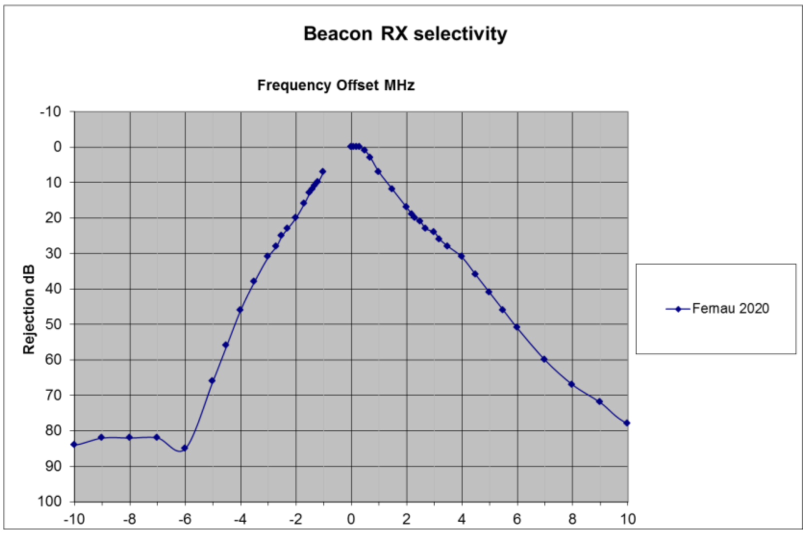


Figure 5-30 – Fernau 2020 Frequency Offset

5.6.3 Thales DME415 Selectivity and Offset Curves

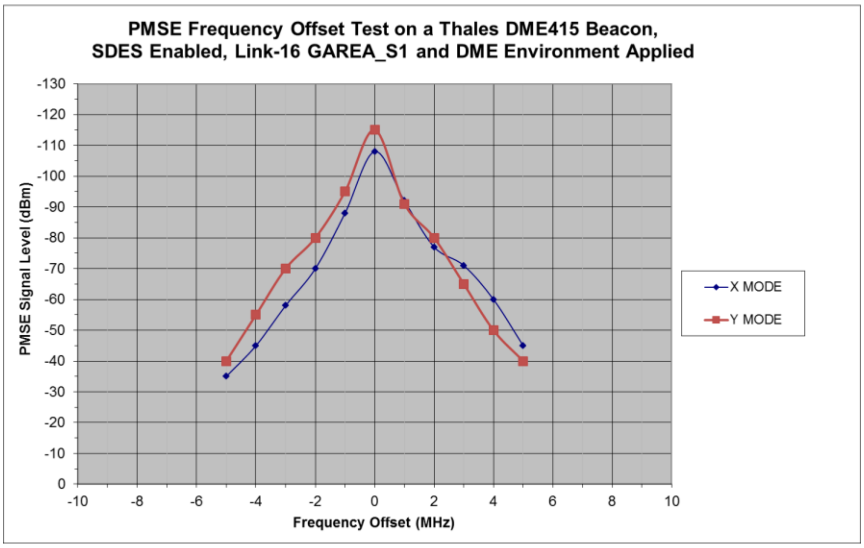


Figure 5-31 – Thales DME415 Selectivity Curve

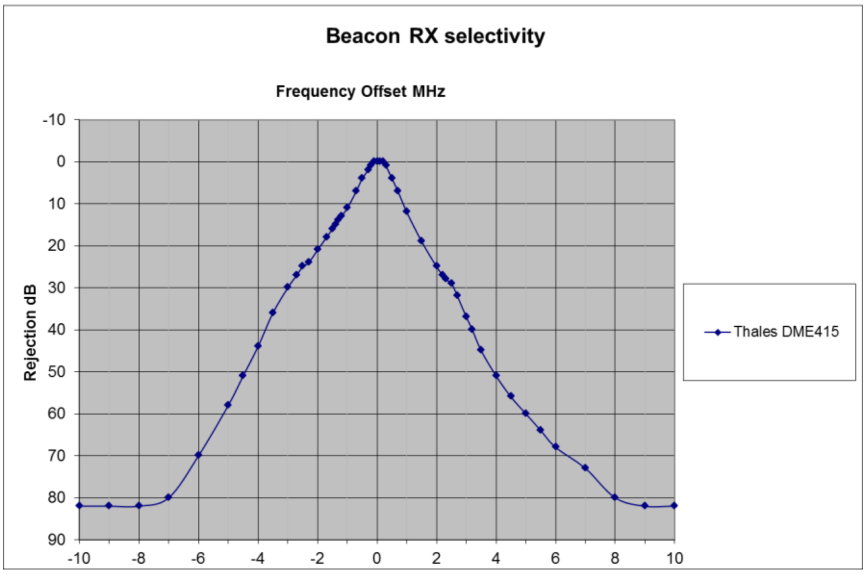


Figure 5-32 – Thales DME415 Frequency Offset

5.6.4 Fernau 1117 Selectivity and Offset Curves

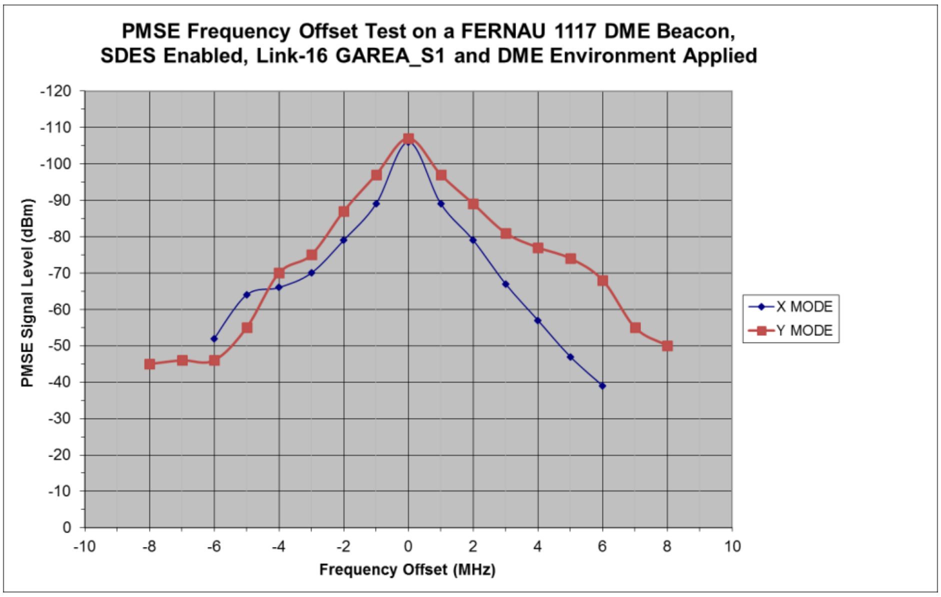


Figure 5-33 – Fernau 1117 Selectivity Curve

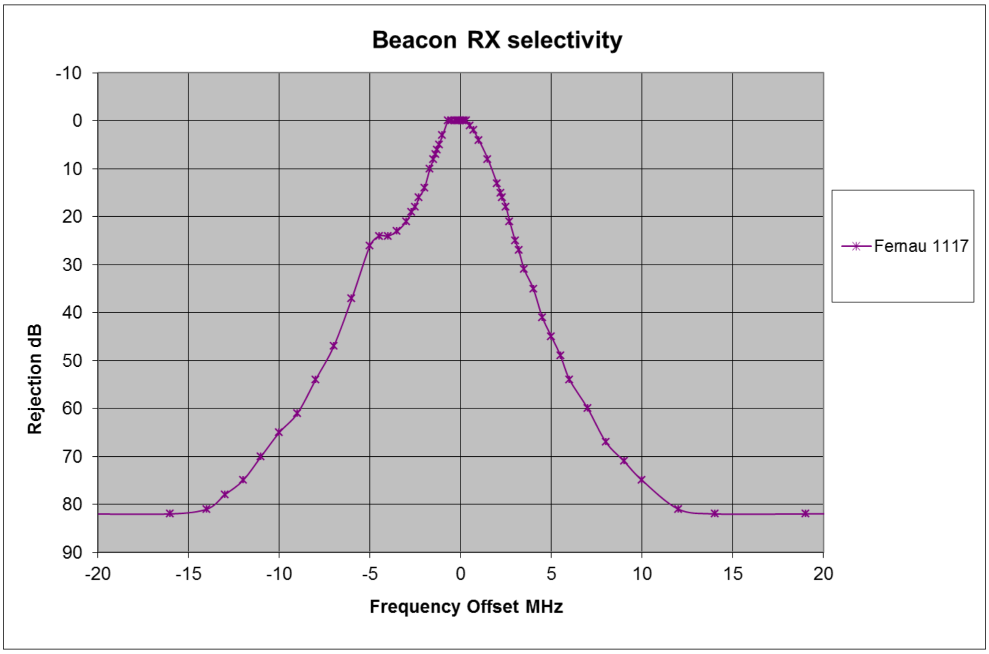


Figure 5-34 – Fernau 1117 Frequency Offset

5.6.5 Selectivity Results

5.6.5.1 The results of the off frequency rejection / selectivity testing indicates that a PMSE signals with a frequency offset from the DME channel would be desirable. A 2MHz offset could provide 20dB difference to PMSE signal strength.

6 DME INTERROGATOR TEST CONFIGURATION

6.1 Introduction

6.1.1 The DME Interrogator test programme encompassed three separate sets of measurements to determine the performance of the DME Interrogators in the presence PMSE signals. The tests completed were:

- PMSE to DME Interrogator ASOP test
- PMSE Breaklock test
- PMSE signal Off-Frequency Rejection (OFR) (Selectivity) test

6.1.2 Three DME Interrogators types were tested:

- Bendix/King KN64 General Aviation (A high number operating within UK FIR) the receiver sensitivity is typically -85dBm.
- Collins 860E-3 (historic to Link-16 Test Programme) the receiver sensitivity is typically -90dBm.
- King KDM 705 (historic to Link-16 Test Programme) the receiver sensitivity is typically -85dBm

6.1.3 All tests were carried out with the inclusion of a Link 16 RF pulse environment, however and where appropriate JCSys also took measurements without the presence of Link 16 for the purposes of comparison.

6.2 PMSE to DME Interrogator ASOP testing

6.2.1 In order to evaluate the performance of a DME Interrogator the Time to Acquire (TTA) was measured at a number of beacon signal levels (BSLs), the raw data was then analysed to determine the Acquire Stable Operating Point (ASOP) of the DME interrogator, the point at which it can expect to receive a reliable service from the DME Ground Beacon. The BSL is controlled by the 8-NET software which in turn controls the beacon simulator signal level, the following parameters were pre-set into the beacon simulator:

- Channel 32X, 59Y (993MHz, 1146MHz)
- Squitter pulses set at 700ppps (Typical UK Beacon Level)
- Beacon Reply Efficiency at 70% (ICAO Annex 10)
- Range set at 200NM
- BSL (dBm) -60 to -100 in 1dB steps

6.2.2 The PMSE signal was introduced via a 20dB RF coupler with the PMSE signal being generated by JCSys test equipment. The PMSE signal level was set to -127dBm then increased in 1dB steps until a change in ASOP was determined.

6.2.3 As the ASOP values for the three DME Interrogator types, both with and without the presence of Link 16 are already known, these were used as a starting point for the testing.

6.2.4 The ASOP test was undertaken as follows: -

- Set beacon simulator to ASOP signal level.
- Ensure DME Interrogator locks on within 5 second search time or (manufacturers specified search time).
- Introduce PMSE Co-Channel signals to determine the PMSE signal level that changes the ASOP.
- If ASOP is already at ICAO Annex 10 signal level, then introduce PMSE Co-Channel signal levels that cause a change in ASOP of 1dB.
- Record PMSE Co-Channel signal level.

6.3 Breaklock Testing

6.3.1 This test determines the PMSE signal levels that is required to cause a Breaklock of a DME interrogator while simulating an aircraft inbound approach to an Aerodrome.

6.3.2 The Beacon signal level was set to a number of signal levels ranging from -78dBm (ICAO level) to -20dBm in 5dB steps. At each predetermined beacon reply signal level the PMSE signal was increased until a Breaklock occurs.

6.3.3 A Breaklock was measured as follows: -

- Set beacon simulator to appropriate range.
- Set beacon simulator squitter/reply signal level (i.e.-50dBm).
- Increase PMSE Co-Channel signals until Interrogator Breaklock occurs (allow 60 seconds for Breaklock to occur).
- Record PMSE signal level.
- Record beacon Simulator signal level.

6.3.4 All Breaklock tests were undertaken in the presence of the Link-16 environment.

6.4 Off-Frequency Rejection (OFR) (Selectivity) of a PMSE Signal test

6.4.1 At the project meeting held on the 5th May it was agreed that having a selectivity curve for the DME Ground beacon was useful and that it would be beneficial to have something similar produced as part of the interrogator testing programme. In order to meet this requirement JCSys have produced an Off-Frequency Rejection curve which is a measure of the increase in PMSE levels that can be tolerated if the PMSE signals are on a different frequency to the DME interrogation.

6.4.2 The Off-Frequency Rejection curve is produced by:

- Setting the beacon simulator signal level to the ASOP value
- Ensure the interrogator is locked onto the beacon signal
- Change the PMSE frequency in steps of 1MHz.
- At each 1MHz step adjust the PMSE signal level until a breaklock occurs, and record that signal level.

7 DME INTERROGATOR TEST RESULTS

7.1 Introduction

7.1.1 JCSys completed testing on three DME interrogators, namely the Bendix/King KN64, Collins 860E-3 and the King KDM 705A.

7.2 Pass/Fail Criteria

7.2.1 For the ASOP test, the interrogator must achieve ASOP at a signal level of -78dBm or greater. Lock must be obtained within the period specified by the manufacturer (typically 5 seconds).

7.2.2 For Breaklock and OFR tests there are no defined pass or fail criteria as they simply provide an indication of performance in the presence in PMSE signals of varying strengths.

7.3 Bendix/King KN-64 Test Results

7.3.1 PMSE Co-Channel ASOP Test on a Bendix/King KN-64

7.3.1.1 The following graphs show the results of the ASOP tests for the Bendix/King KN-64.

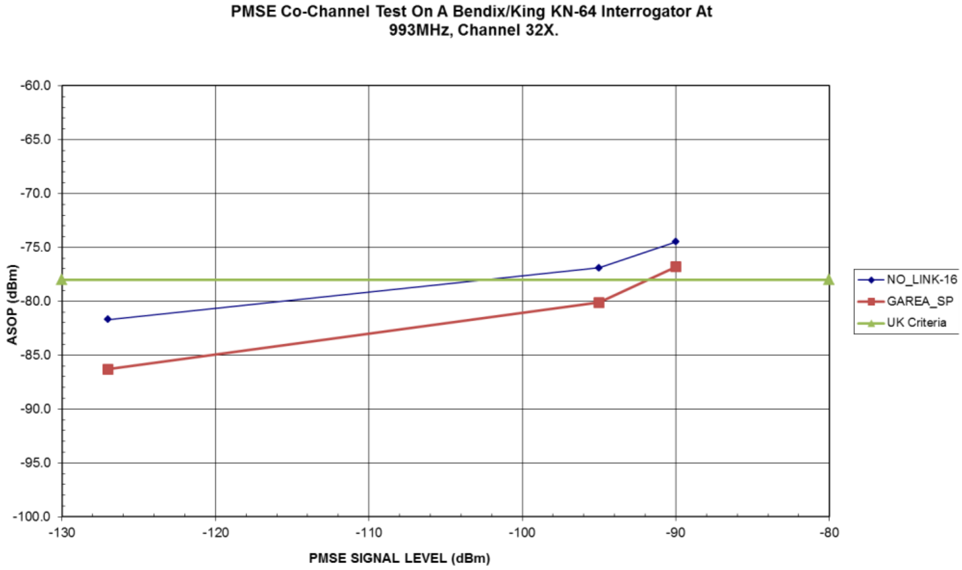


Figure 7-1 – Bendix/King KN-64 ASOP Test, X Channel

7.3.1.2 The test data for X mode indicates that a PMSE signal level of -95dBm causes the No_Link-16 ASOP to rise above the maximum level defined in the criteria. It can also be seen that the presence of the Link-16 environment improves the ASOP performance.

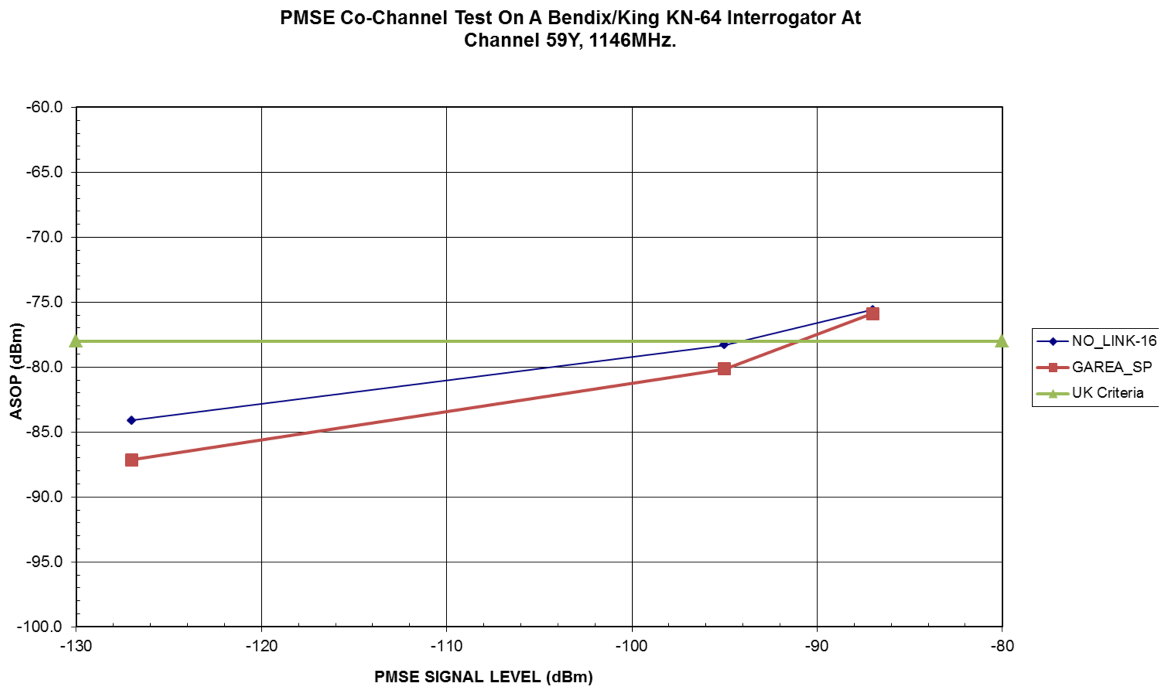


Figure 7-2 – Bendix/King KN-64 ASOP Test, Y Channel

7.3.1.3 The test data gathered for Y Mode, Figure 7-2, indicates that with a PMSE signal level of -95dBm, the No_Link-16 test meets the ASOP criteria of -78dBm. Again it can be seen that the Link-16 environment improves the ASOP performance of this DME interrogator type.

7.3.2 PMSE Co-Channel Breaklock Test on a Bendix/King KN-64

7.3.2.1 Figure 7-3 below shows the relationship between the received signal strength from the DME Beacon and the level of PMSE necessary to cause Breaklock.

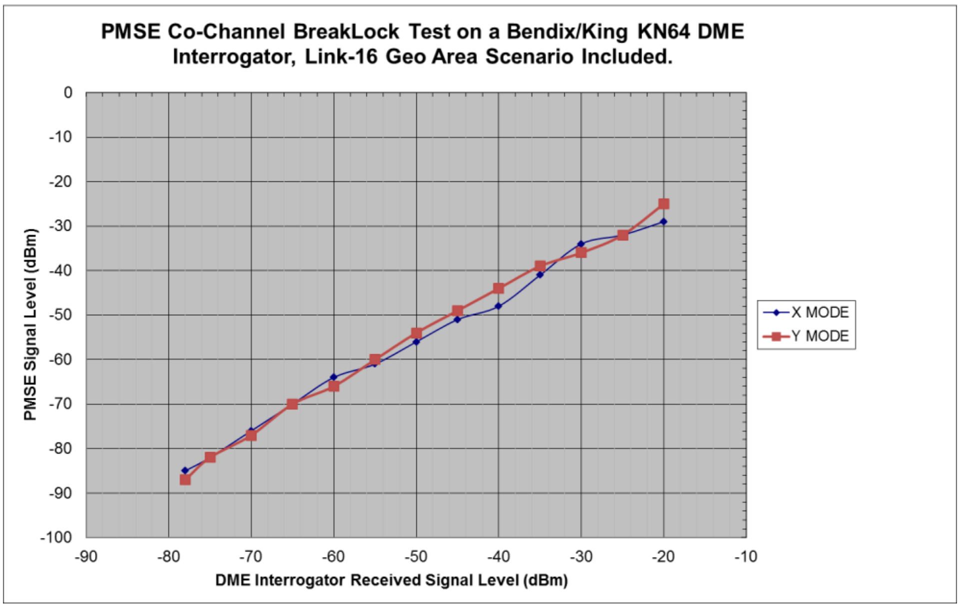


Figure 7-3 - Bendix/King KN-64 Breaklock Test

7.3.2.2 This breaklock data shows PMSE Co-Channel signal levels that cause a Bendix/King KN64 to breaklock while locked on to a DME Ground Beacon. The graph is approximately linear and shows that a 6dB increase in PMSE power causes a 6dB increase in the required received signal in order to maintain lock.

7.3.2.3 Both X-mode and Y-mode are shown in Figure 7-3.

7.3.3 Bendix/King KN64 Off-Frequency Rejection (OFR)

7.3.3.1 The X-Mode OFR curve was measured with a Desired Beacon Signal Level (DBSL) of -78dBm, and for the purposes of comparison the Y-Mode OFR curve was measured with DBSL set at the measured ASOP of the interrogator.

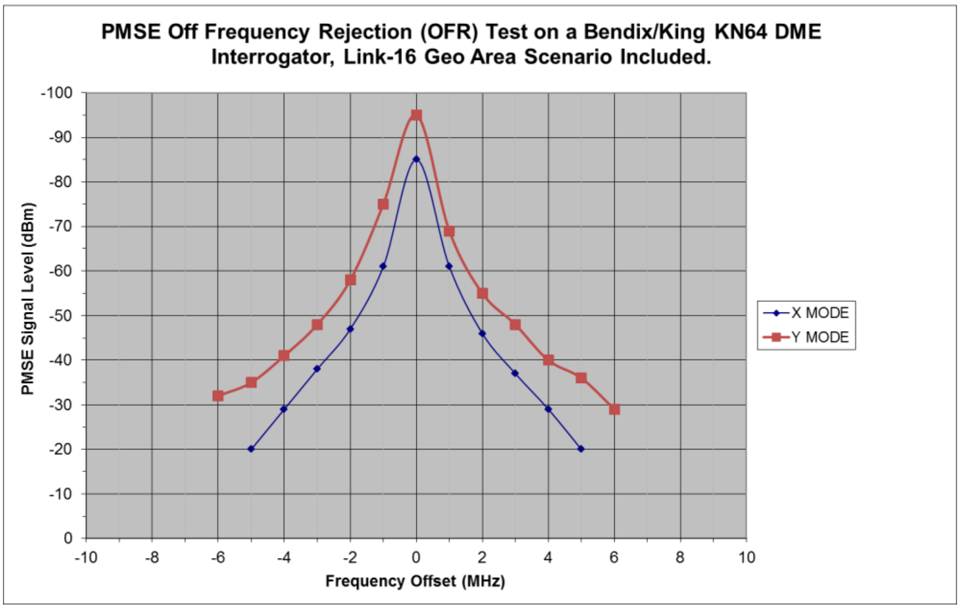


Figure 7-4 - Bendix/King KN64 Off-Frequency Rejection (OFR) Curve

7.3.3.2 Figure 7-4 shows that a breaklock will occur at a PMSE signal level of greater than -75dBm at a frequency 1MHz below the Beacon Reply frequency.

7.4 Collins 860 E-3Test Results

7.4.1 PMSE Co-Channel ASOP Test on a Collins 860 E-3

7.4.1.1 Figure 7-5, 7-6 and 7-7 below show the results of the Collins 860 E-3 ASOP tests.

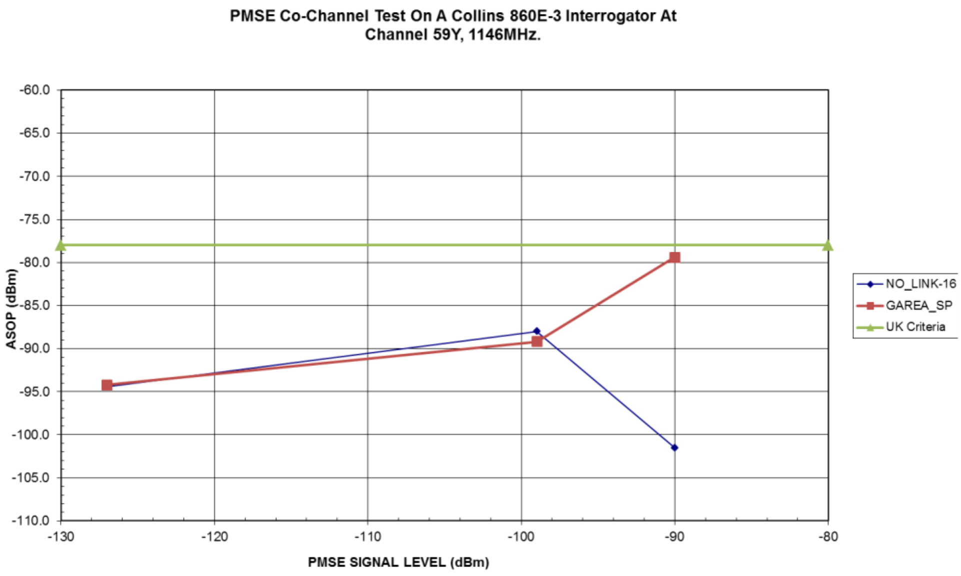


Figure 7-5 – Collins 860 E-3 ASOP Test, Channel 59Y

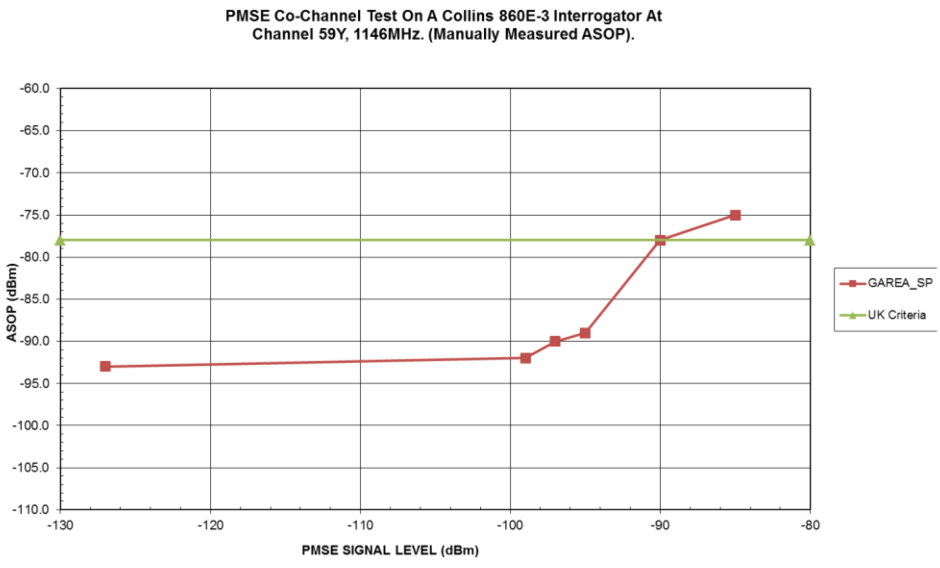


Figure 7-6 – Collins 860 E-3 ASOP Test, Channel 59Y

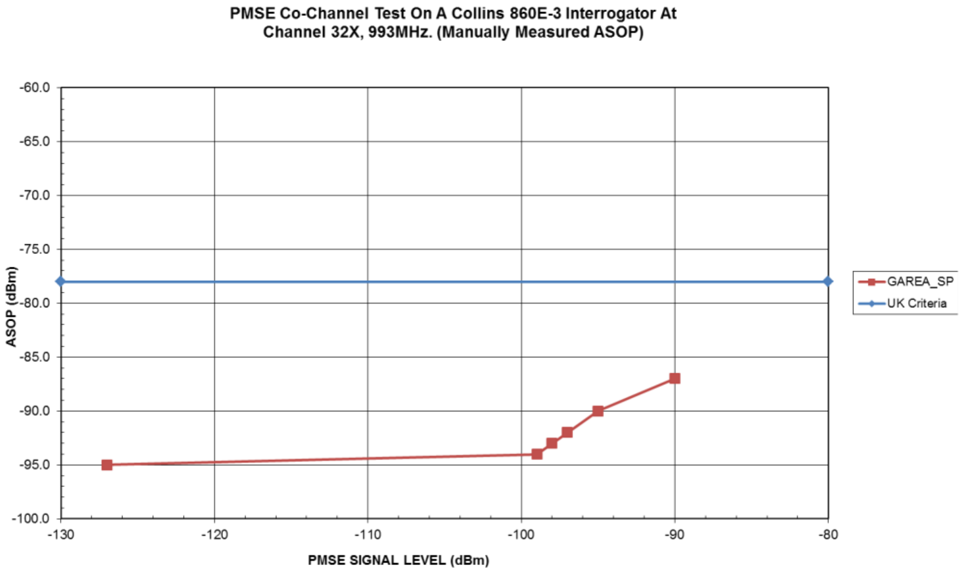


Figure 7-7 – Collins 860 E-3 ASOP Test, Channel 32X

7.4.1.2 The ASOP TTA test data for Y Mode has indicated a problem with a PMSE signal level at -90dBm, specifically when No Link-16 is applied. This signal level causes false locks and incorrect distance readings on the indicator. Figure 7-5 shows an erratic ASOP point with No Link-16.

7.4.1.3 Figures 7-6 and 7-7 show the results of manual ASOP tests in the presence of the full RF environment.

7.4.1.4 In order to understand the false lock issue more clearly, Figure 7-8 below shows a normal data set taken at -99dBm, showing that the interrogator has acquired either a good lock with a distance reading, or no lock at all. Figure 7-9 shows a data set at -90dBm where false distance information has been recorded, this is shown in the table as a series of erratic distance measurements, for example 399.5nm. The reason for this is currently unclear and will require further investigation.

7.4.1.5 Testing has shown that increasing the PMSE signal greater than -97dBm can causes the Collins 860 E-3 to suffer from false readings, and that signals greater than -90dBm will cause it to fail to meet the -78dBm ASOP criteria.

TEST: 849 SCENARIO: GAREA_SP ###

BEACON SIGNAL LEVEL (dBm)	NUMBER OF TTAs < 120 secs	TIME-TO-ACQUIRE LOCK (SECONDS) / INTERROGATOR RECORDED RANGE (nmi)																			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
-60	20	1.0	1.0	1.0	1.0	3.5	5.6	1.4	1.2	1.0	1.2	1.0	1.0	1.4	2.4	1.1	2.7	-0.5	7.1	1.0	1.3
		200.0	0.1	200.0	200.0	200.0	0.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0
-61	20	1.3	1.0	3.3	1.1	1.0	1.0	1.0	-0.5	3.6	1.0	1.0	1.7	1.0	3.5	2.6	1.6	3.5	3.1	-0.5	1.0
		200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0
-62	20	1.0	5.8	1.6	1.0	1.0	1.0	2.3	1.0	1.0	1.1	-0.5	1.8	3.2	2.7	1.0	1.0	1.0	1.9	1.0	1.0
		200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0
-63	20	1.0	2.9	-0.5	3.3	1.0	1.4	1.5	1.3	1.0	1.0	1.6	1.3	1.0	1.0	3.2	-0.5	3.6	1.4	1.0	1.0
		200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0
-64	20	1.0	1.0	1.0	1.0	1.0	1.0	3.9	1.2	6.2	1.5	1.4	1.6	1.3	1.0	1.2	1.0	1.9	2.8	1.2	-0.5
		200.0	200.0	200.0	200.0	200.0	199.9	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0
-65	20	2.4	1.8	1.3	3.3	1.0	3.0	1.0	1.0	1.4	1.0	1.0	6.9	1.4	1.0	2.0	1.0	1.0	1.0	1.0	5.0
		200.0	0.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	240.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0
-66	20	1.0	1.0	-0.5	1.0	1.0	1.0	1.7	1.0	1.8	1.0	1.2	1.8	1.0	4.1	1.7	-0.5	2.6	2.4	5.9	1.0
		200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0
-67	20	1.0	1.8	1.7	1.6	1.0	1.2	1.0	2.8	1.0	3.1	1.9	1.0	1.0	1.2	1.0	1.0	2.3	1.0	1.2	5.7
		200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	23.3	200.0	200.0	200.0	200.0	200.0	200.0
-68	20	1.5	4.3	3.0	1.0	1.4	1.5	1.0	1.0	2.2	-0.5	3.7	1.8	1.0	2.3	2.8	1.0	1.0	1.0	1.5	7.7
		200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0
-69	20	3.4	1.3	1.3	1.0	1.0	1.0	1.4	1.0	3.2	1.0	1.0	2.1	-0.5	3.5	1.0	3.3	1.6	1.0	1.0	1.0
		200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0
-70	20	1.0	1.0	6.1	-0.5	3.8	1.0	1.6	1.4	1.0	1.0	1.1	1.0	1.2	1.0	1.1	1.0	-0.5	1.4	1.0	6.0
		200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0
-71	20	1.0	2.6	1.5	1.0	1.1	1.0	1.0	1.0	-0.5	3.7	1.0	1.0	1.6	1.3	1.0	1.0	1.0	1.0	1.0	1.0
		200.0	200.0	200.0	200.0	200.0	200.0	232.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0
-72	20	1.0	-0.5	3.9	1.0	1.0	1.6	1.0	1.0	1.0	1.0	2.8	1.6	3.5	-0.5	3.2	1.0	1.0	1.7	2.3	1.0
		200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0
-73	20	1.0	1.6	1.0	1.0	1.0	1.0	4.8	1.2	1.9	1.0	1.0	1.6	1.0	1.9	1.3	1.0	1.0	-0.5	3.2	1.4
		200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0
-74	20	1.0	1.0	1.1	2.4	1.0	1.1	1.0	2.2	2.2	-0.5	3.5	3.4	1.1	1.3	1.0	1.0	1.0	1.0	1.0	1.0
		200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.1	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0
-75	20	1.0	-0.5	3.7	1.0	1.0	1.9	1.0	1.0	2.4	1.4	1.0	1.0	1.0	1.0	-0.5	5.7	1.0	1.6	1.0	1.0
		200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0
-76	20	1.0	1.6	1.0	1.0	1.0	1.0	-0.5	3.9	1.0	1.2	1.0	2.0	1.0	1.0	1.0	1.0	1.0	2.0	1.7	-0.5
		200.0	200.0	200.0	200.0	200.0	200.0	120.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0
-77	20	1.5	1.0	2.3	1.0	1.0	3.4	1.3	1.0	1.7	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
		200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0
-78	20	1.0	1.0	2.2	1.0	1.0	3.8	1.0	1.8	1.0	1.0	1.1	1.0	2.7	1.0	1.0	2.0	1.4	-0.5	3.5	1.1
		200.0	240.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0
-79	20	1.7	2.7	1.0	1.7	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.5	1.0	1.0	1.0	1.7	1.7
		200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	48.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0
-80	20	1.0	1.0	1.0	1.0	1.0	1.1	2.2	1.0	1.7	1.0	1.0	1.0	1.0	1.3	1.7	1.0	3.6	2.4	1.2	2.0
		200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0
-81	20	1.0	1.0	1.0	1.0	1.0	1.3	1.0	1.0	-0.5	1.9	1.0	1.5	2.0	2.6	2.0	1.0	1.0	1.0	2.2	1.0
		200.0	200.0	200.0	200.0	2.4	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	24.0	200.0	200.0	200.0	200.0	200.0	200.0
-82	20	1.5	3.9	3.2	1.0	1.0	1.0	1.0	1.3	2.3	1.0	1.0	1.0	1.0	-0.5	1.0	1.0	1.0	1.7	1.0	1.0
		200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0
-83	20	1.0	1.4	1.0	1.6	1.0	1.0	-0.5	1.0	1.0	1.0	1.6	1.1	1.2	1.0	1.0	1.0	1.0	1.0	1.0	1.0
		200.0	24.0	200.0	200.0	200.0	200.1	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0
-84	20	-0.5	4.6	1.0	1.0	1.0	1.0	1.3	1.0	1.0	1.0	1.0	1.4	1.0	-0.5	3.5	1.4	1.0	1.0	1.0	1.3
		80.1	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.1	200.0	200.0	200.0	200.0	200.0	200.0
-85	20	1.0	1.3	1.0	1.0	1.4	1.0	-0.5	3.5	1.8	1.0	2.1	1.5	1.2	1.0	1.6	1.0	1.0	1.3	1.0	-0.5
		200.0	200.1	200.0	200.0	200.0	200.0	200.0	200.0	200.1	200.0	200.1	200.1	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0
-86	20	1.0	1.0	1.0	1.0	1.0	1.0	1.2	1.0	1.0	1.0	1.0	1.0	1.0	-0.5	3.4	1.0	-0.5	1.0	1.1	1.0
		200.1	200.0	200.0	200.0	200.1	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.1	200.0	200.0	200.0	200.1
-87	20	1.0	1.0	1.0	1.4	1.4	1.0	1.0	3.5	1.2	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
		200.1	200.0	200.0	200.1	200.0	200.0	200.1	200.0	200.1	200.1	200.1	200.0	200.0	200.1	200.1	200.0	200.1	200.0	200.0	200.1
-88	20	4.6	1.0	1.0	1.0	1.7	1.0	1.3	1.0	1.7	1.0	1.3	1.0	1.1	3.7	1.0	3.9	1.0	1.5	1.0	3.4
		200.1	200.0	200.1	200.0	200.1	48.0	200.0	200.0	200.1	200.1	12.0	200.0	200.1	200.0	200.1	2.2	200.1	200.1	200.1	200.0
-89	20	1.6	1.2	1.8	1.4	4.3	1.0	2.0	1.0	2.7	1.3	2.4	1.0	1.4	1.0	4.1	-0.5	3.5	1.3	1.3	1.7
		200.1	200.0	200.1	200.1	200.1	200.1	200.1	200.1	200.0	200.1	200.1	200.1	200.1	200.1	200.1	200.1	200.0	200.0	200.1	200.1
-90	20	-0.5	3.7	1.1	1.3	-0.5	2.8	1.0	2.0	7.9	3.7	4.3	3.0	1.0	2.4	2.4	1.4	1.6	1.1	5.7	2.0
		200.1	200.1	200.1	200.1	200.1	200.1	200.0	200.1	200.1	200.1	200.1	200.1	200.1	200.1	200.1	200.0	200.1	200.1	200.1	200.1
-91	20	5.7	8.2	-0.5	7.1	2.8	2.6	1.1	1.5	8.5	2.6	4.2	5.1	2.9	-0.5	1.6	3.6	1.0	-0.5	4.2	6.9
		200.1	200.1	200.1	200.1	200.1	200.1	200.1	200.1	200.1	200.1	200.1	200.1	200.1	200.2	200.1	200.1	200.1	200.1	200.1	200.1
-92	20	8.5	21.7	5.7	-0.5	-0.5	-0.5	9.6	-0.5	-0.5	-0.5	6.0	-0.5	5.5	-0.5	-0.5	-0.5	12.6	-0.5	7.1	-0.5
		200.1	200.1	200.1	200.1	200.1	200.1	200.1	200.1	200.1	200.1	200.1	200.1	200.1	200.2	200.1	200.1	200.1	200.1	200.1	200.1
-93	20	-0.5	-0.5	-0.5	13.0	-0.5	-0.5	-0.5	-0.5	-0.5	43.6	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
		200.1	200.1	200.1	200.1	200.1	200.1	200.1	200.1	200.1	190.0	200.1	180.1	200.1	200.1	200.1	200.1	200.1	200.1	200.1	200.1
-94	19	-0.5	*****	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
		200.1	200.1	200.1	200.1	200.1	200.1	200.0	200.1	200.1	200.1	200.1	200.1	200.1	200.1	200.1	200.0	200.1	200.1	200.1	200.1
-95	2	-0.5	*****	-0.5	*****	*****	*****	*****													
		200.1	200.1	200.1	200.1	200.1	200.1	200.1													
-96	0	*****	*****	*****	*****	*****															
		0.0	0.0	0.0	0.0	0.0															
-97	0	*****	*****	*****	*****	*****															
		0.0	0.0	0.0	0.0	0.0															
-98	0	*****	*****	*****	*****	*****															
		0.0	0.0	0.0	0.0	0.0															

COLLINS 860E-3, S/N 583, CHANNEL 59Y, SUPP OFF, 70% REPLY EFF, 720 SQUITTER

Figure 7-8 – TTA Data for Collins 860 E-3 at a PMSE level of -99dBm

TEST: 848 SCENARIO: GAREA_SP ###

BEACON SIGNAL LEVEL	NUMBER OF TTAs	TIME-TO-ACQUIRE LOCK (SECONDS) / INTERROGATOR RECORDED RANGE (nmi)																			
(dBm)	< 120 secs	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
-60	20	1.0	1.0	1.0	1.0	1.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	-0.5	4.5	1.5	1.0	1.0	1.0	1.0
		200.0	200.0	200.0	199.9	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0
-61	20	1.0	1.0	1.0	1.2	1.0	1.0	-0.5	3.1	1.0	1.0	1.0	1.6	1.0	1.0	1.7	1.0	1.0	1.0	1.0	1.0
		200.0	200.0	200.0	200.0	200.0	200.0	199.9	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.3	200.0	200.0	200.0	199.9	200.0
-62	20	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2.4	1.0	1.0	4.8	1.0	1.0	1.0	1.0	1.0	1.1
		200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	233.3	200.0	200.0	199.9	200.0	200.0
-63	20	1.5	2.0	1.5	1.0	1.0	-0.5	1.0	1.0	1.0	1.0	1.0	3.2	2.1	2.1	2.2	1.0	1.2	1.7	3.7	1.0
		200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	199.9	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	199.9	200.0	200.0
-64	20	1.4	1.0	1.0	1.0	1.0	1.0	1.0	1.2	1.0	1.0	1.0	4.1	1.0	1.0	1.0	1.5	1.0	1.0	2.6	1.8
		200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0
-65	20	1.0	1.0	1.0	5.0	1.0	1.0	1.0	1.0	1.0	1.3	1.0	1.0	1.0	1.4	1.0	1.0	4.6	1.9	1.3	1.6
		200.0	200.0	199.9	200.0	200.0	23.3	199.9	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0
-66	20	1.6	1.0	1.0	1.3	1.0	1.0	1.6	1.0	3.2	1.0	1.0	1.0	1.0	1.0	1.0	2.3	1.0	1.5	1.7	1.0
		200.0	200.0	200.0	200.0	12.3	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	199.9
-67	20	-0.5	3.7	1.0	1.0	1.0	1.0	1.0	2.4	1.0	1.0	3.1	1.0	1.0	4.2	1.0	1.0	1.0	1.0	1.0	2.2
		200.0	266.3	199.9	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0
-68	20	1.5	1.0	1.0	1.0	1.0	-0.5	4.1	2.8	1.0	1.0	1.2	1.0	1.8	3.1	1.0	1.0	1.0	-0.5	3.2	1.0
		200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	199.9	200.0	200.0	200.0	200.0
-69	20	1.0	1.7	2.7	1.0	1.0	1.0	2.5	1.0	1.0	-0.5	1.0	1.0	1.0	1.9	1.8	1.4	1.0	1.0	1.1	1.0
		200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0
-70	20	1.0	1.0	-0.5	3.3	1.0	1.0	1.5	1.0	1.0	1.2	1.0	1.0	1.0	1.0	1.0	1.1	4.1	1.0	1.2	1.0
		200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	199.9	200.0	200.0	200.0	200.0	200.0	200.0	200.0	334.0	200.0
-71	20	1.0	1.0	1.0	1.0	1.0	1.0	1.7	1.0	-0.5	3.2	2.0	2.9	1.0	1.0	1.0	1.0	1.1	1.7	1.0	1.3
		200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0
-72	20	-0.5	1.0	2.7	1.0	1.8	1.0	1.2	1.0	1.3	1.8	1.0	1.0	1.0	-0.5	4.0	1.0	1.0	1.5	1.0	1.5
		200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	330.0
-73	20	1.0	1.0	1.0	1.0	2.0	1.0	4.4	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.3	1.0	1.1	1.0	-0.5	1.0
		200.0	200.0	200.0	200.0	200.0	199.9	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0
-74	20	1.0	1.0	1.0	1.7	1.0	1.4	2.0	1.2	1.0	1.0	2.4	5.4	1.0	1.0	1.0	1.0	2.7	1.0	1.5	3.1
		200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0
-75	20	1.0	3.8	3.8	7.8	2.5	1.6	3.4	4.7	1.6	1.0	-0.5	3.7	5.3	1.3	1.6	1.0	1.0	1.0	1.6	1.0
		200.0	200.0	200.0	200.0	92.7	200.0	180.0	200.0	200.0	200.0	0.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0
-76	20	5.8	9.5	1.0	1.3	1.0	3.1	1.6	1.0	1.6	2.0	1.8	-0.5	3.8	1.0	1.1	2.7	1.0	1.0	1.0	1.0
		200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.1	200.0	200.0	200.0	200.0	200.0	200.0	200.0
-77	20	1.0	1.0	1.0	1.0	3.4	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.6	1.0	1.0	1.0	1.0	4.7	1.0	1.0
		200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0
-78	20	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	3.8	1.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
		200.0	200.1	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.1	200.0	200.0	200.0	200.1	200.0	200.0	200.0
-79	20	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	1.0	-0.5	-0.5	-0.5	1.0	-0.5	-0.5	1.3	-0.5	-0.5	-0.5	-0.5	-0.5
		200.0	200.0	200.1	200.0	200.0	200.0	399.8	200.0	0.1	400.0	200.1	200.0	200.0	200.0	200.0	200.0	200.0	200.1	200.0	200.0
-80	20	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	1.0	-0.5	1.0	-0.5	-0.5	-0.5	1.0	-0.5
		200.0	200.0	200.1	200.1	200.0	200.0	399.7	399.6	200.0	399.7	200.0	200.0	399.6	0.6	399.6	200.0	200.0	16.5	200.0	200.1
-81	20	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	1.0	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
		200.0	399.6	200.1	399.5	200.1	399.5	399.3	200.0	200.1	399.6	200.1	200.1	200.0	200.1	200.0	180.8	399.6	399.6	199.7	399.6
-82	20	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	5.4	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
		20.0	0.7	200.1	200.0	399.5	236.5	200.1	200.1	0.6	399.5	0.7	200.1	399.6	200.1	200.1	200.1	0.6	200.0	399.6	161.9
-83	20	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	3.2	-0.5	3.1	7.2	1.0	-0.5	2.7	-0.5	-0.5	-0.5	-0.5
		200.1	200.1	200.1	200.0	202.5	0.6	399.5	399.6	200.0	0.7	199.1	0.8	0.7	0.7	186.3	0.7	399.5	1.2	399.5	202.4
-84	20	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	3.9	-0.5	2.0	-0.5	-0.5	-0.5	-0.5	-0.5
		399.6	0.6	0.6	0.8	399.5	399.5	399.5	399.6	200.1	202.5	399.5	200.1	0.6	0.7	0.7	399.6	200.0	399.6	399.5	399.6
-85	20	-0.5	-0.5	-0.5	-0.5	-0.5	3.9	-0.5	-0.5	6.1	-0.5	-0.5	-0.5	-0.5	8.2	-0.5	-0.5	-0.5	2.3	3.5	-0.5
		202.5	200.1	200.0	0.6	199.1	0.6	149.2	0.5	0.7	0.5	0.7	0.6	0.6	0.8	0.7	0.7	0.6	0.6	0.7	202.4
-86	20	-0.5	2.5	3.9	-0.5	1.0	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
		199.2	0.7	0.6	200.0	399.5	0.5	0.7	0.0	202.5	399.5	200.1	0.6	0.7	0.6	400.1	0.7	202.6	81.7	0.5	399.5
-87	20	-0.5	-0.5	6.6	1.2	-0.5	2.1	-0.5	-0.5	2.0	3.2	1.5	8.4	-0.5	2.4	-0.5	-0.5	-0.5	1.3	-0.5	-0.5
		0.6	202.5	0.8	0.6	399.6	0.6	0.4	0.6	0.6	0.7	0.6	0.7	104.6	420.0	0.7	200.1	399.6	42.0	202.5	0.7
-88	20	-0.5	1.5	-0.5	-0.5	-0.5	4.4	-0.5	4.5	-0.5	1.0	2.7	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	6.4	-0.5
		0.7	0.6	399.6	0.7	0.6	0.7	202.5	0.6	202.6	399.5	0.7	202.5	0.7	266.7	116.1	0.5	202.6	0.6	0.7	399.6
-89	20	2.9	-0.5	3.8	-0.5	-0.5	-0.5	4.2	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
		0.6	0.6	0.7	202.5	202.6	164.1	0.6	202.4	399.6	5.6	399.6	202.5	202.6	0.7	399.7	140.6	399.6	74.6	0.1	202.6
-90	20	5.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	7.9	-0.5	-0.5	-0.5	-0.5	9.5	-0.5	-0.5	3.7	-0.5	-0.5	-0.5
		202.6	202.6	399.5	202.5	202.5	318.0	0.7	202.6	202.6	399.5	178.2	9.0	202.6	0.7	202.6	399.5	0.7	0.6	104.1	39.3
-91	20	-0.5	3.2	-0.5	-0.5	-0.5	-0.5	-0.5	4.5	-0.5	-0.5	16.4	-0.5	8.3	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
		202.5	0.6	0.6	202.6	0.6	202.5	202.5	0.6	202.6	202.6	0.8	0.7	0.7	0.7	202.6	399.5	202.5	202.6	202.5	399.6
-92	20	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	1.1	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	2.4	-0.5	-0.5
		399.9	0.6	0.7	399.6	146.6	0.6	202.6	0.7	202.6	0.6	399.5	399.5	0.5	0.8	140.7	0.7	0.7	0.7	399.6	202.6
-93	20	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	5.4	-0.5	2.3	-0.5	-0.5	-0.5	-0.5	-0.5	2.8	2.3	-0.5	-0.5
		399.6	399.5	0.7	202.5	202.6	0.7	202.6	202.6	0.7	399.5	0.7	20.0	0.7	202.6	0.7	202.6	0.7	0.6	0.6	0.6
-94	20	3.1	-0.5	-0.5	-0.5	-0.5	-0.5	1.0	-0.5	-0.5	-0.5	1.8	2.1	-0.5	1.7	4.0	1.9	5.1	-0.5	-0.5	-0.5
		0.7	202.5	202.5	202.6	0.7	0.6	399.6	0.7	0.6	199.2	0.5	0.7	0.6	0.6	0.8	0.6	0.7	399.7	399.6	0.7
-95	20	-0.5	-0.5	-0.5	-0.5	4.9	2.9	3.3	-0.5	1.8	-0.5	3.6	-0.5	-0.5	-0.5	1.0	-0.5	-0.5	-0.5	-0.5	-0.5
		0.8	399.6	0.6	0.7	0.7	1.8	0.7	399.5	0.7	202.6	0.7	0.7	0.7	399.7	399.6	399.6	200.2	0.9	0.7	399.7
-96	20	-0.5	5.1	-0.5	-0.5	6.8	1.0	4.9	1.0	1.1	14.0	-0.5	8.1	4.3	1.2	1.0	6.9	2.1	-0.5	-0.5	-0.5
		0.7	0.6	0.6	0.7	0.7	0.2	0.7	0.7	0.7	0.7	399.6	0.7	0.7	0.6	0.6	0.7	80.1	0.7	0.7	0.7
-97	20	-0.5	-0.5	1.0	12.4	2.5	6.5	3.2	8.7	-0.5	-0.5	-0.5	1.0	-0.5	-0.5	-0.5	-0.5	7.0	-0.5	3.7	-0.5
		0.7	0.7	0.6	0.8	0.6	0.8	0.6	0.8	399.5	0.6	0.7	399.5	399.6	0.6	0.7	0.6	0.7	0.7	0.7	0.6
-98	20	1.4	2.6	-0.5	5.2	8.1	5.1	6.8	-0.5	-0.5	1.4	-0.5	-0.5	1.0	-0.5	-0.5	1.0	1.2	-0.5	3.1	-0.5
		0.7	0.8	0.5	0.8	0.7	0.7	0.8	0.6	0.7	0.6	0.6	399.6	0.6	0.5	0.7	399.5	0.5	0.5	0.7	399.6
-99	20	-0.5	3.0	5.0	1.6	-0.5	-0.5	-0.5	1.1	-0.5	1.5	1.4	1.9	1.0	1.8	-0.5	3.2	-0.5	2.1	2.9	1.3
		399.6	0.6	0.6	0.6	0.6	0.6	0.7	0.6	0.6	0.5	0.7	0.6	0.5	0.6	399.6	0.6	0.6	0.6	0.7	0.6
-100	20	1.2	4.4	-0.5	1.0	5.5	-0.5	-0.5	5.5	2.4	-0.5	3.4	3.0	-0.5	2.3	2.8	2.4	2.3	-0.5	2.7	-0.5
		0.5	0.6	0.7	399.6	0.6	399.6	0.7	0.6	0.6	0.7	0.7	0.6	0.6	0.6	0.8	0.7	0.6	0.6	0.6	0.7
-101	20	-0.5	-0.5	4.2	-0.5	2.6	2.2	-0.5	2.0	1.0	-0.5	1.7	1.3	1.7	-0.5	-0.5	-0.5	1.6	6.5	-0.5	-0.5
		0.6	399.5	0.7	0.5	0.6	0.6	0.7	0.7	0.6	0.6	399.6	0.6	0.6	0.6	399.6	0.6	0.5	0.7	0.6	0.7
-102	20	-0.5	-0.5	-0.5	4.5	1.0	-0.5	-0.5	-0.5	1.4	4.4	1.0	2.2	-0.5	1.0	-0.5	-0.5	1.0	1.6	-0.5	-0.5
		0.8	399.6	199.6	0.6	0.5	10.0	399.6	399.7	0.6	0.7	0.5	0.7	140.0	399.6	0.7	0.5	0.6	0.5	0.6	399.6
-103	20	-0.5	1.9	-0.5	-0.5	3.0	-0.5	3.5	3.0	3.1	2.7	1.8	1.0	1.6	-0.5	1.0	1.0	-0.5	-0.5	-0.5	1.0
		399.6	0.6	399.7	0.6	0.6	0.6	0.6	0.6	0.6	0.7	0.5	0.5	0.5	0.7	399.6	399.6	0.7	0.6	0.6	0.6

COLLINS 860E-3, S/N 583, CHANNEL 59Y, SUPP OFF, 70% REPLY EFF, 720 SQUITTER

Figure 7-9 – TTA Data for Collins 860 E-3 at a PMSE level of -90dBm

7.4.2 PMSE Co-Channel Breaklock Test on a Collins 860 E-3

7.4.2.1 Figure 7-10 below shows the relationship between the received signal strength from the DME Beacon and the level of PMSE necessary to cause Breaklock.

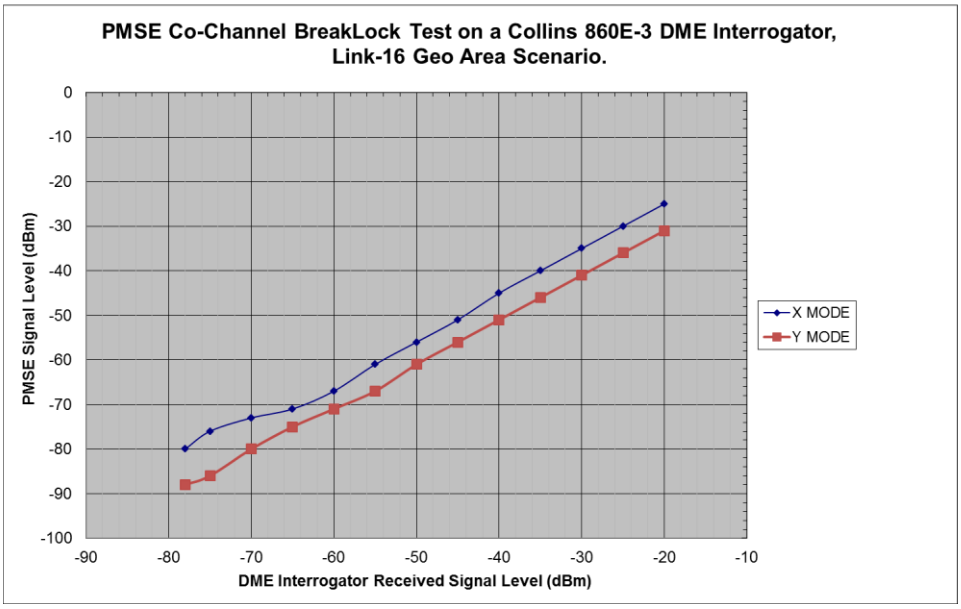


Figure 7-10 – Collins 860E-3 Breaklock Test

7.4.2.2 The Breaklock data again shows the PMSE Co-Channel signal levels that cause a Collins 860 E-3 to breaklock while locked on to a DME Ground Beacon.

7.4.2.3 Both X-mode and Y-mode are shown below. Unlike the Bendix/King KN-64 there is a difference between the X and Y tests, with X mode being marginally more susceptible to PMSE interference. Again the liner relationship that shows that a 6dB increase in PMSE power causes a 6dB increase in the required received signal in order to maintain lock.

7.4.3 Collins 860 E-3 Off-Frequency Rejection (OFR)

7.4.3.1 For the Collins 860 E-3 the OFR curve was measured with a Beacon Signal Level set to the measured ASOP level on both X and Y Channels.

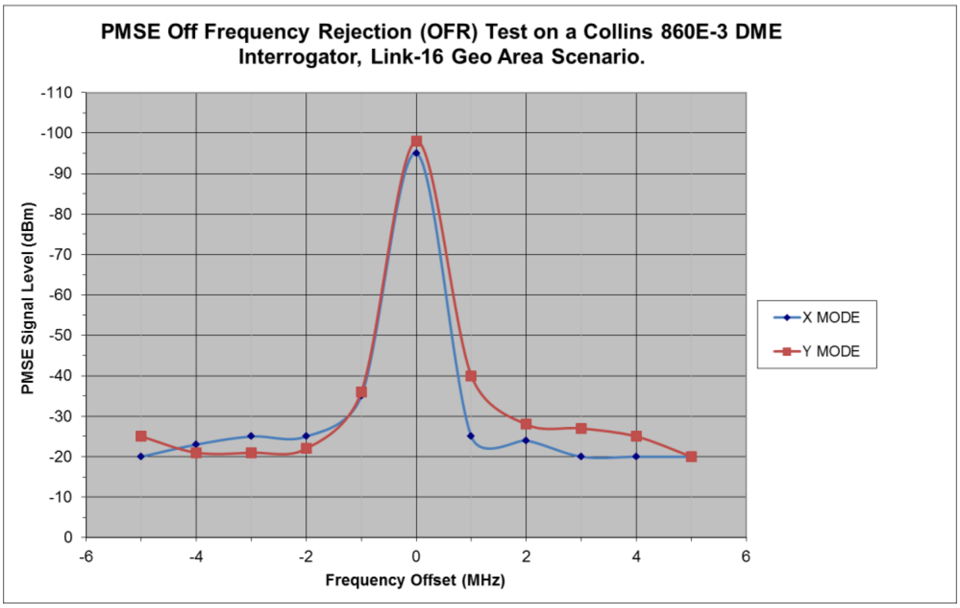


Figure 7-11 – Collins 860E-3 Off-Frequency Rejection (OFR) Curve

7.4.3.2 Figure 7-11 shows that the Collins 860 E-3 is a more selective receiver when compared to the Bendix/King KN-64, and that the performance on both X and Y channel is similar.

7.5 King KDM 705 E-3Test Results

7.5.1 PMSE Co-Channel ASOP Test on a King KDM 705

7.5.1.1 Figure 7-12 and 7-13 below show the results of the King KDM 705 ASOP tests.

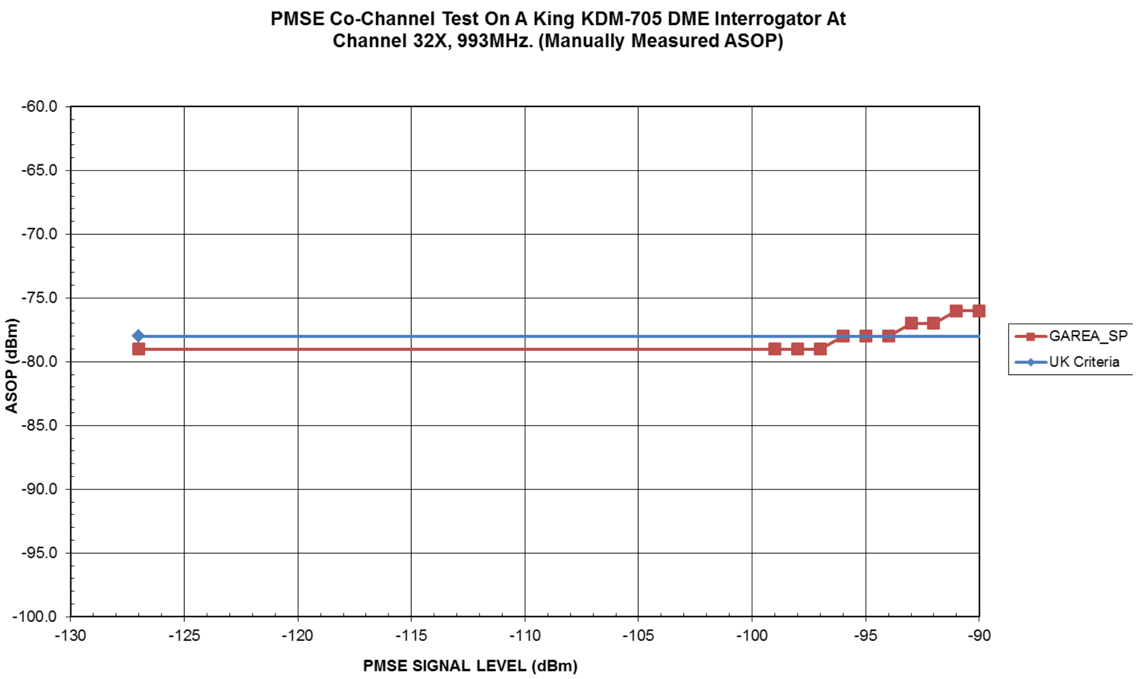


Figure 7-12 – King KDM 705 ASOP Test, Channel 32X

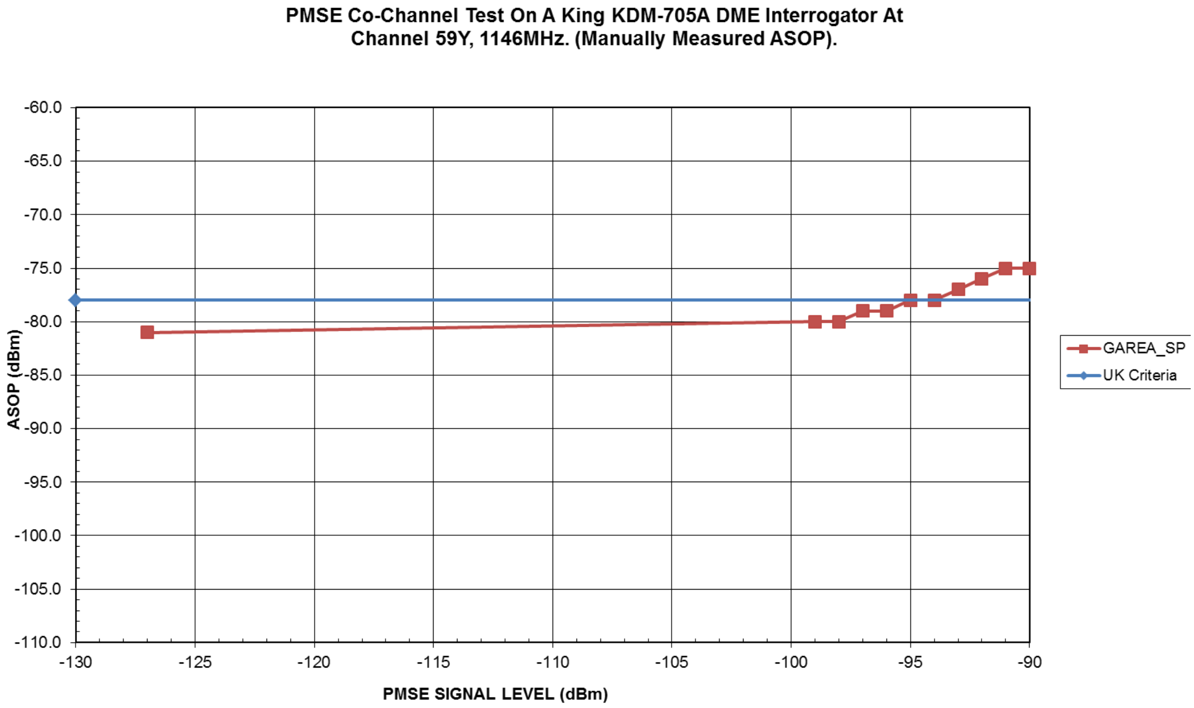


Figure 7-13 – King KDM 705 ASOP Test, Channel 59Y

7.5.1.2 The Manual ASOP tests show that PMSE signal greater than -96dBM for the King KDM 705 causes the Interrogator to drop below the specified performance criteria.

7.5.2 PMSE Co-Channel Breaklock Test on a King KDM 705

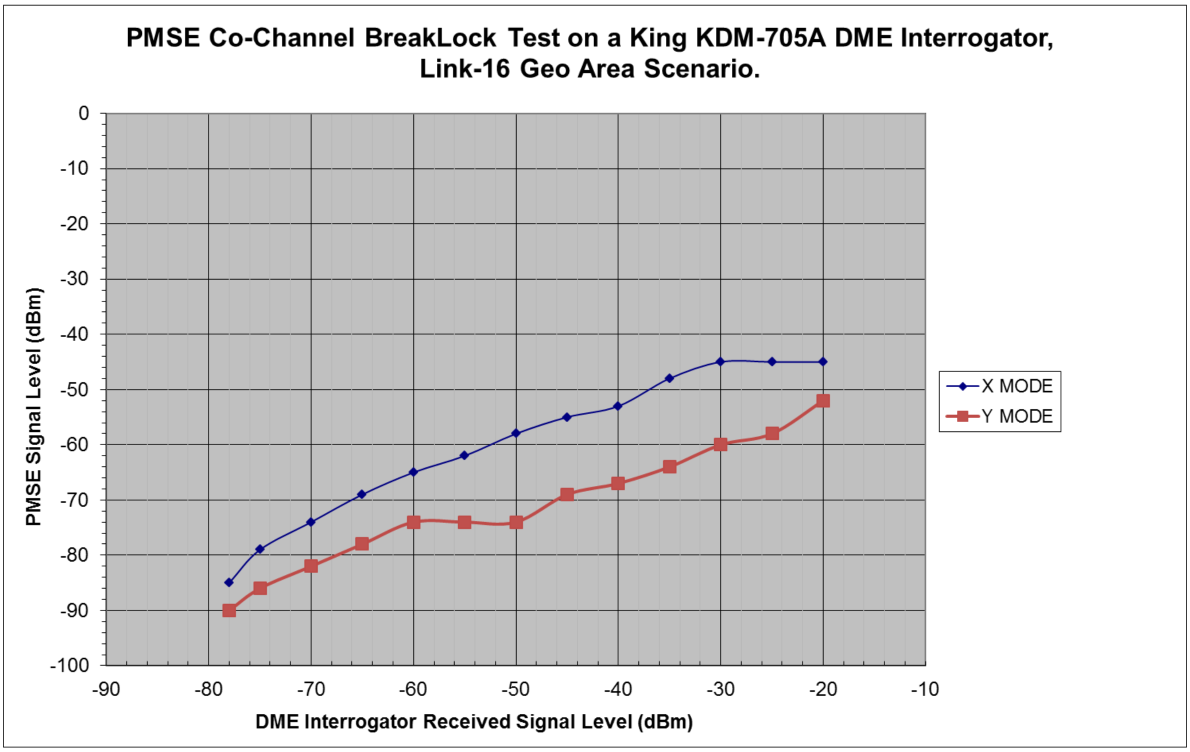


Figure 7-14 – King KDM 705 Breaklock Test

7.5.2.1 The breaklock test on the King KDM 705A showed the relationship between the PMSE signal levels and DME interrogator received signal strength. It can be seen in Figure 7-14 that the PMSE signals do not increase linearly as with the other interrogators tested. In addition false range anomalies were observed during both the X and Y mode breaklock tests.

7.5.3 King KDM 705 Off-Frequency Rejection (OFR)

7.5.3.1 For the King KDM 705 the OFR curves were again measured with a Beacon Signal Level set to the measured ASOP level on both X and Y Channels.

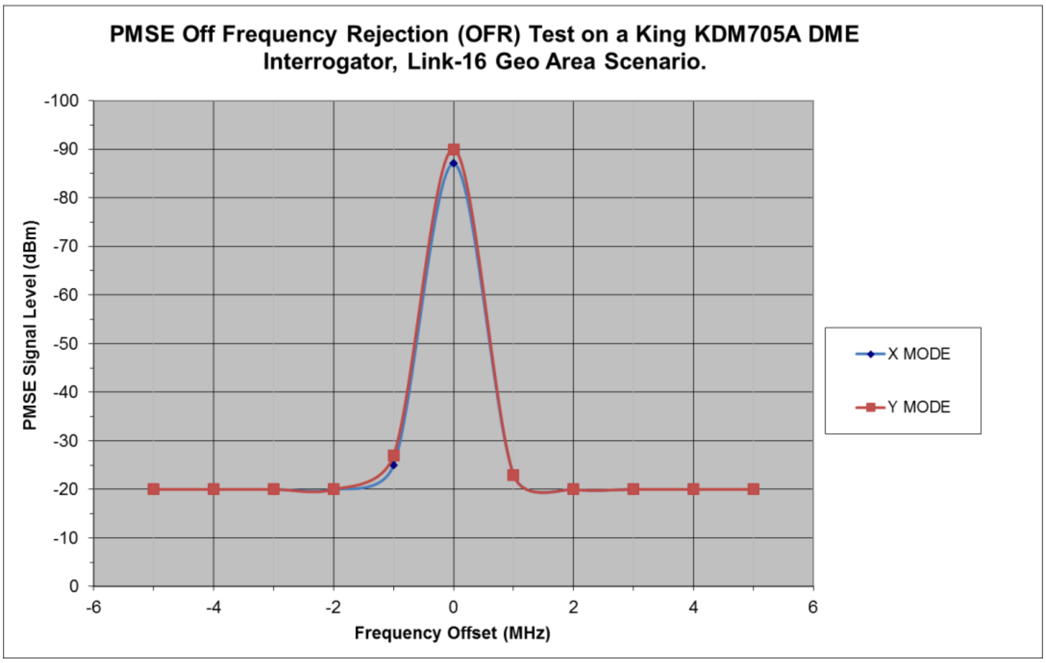


Figure 7-15 – King KDM 705A Off-Frequency Rejection (OFR) Curve

7.5.3.2 Figure 7-15 shows that the King KDM 705, like the Collins 860 E-3, is a more selective receiver when compared to the Bendix/King KN-64. The OFR curve for both X and Y mode is similar.

8 SSR TEST CONFIGURATION

8.1 Overview

8.1.1 In accordance with the agreed test specification, SSR performance was assessed without any extraneous pulses from DME or Link 16. A desired signal was produced using the JCSys test environment which is able to vary the power level and pulse rate.

8.1.2 All testing was carried out under laboratory conditions and with a closed system: no external signals were radiated or received.

8.1.3 For testing at 1090 MHz, the Comsoft manufactured Quadrant Sensor was configured to respond to all message types and the decoded messages were streamed to a text file. A utility programme was developed to parse these files and to count the number of each received message type.

8.1.4 For testing at 1030 MHz, the replies generated by the Trig Avionics manufactured TT21 transponder were received by the Quadrant Sensor which was incorporated into the TT21 test set-up. The same utility programme was used to count the number of replies, and hence determine the number of TT21 transmissions.

8.1.5 A pulse rate of 1000 messages per second was used for SSR testing at 1090 MHz and 100 messages per second for 1030 MHz.

8.2 PMSE Interference

8.2.1 Following discussions with Ofcom (reference email from Vaughan John to JCSys, 8th May 2015) interference from PMSE consists of a single CW signal at the frequency of interest. Adjacent channel interference is replaced by multiple measurements of a single CW signal offset from the frequency of interest. A resultant selectivity graph is produced.

9 SSR RECEIVER TEST RESULTS

9.1 Introduction

9.1.1 An SSR receiver is used to receive replies and includes the services Mode A, Mode C, Mode S and ADS-B. Replies, also known as Downlink Format or DF messages, are sent on 1090 MHz.

9.1.2 The format of Mode A and Mode C replies is identical and it is not possible to distinguish between the two without knowledge of the interrogation. As such, Mode A and Mode C replies are often written as Mode A/C or Mode AC.

9.1.3 Mode S replies contain a unique Mode S address, also known as ICAO 24-bit Address.

9.1.4 Mode A/C receivers are required to identify multiple overlapping replies in a cluttered RF environment; Mode S receivers are required to decode a received message and perform some integrity checking. As a consequence of this, the SSR receiver was measured for Mode A/C and Mode S performance separately.

9.1.5 The ADS-B service is provided using two specific Mode S messages: DF11 (short squitter) and DF17 (extended squitter). As ADS-B is a subset of the Mode S message set, its performance is covered by the performance of Mode S.

9.1.6 The following equipment was used by JCSys as part of the PMSE test programme:-

- Quadrant Mode A/C/S Sensor (used extensively throughout Europe and Asia).

9.2 Pass/Fail Criteria

9.2.1 The role of a Mode A/C/S receiver is to detect and decode a message transmitted on 1090 MHz and pass this message onto the next processing element in the surveillance system. The performance is characterised by Successful Message Rate (SMR) expressed as a percentage of the maximum possible message rate.

9.2.2 The Quadrant Sensor is expected to achieve >90% SMR at -88 dBm [Comsoft requirement to meet ED142 and ED129].

9.3 Quadrant Mode S Test Results

9.3.1 The JCSys test system created multiple DF11 (All Call Reply) messages containing the Mode S address "400001"[1]. The Quadrant Sensor was configured to respond to all Mode S message types but to ignore Mode A/C.

9.3.2 The following charts show the performance in three distinct ways:-

- Normal performance as a function of message power
- Sensitivity of performance to PMSE at the message frequency

[1] The address is in hexadecimal format and was chosen arbitrarily.

- Selectivity against PMSE at frequencies offset from the message frequency

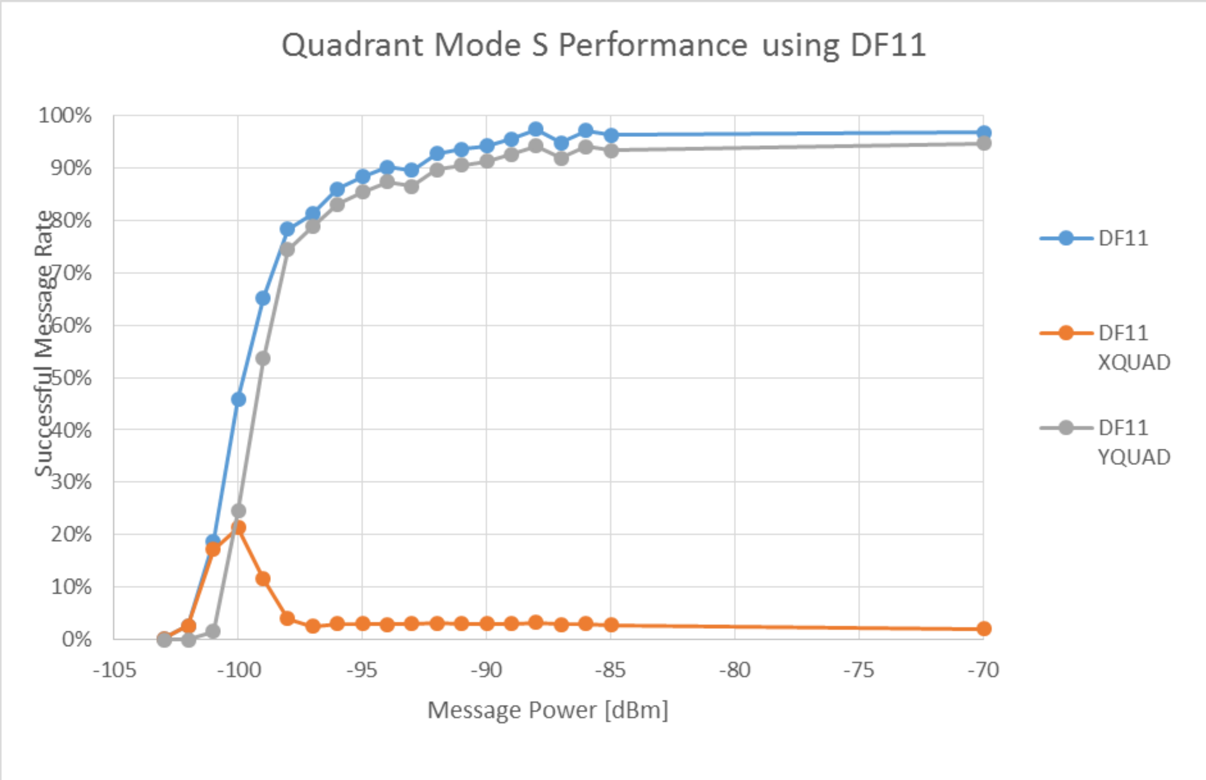


Figure 9-1 - Quadrant Performance using Mode S

9.3.3 The Successful Message Rate (SMR) shows the total number of DF11 messages successfully decoded. A message is either decoded as high confidence (YQUAD) or low confidence (XQUAD).

9.3.4 The chart in Figure 9-1 shows that the number of low confidence messages (XQUAD) only increases for signal power less than -97 dBm.

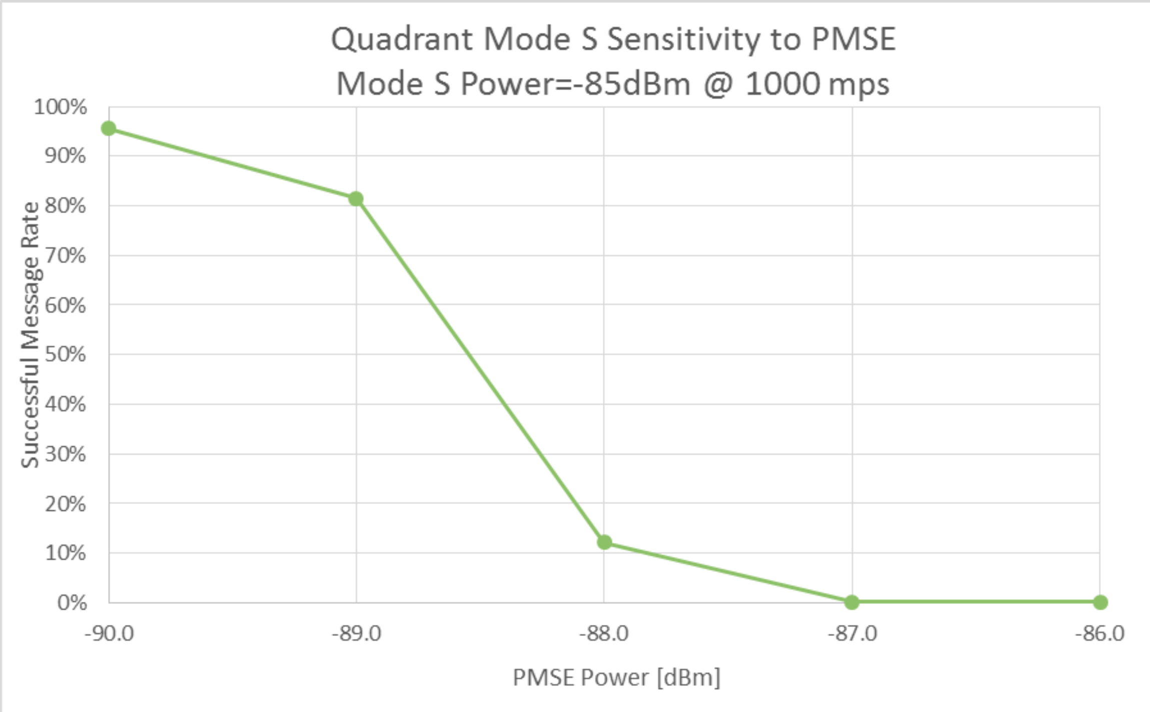


Figure 9-2 - Quadrant Sensitivity to PMSE using Mode S

9.3.5 The sensitivity to PMSE was measured over a range of offset frequencies. The failure criteria of 90% was selected and a failure power was established by interpolating the two results either side of 90%. The selectivity is obtained by plotting the failure power against offset frequency as shown in Figure 9-3 below.

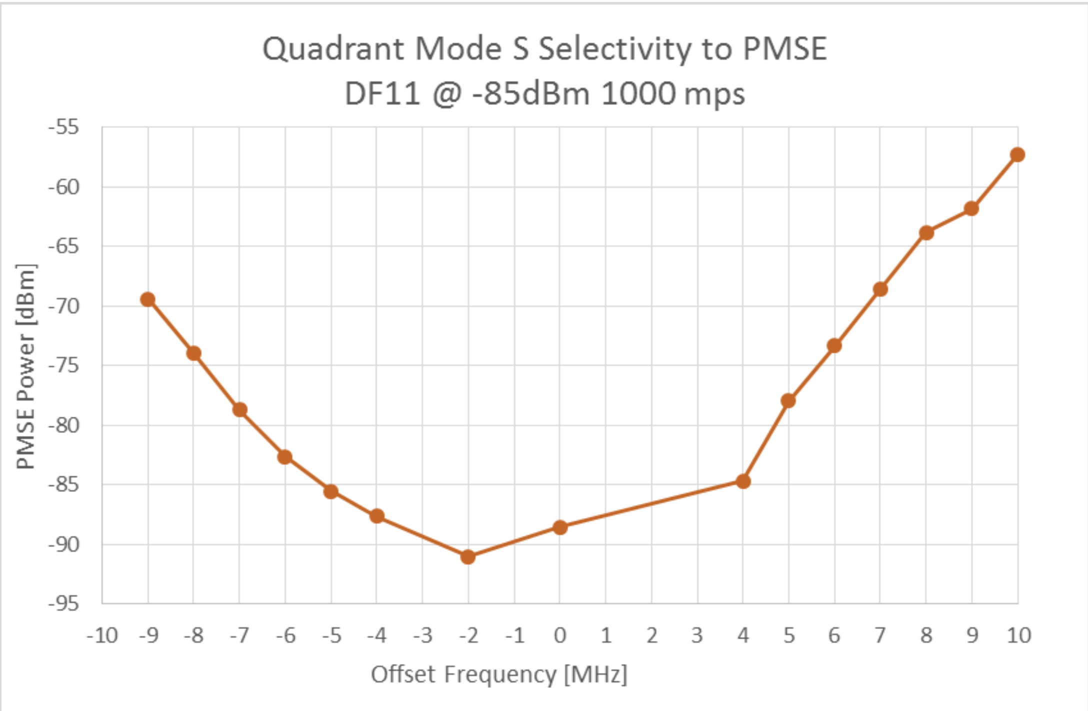


Figure 9-3 - Quadrant Selectivity to PMSE using Mode S

9.3.6 The Mode S performance of Quadrant decreases as the PMSE power increases and shows that PMSE power greater than -90 dBm will cause the Mode S performance to drop below the statutory minimum. The decline with PMSE power is steep and all Mode S performance is lost when PMSE power is greater than -87 dBm.

9.3.7 The PMSE selectivity of the Quadrant Sensor using Mode S shows that an additional 20 dB of PMSE power can be tolerated if the PMSE frequency is offset by greater than 9 MHz

9.4 Quadrant Mode AC Test Results

9.4.1 The JCSys test system created multiple Mode AC messages containing the Mode A code “7600”[2]. The Quadrant Sensor was configured to respond to Mode A/C messages and to ignore Mode S.

9.4.2 The Quadrant Sensor has an adjustable minimum detection threshold. In normal operation, this threshold is adjusted according to the required detection range of the sensor. The correct setting of this threshold prevents the sensor from triggering on noise or from FRUIT[3].

9.4.3 The Mode A/C threshold was set for these measurements to ensure there were no messages generated by noise. The signal of interest was set 10 dB above this level at -75 dBm.

9.4.4 The following charts show the performance in three distinct ways:-

- Normal performance as a function of message power
- Sensitivity of performance to PMSE at the message frequency
- Selectivity against PMSE at frequencies offset from the message frequency

[2] The code is in octal format and was chosen arbitrarily. This value represents a “loss of radio” message
[3] False Replies Unsynchronised with Interrogator Transmission – replies from other SSR.

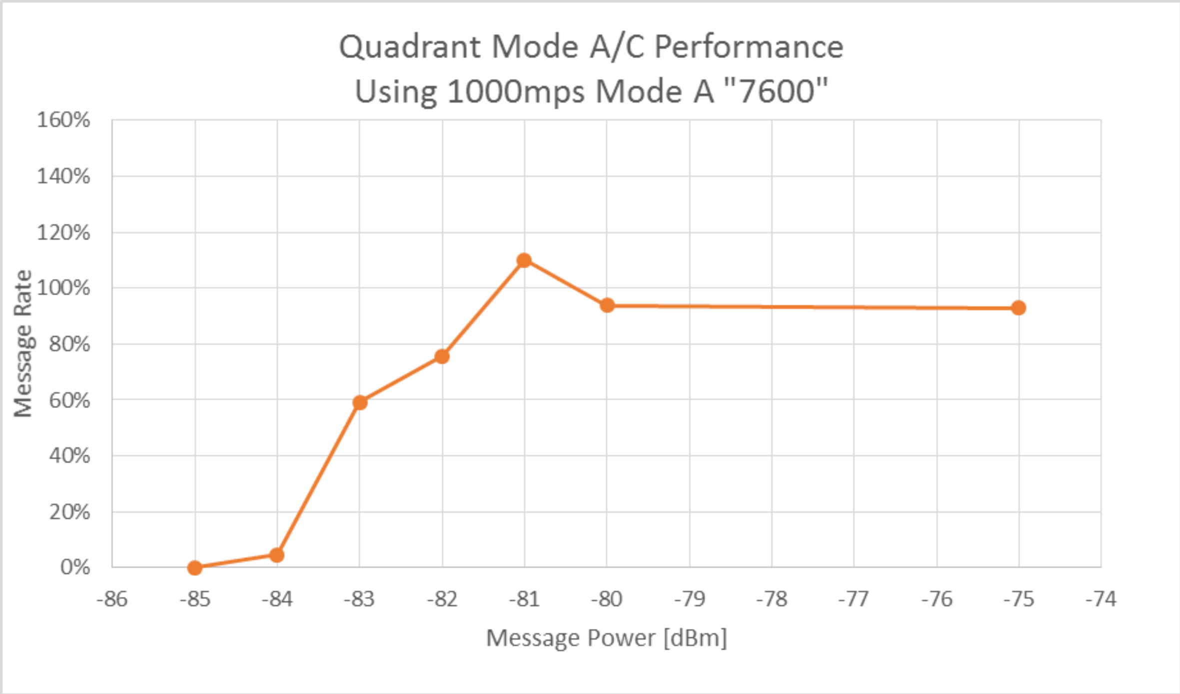


Figure 9-4 - Quadrant Performance using Mode A/C

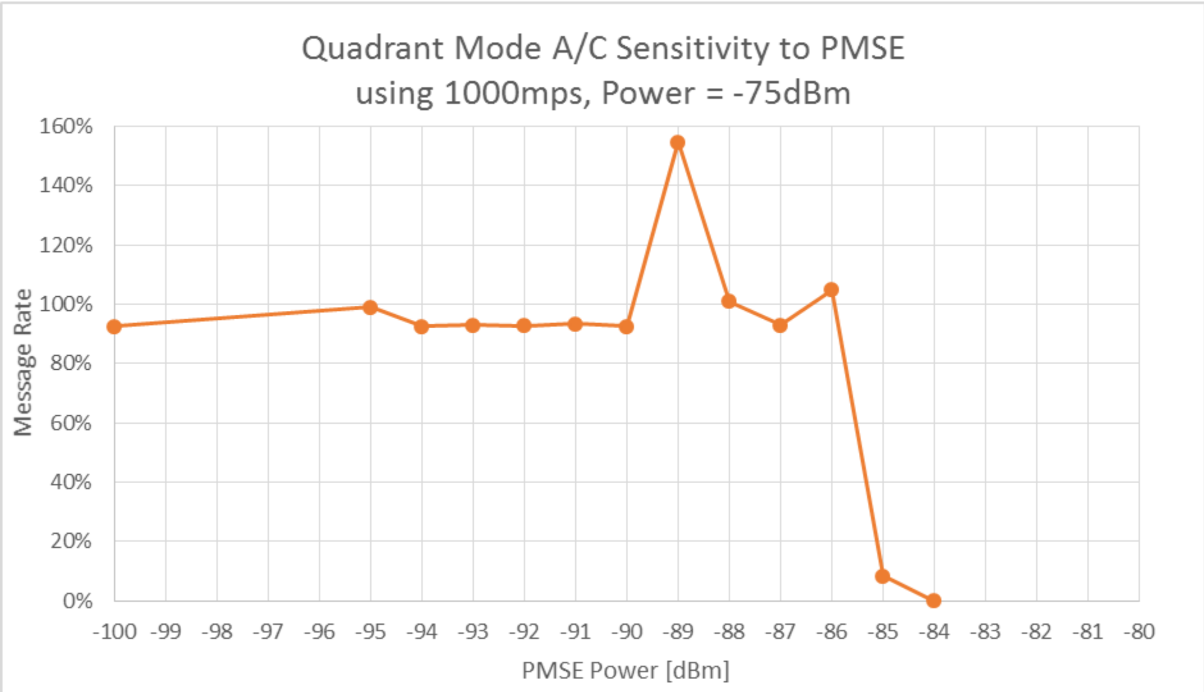


Figure 9-5 - Quadrant Sensitivity to PMSE using Mode A/C

9.4.5 The failure mode for Mode A/C is different to that of Mode S. In Figure 9-4 above, it can be seen that the message rate for the desired signal increases to >100% (at -81 dBm) before dropping away to <10% (at -84 dBm).

9.4.6 The receiver triggers on both the rising and falling edge of a pulse to enable it to detect overlapping replies from different aircraft. As the signal power reduces, noise causes the

Mode A/C pulses to distort. The receiver treats the distorted pulse as a pair of overlapping replies and decodes them both.

9.4.7 The sensitivity to PMSE was measured over a range of offset frequencies. The failure criteria of 90% was selected and a failure power was established by interpolating the two results either side of 90%. The selectivity is obtained by plotting the failure power against offset frequency as shown in Figure 9-6 below.

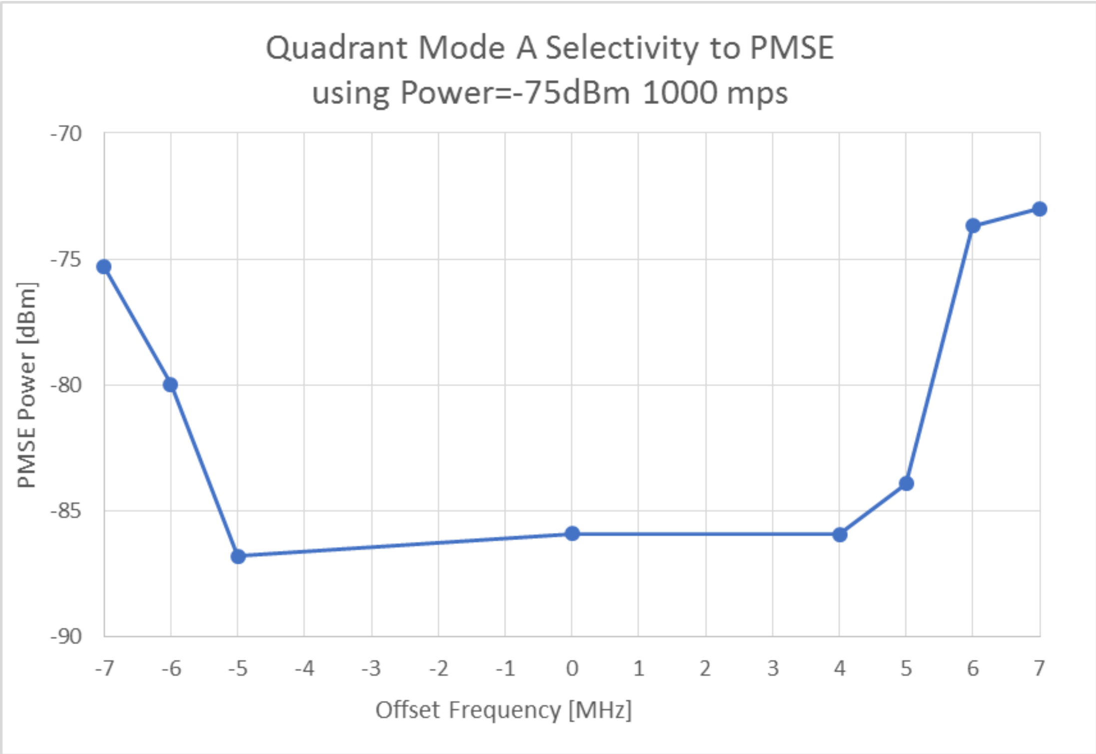


Figure 9-6 - Quadrant Selectivity to PMSE using Mode A/C

9.4.8 The Mode A/C performance of Quadrant is affected by PMSE when the power level exceeds -90 dBm. The failure mechanism for Mode A/C is different to that of Mode S and multiple additional erroneous messages are generated. All Mode A/C performance is lost when PMSE power is greater than -84 dBm.

10 SSR TRANSPONDER TEST RESULTS

10.1 Introduction

10.1.1 An SSR transponder receives interrogations and generates replies to perform services Mode A, Mode C, Mode S and ADS-B. Interrogations, also known as Uplink Format or UF messages, are received on 1030 MHz.

10.1.2 Mode A and Mode C interrogations consist of a pair of pulses with a characteristic spacing. Any aircraft receiving a Mode A/C interrogation will reply.

10.1.3 Mode S interrogations contain a unique address and are intended for a specific aircraft (with the exception of UF11 All Call). The Mode S address, also known as ICAO 24-bit Address, is unique to the aircraft and does not change with flights.

10.1.4 The following equipment was used by JCSys as part of the PMSE test programme:-

- Trig Avionics TT21 Class 2 Mode S and 1090ES ADS-B Out Transponder.

10.2 Pass/Fail Criteria

10.2.1 The role of a Mode A/C/S transponder is to detect and decode a message transmitted on 1030 MHz and to generate and transmit the correct reply on 1090 MHz. The performance is characterised by Successful Message Rate (SMR) for generated messages expressed as a percentage of the rate of interrogations.

10.2.2 The TT21 Transponder is specified to receive at -74 dBm and an SMR >90% was expected [ICAO Annex 10 3.1.2.10.1.1.4].

10.3 TT21 Mode S Test Results

10.3.1 The JCSys test system created multiple UF4 messages which should prompt the TT21 to generate a DF4 reply. The test system was configured to record all message types but to ignore Mode A/C.

10.3.2 The following charts show the performance in three distinct ways:-

- Normal performance as a function of message power
- Sensitivity of performance to PMSE at the message frequency
- Selectivity against PMSE at frequencies offset from the message frequency

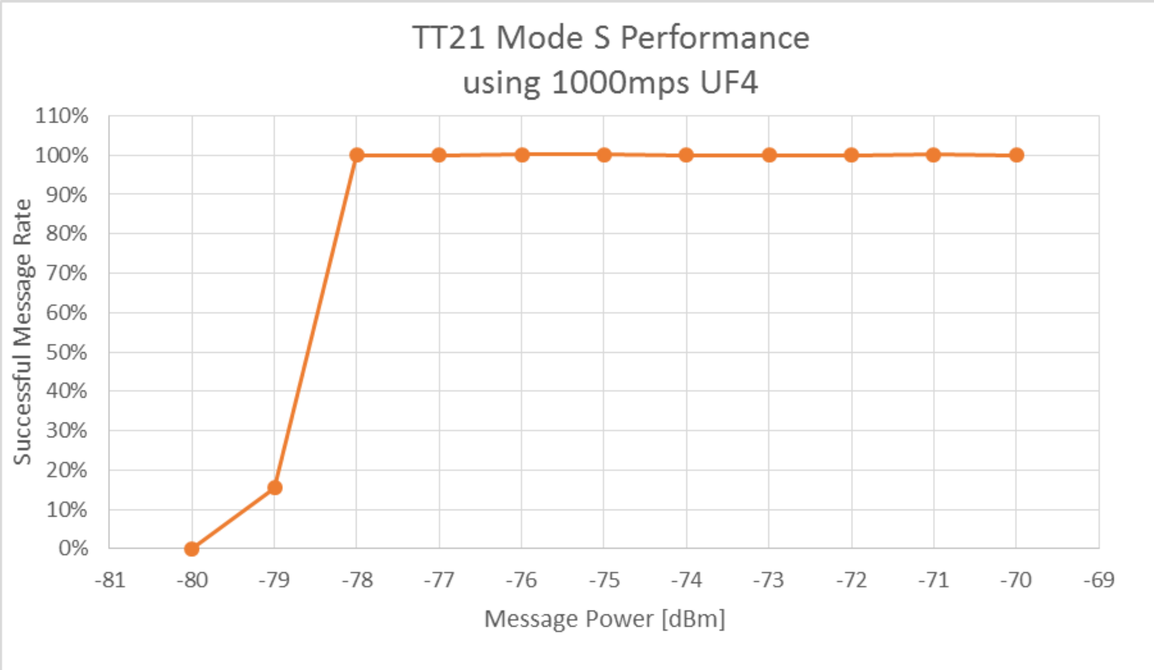


Figure 10-1 - TT21 Performance using Mode S

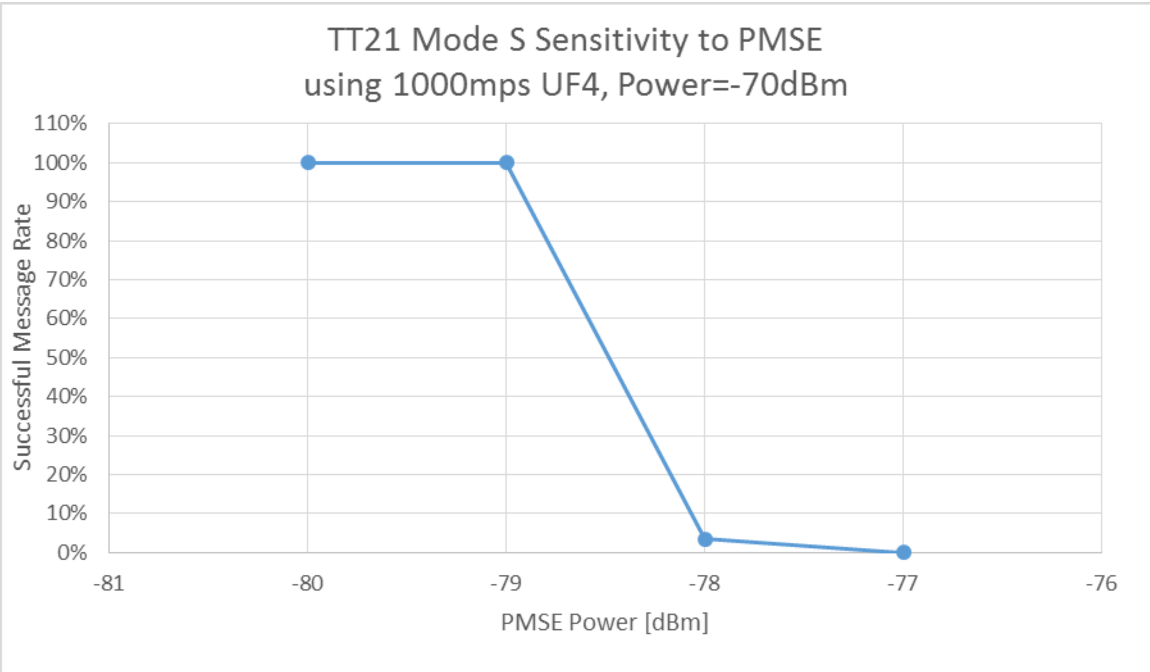


Figure 10-2 - TT21 Sensitivity to PMSE using Mode S

10.3.3 The sensitivity to PMSE was measured over a range of offset frequencies. The failure criteria of 90% was selected and a failure power was established by interpolating the two results either side of 90%. The selectivity is obtained by plotting the failure power against offset frequency as shown in Figure 10-3 below.

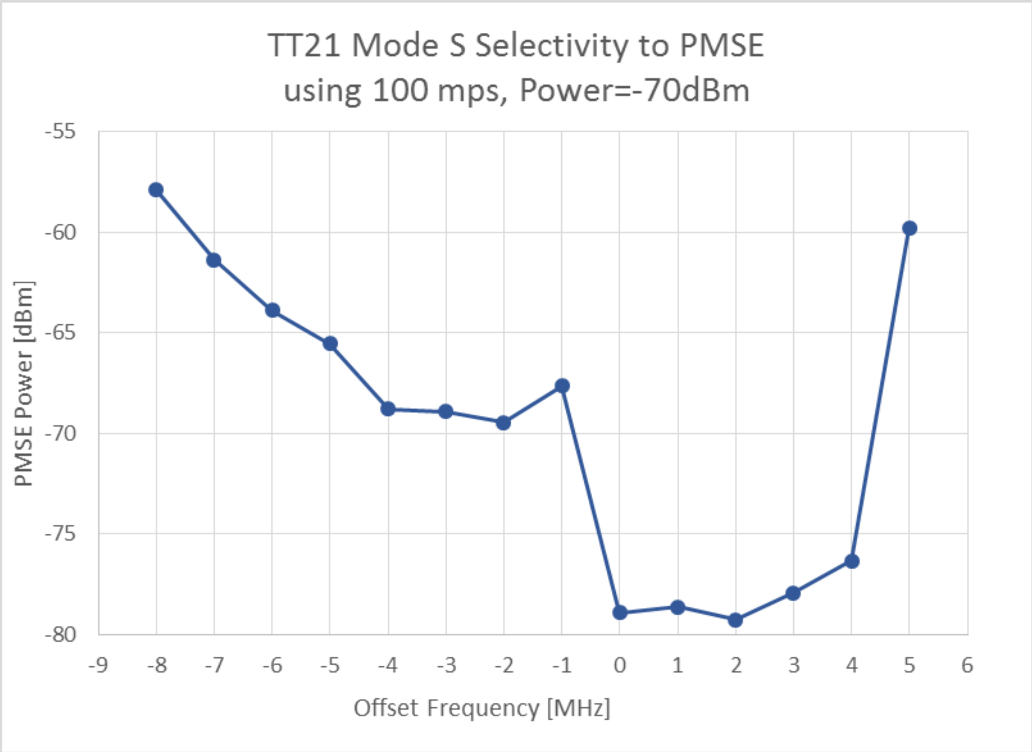


Figure 10-3 - TT21 Selectivity to PMSE using Mode S

10.3.4 The Mode S performance of TT21 decreases sharply for PMSE power greater than -79 dBm. All Mode S performance is lost when PMSE power is greater than -77 dBm.

10.3.5 The PMSE selectivity of the TT21 transponder using Mode S is asymmetric. The tolerance to PMSE is increased by 20 dB if the PMSE frequency is less than 1025 MHz or greater than 1036 MHz

10.4 TT21 Mode AC Test Results

10.4.1 The JCSys test system created multiple Mode A interrogations which should prompt the TT21 to generate a Mode A reply containing the code "7600"[4]. The test system was configured to record all message types but to ignore Mode S.

10.4.2 The following charts show the performance in three distinct ways:-

- Normal performance as a function of message power
- Sensitivity of performance to PMSE at the message frequency
- Selectivity against PMSE at frequencies offset from the message frequency

[4] This Mode A code was programmed into the TT21.

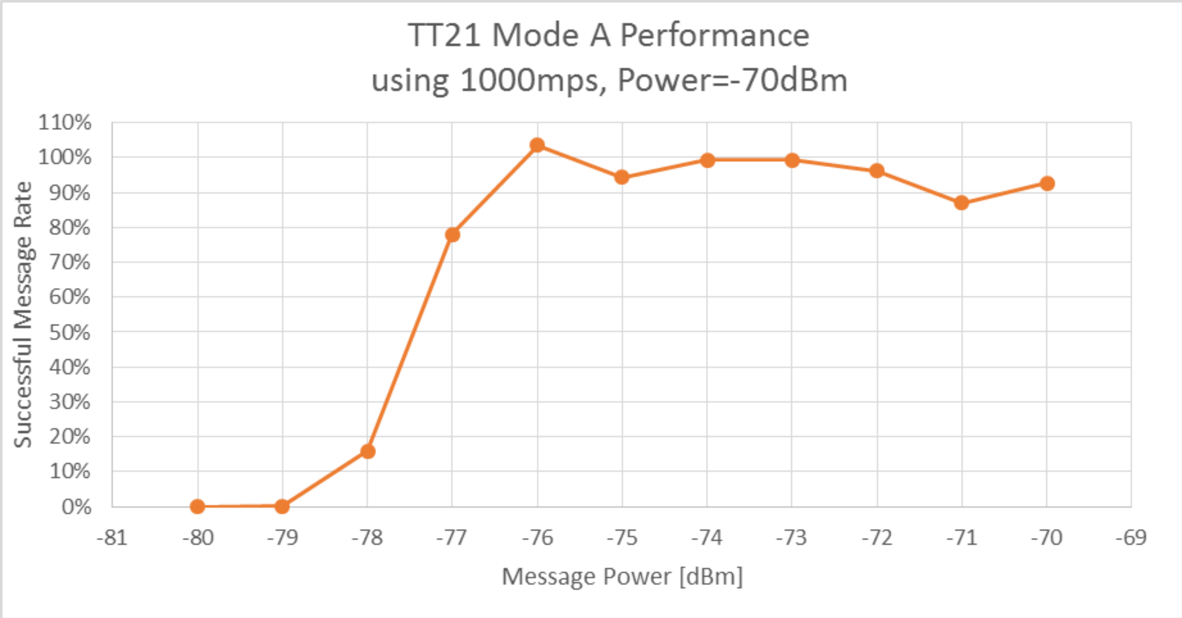


Figure 10-4 - TT21 Performance using Mode A

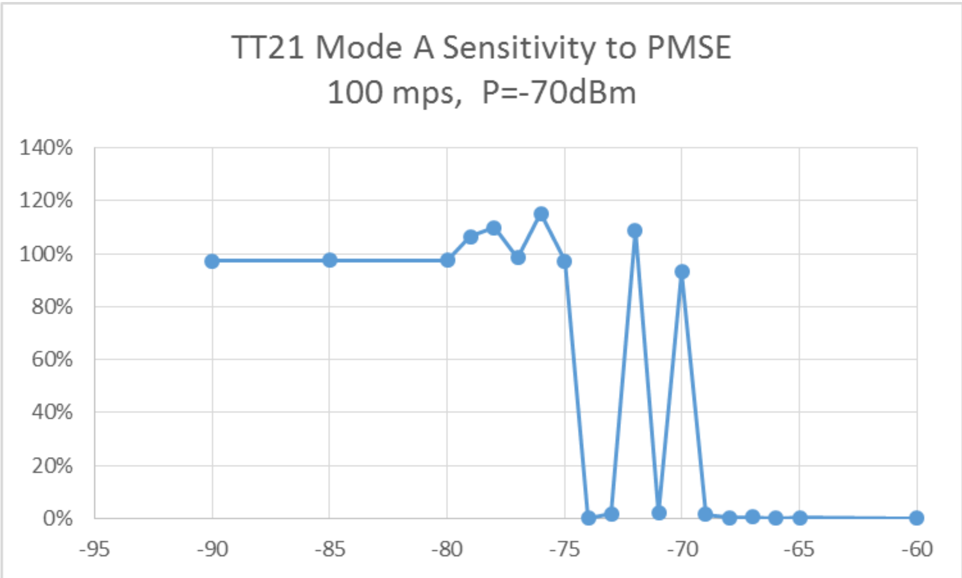


Figure 10-5 - TT21 Sensitivity to PMSE using Mode A

10.4.3 The sensitivity to PMSE was measured over a range of offset frequencies. The failure criteria of 90% was selected and a failure power was established by interpolating the two results either side of 90%. The selectivity is obtained by plotting the failure power against offset frequency as shown in Figure 10-6 below.

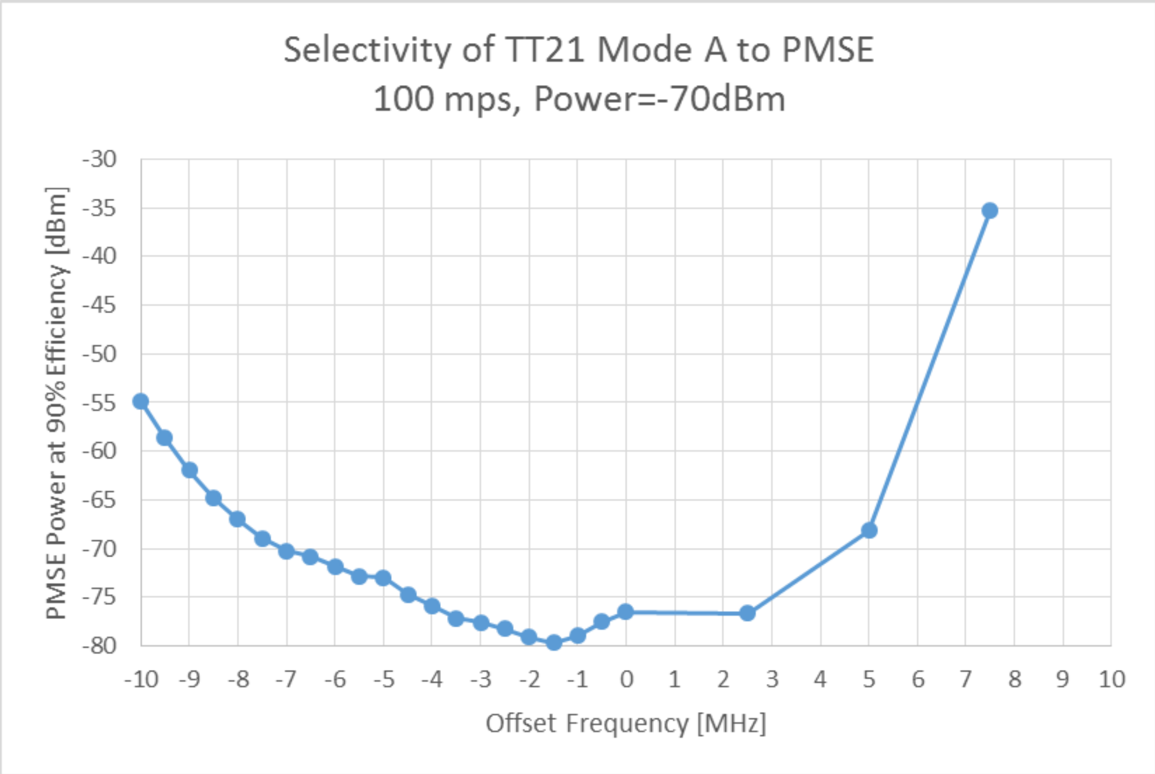


Figure 10-6 - TT21 Selectivity to PMSE using Mode A

10.4.4 The TT21 performance begins to degrade when the PMSE power is greater than -80 dBm. All performance is lost when PMSE power exceeds -69 dBm. The degradation of performance is not smooth or predictable: the behaviour for power greater than -75 dBm can vary by 100% from measurement to measurement.

10.4.5 Offsetting the PMSE frequency by 10 MHz can increase the tolerance to PMSE by 20 dB.

10.4.6 The TT21 generates additional messages when PMSE levels are greater than -80 dBm. These messages are real and not an artefact of the measurement system (Quadrant).

11 CNS TO PMSE TEST CONFIGURATION

11.1 Overview

11.1.1 PMSE performance was assessed using an audio analysis tool provided and configured by Ofcom. The tool provides a measure of the Average Deviation of an audio signal from the baseline “no interference” level.

11.1.2 A desired signal was provided by the Ofcom Analysis Tool and routed through a PMSE transmitter to a Sennheiser receiver. The antenna link was replaced by a cable and a coupler through which interfering signals were introduced.

11.1.3 All testing was carried out with a carrier of 666 MHz.

11.2 CNS Interference

11.2.1 All interfering signals were generated by the JCSys test environment and transposed to 666 MHz. These signals were used to determine the co-channel interference.

11.2.2 Adjacent channel interference is replaced by multiple measurements of interfering signals using offset frequencies. A resultant selectivity graph is produced.

12 CNS TO PMSE TEST RESULTS

12.1 Introduction

12.1.1 The PMSE transmitter has several configuration options. For these tests, the maximum output power was selected and external attenuation used to bring the signal level at the receiver input to -64 dBm.

12.1.2 External attenuation and coupling losses were measured so that interfering signal power can also be referred to the receiver input.

12.1.3 It is recommended (reference email from Vaughan John, 20th March 2015) that the analysis tool is not used below 700 ppps. All interference generated was at a nominal 1000 ppps.

12.2 Pass/Fail Criteria

12.2.1 An Average Deviation (AvD) greater than 15 is considered a fail. The AvD display updates frequently and a visual assessment was made. For this reason, the uncertainty on the reading is 1.

12.3 PMSE DME Test Results

12.3.1 The JCSys test system generated DME interrogations pulse pairs on either X channel or Y channel.

12.3.2 The following charts show the performance in three distinct ways:-

- Performance as a function of pulse rate and message power
- Sensitivity of performance to DME at the message frequency
- Selectivity against DME at frequencies offset from the channel frequency

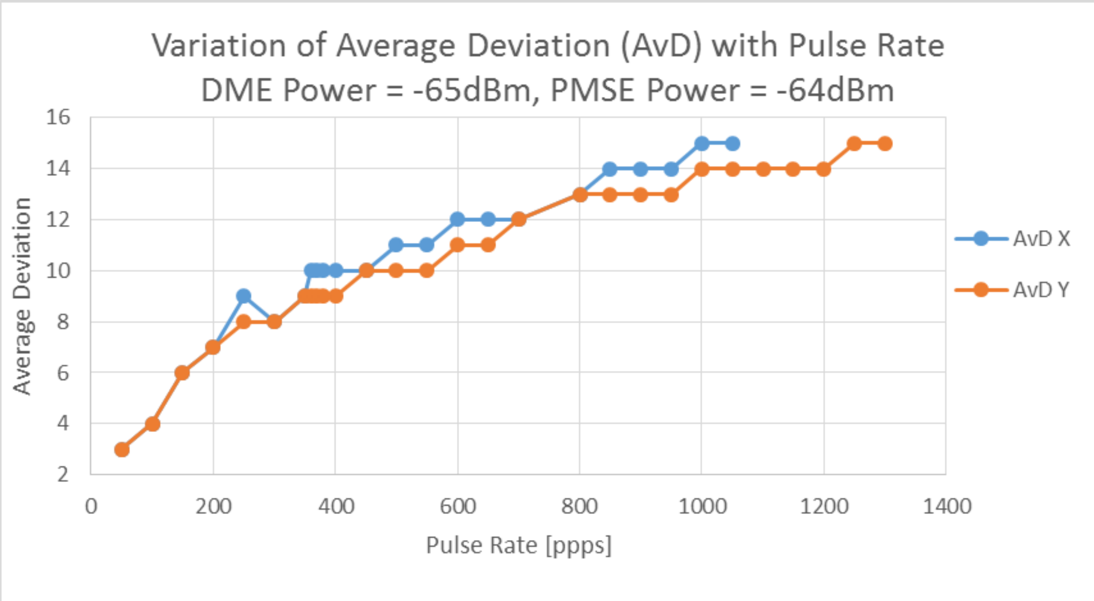


Figure 12-1 - Performance of PMSE with DME Pulse Rate

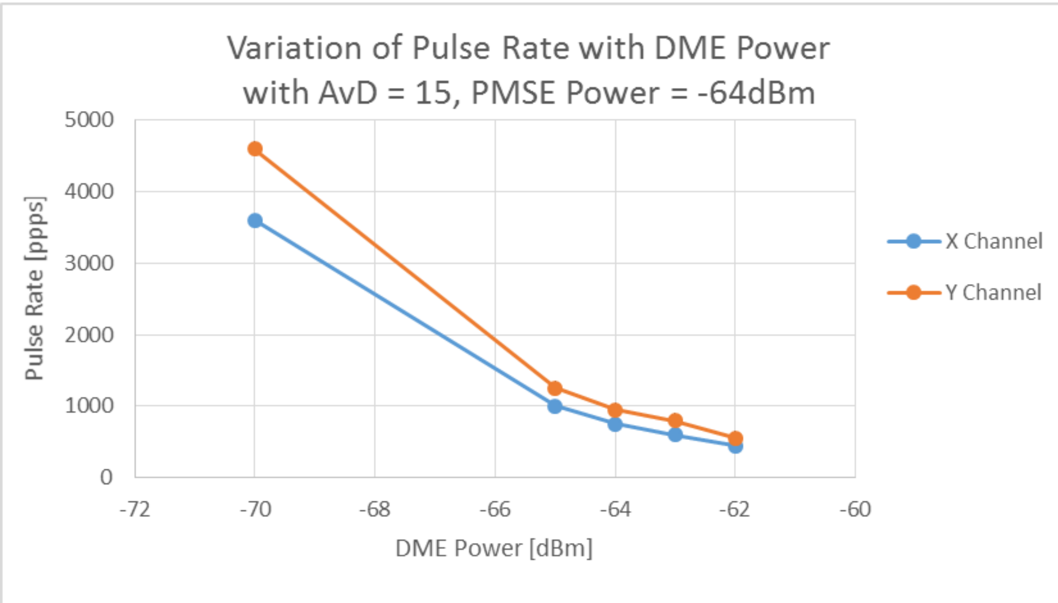


Figure 12-2 - Trade-off of DME Power and Pulse Rate

12.3.3 The DME frequency was offset and the power level adjusted to achieve an AvD of 15. This is used to show the selectivity of the PMSE system to DME interference.

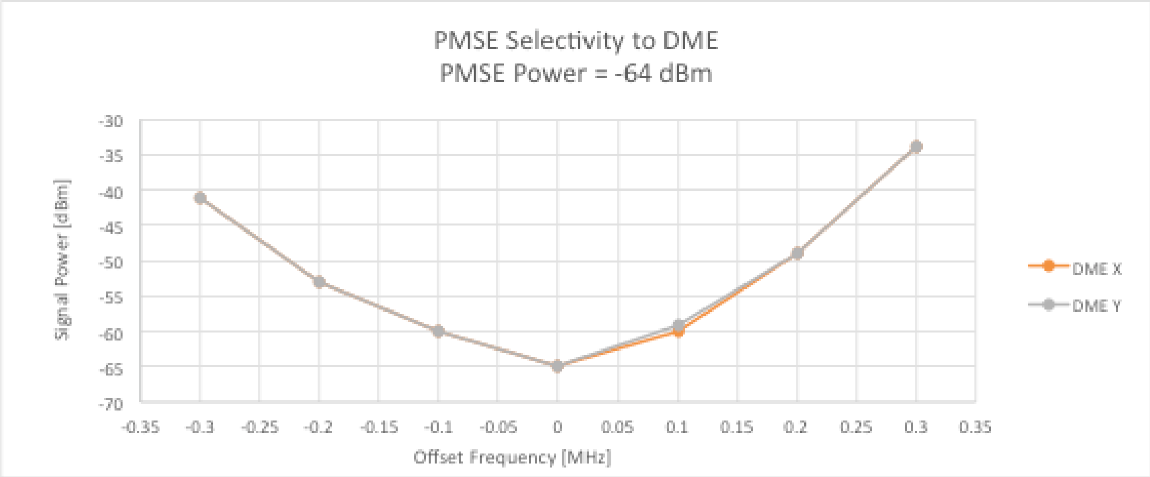


Figure 12-3 - PMSE Selectivity to DME

12.3.4 The performance of PMSE is poorer with X channel interference than with Y channel for the same rate of pulse pairs. X channel pulse spacing is 12 µs; Y channel pulse spacing is 36 µs.

12.3.5 At a minimum interrogation rate of 700 ppps[5], the PMSE performance fails when DME power is greater than -63.6 dBm for X channel or greater than -62.6 dBm for Y channel.

12.3.6 The PMSE selectivity to DME interference shows that an additional 25 dB of DME power can be tolerated if the PMSE frequency is offset from the DME interrogation frequency by greater than 300 kHz.

12.4 PMSE Link 16 Selectivity Test Results

12.4.1 The PMSE selectivity to Link 16 interference was determined by increasing the power level of Link 16 pulses and offsetting the frequency until the PMSE AvD fell below the failure criterion of 15.

12.4.2 The AvD variation has a periodic dependency on offset frequency so additional measurements were taken on a single sideband.

12.4.3 The Link 16 power levels were interpolated to find the power level for AvD=15 and plotted against offset frequency to show the PMSE selectivity to Link 16. The PMSE selectivity to Link 16 and DME is shown in Figure 12-4 below.

[5] This is the minimum rate for which the Ofcom Analysis Tool is calibrated.

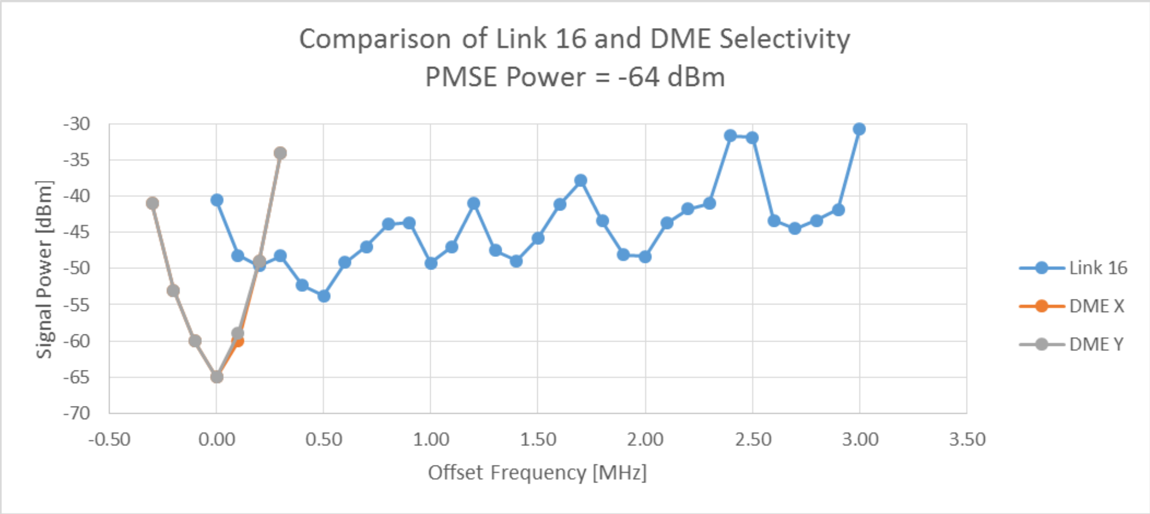


Figure 12-4 - Comparison of PMSE Selectivity to Link 16 and DME

12.4.4 The PMSE selectivity to Link 16 shows a large variation with offset frequency. The Link 16 waveform incorporates Minimum Shift Keying (MSK) which generates energy in the sidebands that depends upon the message content.

13 CONCLUSIONS

13.1 DME Beacon Testing

13.1.1 The DME Beacon test data recorded for the three different beacon types indicates that PMSE Co-Channel signal levels greater than -115dBm received at a DME beacon receiver input will have an impact on BRE performance. The signal environment used for this testing was based on typical DME pulse load, a typical Link-16 pulse load and 4 PMSE signals.

13.1.2 The PMSE selectivity curves can be used to reduce the impact on DME beacon reply efficiency performance. The results of the selectivity testing indicate that offsetting a PMSE signal by more than 2MHz will provide an additional 20dB margin for PMSE signals.

13.1.3 A summary of DME Beacon Selectivity is shown in table 13-1 below.

Table 13-1

	PMSE Power [dBm] at which System Fails					
	Fernau 1117		Fernau 202		Thales 415	
Offset [MHz]	X MODE	Y MODE	X MODE	Y MODE	X MODE	Y MODE
-8		-45				
-7		-46				
-6	-52	-46				
-5	-64	-55	-56	-50	-35	-40
-4	-66	-70	-59	-52	-45	-55
-3	-70	-75	-70	-69	-58	-70
-2	-79	-87	-89	-82	-70	-80
-1	-89	-97	-100	-102	-88	-95
0	-106	-107	-111	-111	-108	-115
1	-89	-97	-100	-100	-92	-91
2	-79	-89	-87	-89	-77	-80
3	-67	-81	-74	-82	-71	-65
4	-57	-77	-59	-74	-60	-50
5	-47	-74	-41	-63	-45	-40
6	-39	-68				
7		-55				
8		-50				

13.2 DME Interrogator Testing

13.2.1 The DME Interrogator test data indicates that PMSE co-channel signal levels greater than -97dBm received at a DME Interrogator receiver result in a change in ASOP performance below the defined criteria.

13.2.2 The results of the selectivity testing indicate that offsetting a PMSE signal by more than 1MHz will provide an additional 20dB margin for PMSE signals.

13.2.3 It was evident from the test data gathered for the Collins 860E-3 that PMSE co-channel signal levels greater than -90dBm result in false range locks. The interrogator appeared to lock on to a false range and track. It was concluded that the issue only occurs when PMSE signals greater than -90dBm are present and the DME is at the edge of its expected performance requirement. It was further concluded that false locks would not be expected to occur during normal operations where protection is applied from PMSE to prevent a change in ASOP as detailed above in para. 13.2.1.

13.2.4 The KDM 705A Interrogator breaklock test data highlighted a false range lock problem. It was concluded that this issue will require further investigation even though in this case it only occurred in the presence of high PMSE signal levels.

13.2.5 A summary of DME Transponder Selectivity is shown in table 13-2 below.

Table 13-2

	PMSE Power [dBm] at which System Fails					
	KN64		Collins 860E-3		KDM705A	
Offset [MHz]	X MODE	Y MODE	X MODE	Y MODE	X MODE	Y MODE
-6		-32				
-5	-20	-35	-20	-25	-20	-20
-4	-29	-41	-23	-21	-20	-20
-3	-38	-48	-25	-21	-20	-20
-2	-47	-58	-25	-22	-20	-20
-1	-61	-75	-35	-36	-25	-27
0	-85	-95	-95	-98	-87	-90
1	-61	-69	-25	-40	-23	-23
2	-46	-55	-24	-28	-20	-20
3	-37	-48	-20	-27	-20	-20
4	-29	-40	-20	-25	-20	-20
5	-20	-36	-20	-20	-20	-20
6		-29				

13.3 SSR Receiver Testing

13.3.1 The SSR Receiver test data indicates that PMSE co-channel signal levels greater than -90 dBm result in a drop in performance below the defined criteria for Mode S and Mode A/C.

13.3.2 A reduction in PMSE interference can be achieved by offsetting the PMSE frequency. The results of the selectivity testing indicate that offsetting a PMSE signal by more than 9 MHz will provide an extra 20dB tolerance to PMSE interference; this dependency is likely to vary with receiver make.

13.3.3 The failure effect for Mode S is a loss of service; the failure effect for Mode A/C also includes additional spurious message decodes.

13.3.4 The tolerance to PMSE is increased by offsetting the PMSE frequency from the SSR downlink frequency of 1090 MHz. This is summarised in the table below.

Table 13-3

	PMSE Power [dBm] at which SMR falls below 90% at 1090 MHz	
Offset [MHz]	**Mode S**	**Mode A/C**
-9.0	-69.4	
-8.0	-74.0	
-7.0	-78.7	-75.3
-6.0	-82.7	-80.0
-5.0	-85.6	-86.8
-4.0	-87.7	
-2.0	-91.0	
0.0	-88.6	-85.9
4.0	-84.7	-85.9
5.0	-78.0	-83.9
6.0	-73.4	-73.7
7.0	-68.6	-73.0
8.0	-63.8	
9.0	-61.8	
10.0	-57.2	

13.4 SSR Transponder Testing

13.4.1 The SSR Transponder test data indicates that PMSE co-channel signal levels greater than -79 dBm could result in a drop in Mode S performance below the defined criteria.

13.4.2 PMSE co-channel signal levels greater than -80 dBm could result in a drop in Mode A/C performance below the defined criteria.

13.4.3 The tolerance to PMSE is increased by offsetting the PMSE frequency from the SSR downlink frequency of 1090 MHz. A reduction in PMSE interference of greater than 20 dB can be achieved by offsetting the PMSE frequency by at least 8 MHz. This is summarised in the table below.

Table 13-4

	PMSE Power [dBm] at which SMR falls below 90% at 1030 MHz	
Offset [MHz]	**Mode S**	**Mode A/C**
-10.0	-54.9	
-9.5	-58.7	
-9.0	-62.0	
-8.5	-64.8	
-8.0	-67.0	-57.9
-7.5	-68.9	
-7.0	-70.3	-61.4
-6.5	-70.8	
-6.0	-71.8	-63.9
-5.5	-72.8	
-5.0	-73	-65.5
-4.5	-74.7	
-4.0	-75.9	-68.8
-3.5	-77.2	
-3.0	-77.6	-68.9
-2.5	-78.2	
-2.0	-79.1	-69.4
-1.5	-79.7	
-1.0	-79.0	-67.6
-0.5	-77.5	
0.0	-76.5	-78.9
1.0		-78.6
2.0		-79.2
2.5	-76.7	
3.0		-77.9
4.0		-76.3

5.0	-68.1	-59.8
7.5	-35.3	

13.5 Impact on TCAS

13.5.1 The TCAS service requires additional equipment on-board aircraft but makes use of the Mode S message set. TCAS equipped aircraft transmit aircraft to aircraft interrogations using UF0 on 1030 MHz and receive aircraft to aircraft replies using DF0 or DF16 on 1090 MHz.

13.5.2 The TCAS system provides two types of advisory to the pilot: Traffic Advisory (TA) and Resolution Advisory (RA). The TA informs the pilot of a possible collision and is for information. The RA provides the pilot with a resolution manoeuvre which he is expected to follow even if it contradicts Air Traffic Control.

13.5.3 During the period of issuing an RA, all transmissions shall be sent on full power; there is an allowance to use a reduced power during TA [ICAO Annex 10 4.3.2.2.2.2.1].

13.5.4 TCAS equipped aircraft have two antennas, one mounted on the top of the aircraft and the other on the bottom. Transmission and reception of TCAS messages shall occur via both antennas [ICAO Annex 10 4.3.9.2].

13.5.5 Given the requirements above, it is reasonable to state that

- TCAS messages will be received with relatively high power due to the proximity of conflicting aircraft.
- The aircraft body will provide additional shielding of the upper antenna from ground-based interference.

13.5.6 The susceptibility of the TCAS service to PMSE interference is likely to be no poorer than the Mode S performance and could be considerably better.

13.6 PMSE System Testing with DME

13.6.1 The PMSE test data indicates that DME interference will affect performance. PMSE performance becomes unacceptable when DME power levels are within 2 dB of the PMSE signal power at 700ppps.

13.6.2 A reduction in DME interference of greater than 25 dB can be achieved by offsetting the PMSE frequency by more than 300 kHz.

13.6.3 PMSE performance has only been tested with DME interrogation rates greater than 700 per second. DME interference is clearly audible for pulse rates as low as 50 pulse per second at a power level of -60 dBm. This was a subjective evaluation.

13.7 PMSE Selectivity Testing with Link 16

13.7.1 The PMSE test data indicates that Link 16 interference occurs over a wider bandwidth than DME. Offsetting the PMSE frequency could improve or degrade performance depending on the offset frequency and the Link 16 message content.

13.7.2 Link 16 message content is continually varying and all Link 16 channels are in use for each network. It is unlikely that offsetting the PMSE frequency can produce any improvement in performance that is consistent and calculable.

13.7.3 The tolerance to DME and Link 16 is increased by offsetting the PMSE frequency. This is summarised in the table below.

Table 13-5

	Power [dBm] at which PMSE Performance falls below AvD=15		
Offset [MHz]	**DME X**	**DME Y**	**Link 16**
-0.3	-41.0	-41.0	
-0.2	-53.0	-53.0	
-0.1	-60.0	-60.0	
0.0	-65.0	-65.0	-40.6
0.1	-60.0	-59.0	-48.2
0.2	-49.0	-49.0	-49.6
0.3	-34.0	-34.0	-48.2
0.4			-52.3
0.5			-53.8
0.6			-49.2
0.7			-46.9
0.8			-43.9
0.9			-43.7
1.0			-49.3
1.1			-47.0
1.2			-41.0
1.3			-47.5
1.4			-48.9
1.5			-45.8
1.6			-41.2
1.7			-37.9
1.8			-43.4

1.9			-48.1
2.0			-48.3
2.1			-43.8
2.2			-41.8
2.3			-41.0
2.4			-31.7
2.5			-31.9
2.6			-43.3
2.7			-44.4
2.8			-43.3
2.9			-41.8
3.0			-30.6

14 RECOMMENDATIONS

14.1 DME Testing

14.1.1 It is recommended that in order to protect the reply efficiency performance of DME Ground beacons either a frequency offset of 4MHz should be maintained, or a signal level of no greater than -115dBm should be received.

14.1.2 It is recommended the DME Interrogator false range indications should be investigated if DME interrogators are likely to receive PMSE signals at levels greater than -97dBm.

14.1.3 As only fixed frequency DME interrogators have been tested, it is further recommended that at least one scanning DME interrogator is tested when available.

14.2 SSR Testing

14.2.1 It is recommended that PMSE should not be operated within ±10MHz of 1030MHz or 1090MHz. This will remove the potential impact of PMSE on the surveillance services operating on these frequencies.

14.3 Testing of PMSE as a Victim

14.3.1 It is recommended that the performance with low DME pulse rates is further investigated as low pulse rates still have an impact on PMSE.

14.3.2 It is further recommended that digital PMSE systems are evaluated and that such systems provide an accessible performance metric, such as Bit Error Rate (BER), to aid such an evaluation.

15 APPENDIX 1 – DME ALLOCATION

15.1.1 DME channels are defined in ICAO Annex 10. The table below shows how this allocation assigns interrogation and reply frequencies according to channel number and DME channel (X or Y).

Table 15-1

DME Receiver Frequencies				
Mode	DME Beacon Receiver Channels	DME Beacon Receiver Frequencies	DME Interrogator Receiver Channels	DME Interrogator Receiver Frequency
X	1 to 63	1025MHz to 1087MHz	1 to 63	962MHz to 1024MHz
Y	1 to 63	1025MHz to 1087MHz	1 to 63	1088MHz to 1150MHz
X	64 to 126	1088MHz to 1150MHz	64 to 126	1151MHz to 1213MHz
Y	64 to 126	1088MHz to 1150MHz	64 to 126	1025MHz to 1087MHz

15.1.2 Although the channel allocation covers all frequencies in the band, the channels around the SSR frequencies of 1030 MHz and 1090 MHz are generally avoided.

15.1.3 The channels surrounding the SSR frequencies are for national allocation and are shown in the table below.

DME Channels Used for National Allocation on a Secondary Basis to Ensure SSR Protection			
At DME Beacon Receiver		At DME Interrogator Receiver	
Channel	Frequencies	Channel	Frequencies
1Y to16Y	1025MHz to 1040MHz	1Y to 16Y	1088MHz to 1103MHz
60X to 69X	1084MHz to 1093MHz	60X to 63X	1021MHz to 1024MHz
		64Y to79Y	1025MHz to 1040MHz

15.1.4 An interrogator receiver is airborne and interference is most likely to be with the SSR uplink on 1030 MHz; the DME beacon is ground-based and more likely to interference with SSR downlink on 1090 MHz.

16 APPENDIX 2 – SSR OVERVIEW

16.1 Mode A/C

16.1.1 Mode A interrogations occur on 1030 MHz and consist of a pair of pulses with a separation of 8µs. The receiving aircraft transponder will reply with its Mode A code which identifies it to the controller.

16.1.2 Mode C interrogations occur on 1030 MHz and consist of a pair of pulses with a separation of 21µs. The receiving aircraft transponder will reply with its Mode C code which encodes its current altitude.

16.1.3 The Mode A and Mode C replies are identical in format and the receiving system needs to know which interrogation was made in order to interpret the reply correctly.

16.1.4 Mode A and Mode C interrogations are not addressed. Hence, all aircraft that receive an interrogation will generate a reply. The receiving SSR has the task of separating the multiple replies and decoding them accordingly. This task is made simpler by interrogating aircraft in batches to reduce the number of overlapping replies; this task is complicated if multiple SSRs are in operation or if the aircraft generates spurious replies.

16.1.5 Replies that cannot be correlated with a transmission, or are received when no transmission has been made are known as FRUIT.

16.1.6 An SSR will employ multiple techniques to reduce the amount of FRUIT and valid replies that is generates. Techniques, such as "whisper-shout", are beyond the scope of this section. Suffice to say, FRUIT or multiple valid replies are an issue for SSR receivers and should be discouraged from interfering systems.

16.2 Mode S

16.2.1 Mode S is an enhancement to SSR to reduce the number of replies that a receiver must process. Each aircraft is given a unique address and all interrogations and replies contain that address.

16.2.2 An SSR using Mode S will generate an interrogation for a specific aircraft on 1030 MHz. Aircraft that do not match the address will receive the interrogation but not generate a reply; aircraft that match the address will reply on 1090 MHz.

16.2.3 An SSR using Mode S needs to acquire an unknown target when it enters its area of responsibility. It does this by issuing an "All Call" request periodically. Aircraft that have not previously been acquired, will return with their unique address and be interrogated directly thereafter.

16.2.4 Some aircraft are able to periodically broadcast their unique address without being interrogated. The basic capability is known as short squitter and uses DF11. Extended squitter uses DF17 and includes additional information about the position and velocity of the aircraft. This is part of the ADS-B service.

17 APPENDIX 3 – LINK 16 OVERVIEW

17.1.1 Link 16 is a communication system for a network of enabled platforms. Platforms can be on ground, at sea or airborne.

17.1.2 The network provides access to platforms by allocating a period of time for that platform to transmit its messages. Transmissions are therefore distributed across available time slots using time division multiplexing.

17.1.3 Multiple networks can exist but the method of coexistence is beyond the scope of this section.

17.1.4 The data to be transmitted during a specific time slot is encrypted in multiple ways known only to the members of that network. Once encrypted, it is encoded as a series of pulses and each pulse is transmitted at a specific time within the time slot. The details of this encryption, encoding and allocation are not important from an interference point of view.

17.1.5 Each transmitted pulse is allocated to one of 51 transmission frequencies in a pattern known only to the members of the network. The allocation is done, however, so that all 51 channels are used evenly and the channel selection appears random.

17.1.6 For each network, it can be assumed that the pulses generated by all of the platforms will be distributed equally across each of the 51 channels and that every channel will be in use.