Spectrum Engineering Services

Test Report

Coexistence testing between wireless microphones and Mobile Satellite System receivers in the band 1525-1559 MHz

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Executive Summary

This document describes the test setup, methodology and test results for assessing potential interference from Program Making and Special Events (PMSE) equipment into Mobile Satellite System (MSS) User Equipment (UE). This test plan only covers co-channel and adjacent channel interference to services on the Inmarsat 4-F2, positioned in a geostationary orbit at 149.12º and elevation 26.03º.

The UEs covered within this test plan are a BGAN (Broadband Global Area Network) data terminal and a GSPS (Global Satellite Phone Service) satellite telephone.

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1 Introduction

As part of the release of 700 MHz band for cellular communications, the available frequencies for some low power audio PMSE aplications will decrease, secifically wireless microphones. In order to mitigate this loss we have been looking at alternative spectrum sharing options. The analysis detailed in this report looks at the area of spectrum suggested for sharing PMSE is the MSS downlink band from 1525 to 1559 MHz.

Testing took place on co-channel and adjacent frequencies to determine the minimum operational level, and the resulting C/No degradation for each of the channels used by the UE, in the presence of the PMSE signal.

This document details the test setup, test procedure and the test results for determining the protection ratio for PMSE equipment with a maximum output power of 100 mW (20 dBm).

2 Test Variations

The following table lists the essential tests to be covered in the measurement program.

Parameter	Variations
Wanted Power Level	Normal operational value
PMSE Signal Bandwidth	200kHz analogue channel bandwidth signal (1kHz test tone with a deviation 24kHz).
PMSE Tx Frequency	This was determined by the channel the terminal equipment was allocated by the satellite network.
PMSE Signal level	Depending upon the functionality of the channel, determined if the power of the PMSE signal started high and was decreased in incremental steps, or if the signal started low and was increased in incremental steps. Note: - when determining the minimum operational level of the UE in the presence of PMSE interference, it is important to take into account that the level of interference is dependent upon the initial state of the UE, i.e. the interference level at which the UE goes from "non-registered" state to "registered" state is different to the interference level at which the UE goes from "registered" state to "non-registered" state.

Table 1: Essential Tests Variations

3 Signal Parameters

3.1 Wanted Signal

Two terminal types were tested, a BGAN terminal and a GSPS handset. The setup for each device can be seen below in Figure 1 and Figure 2 respectfully.

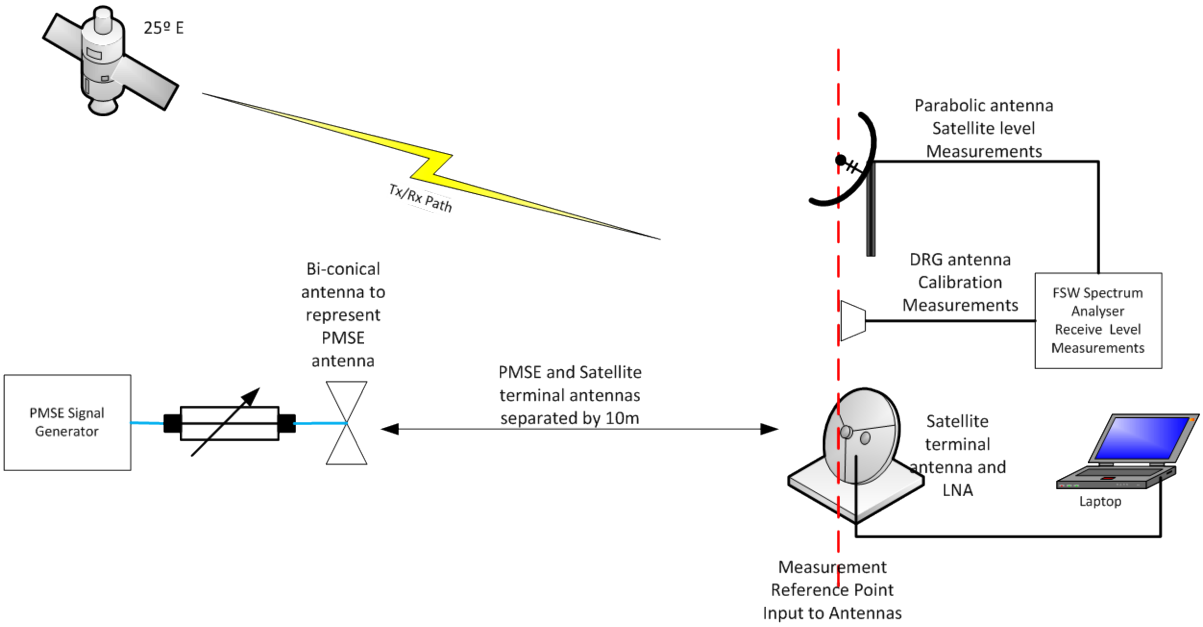

Figure 1 PMSE into MSS BGAN Test Setup

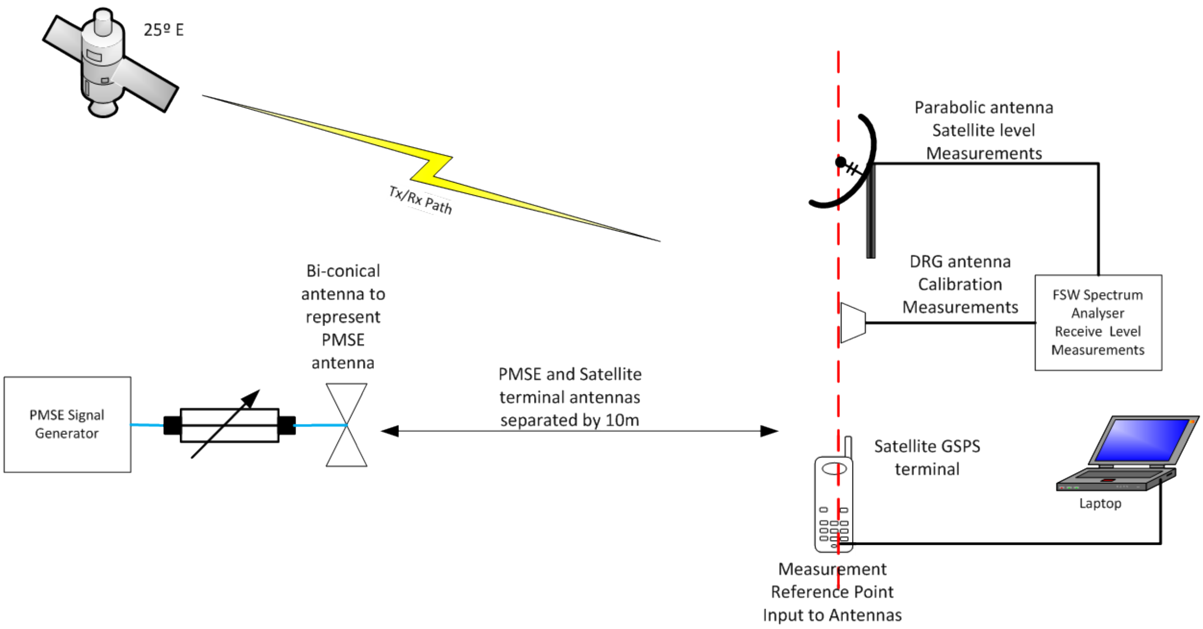

Figure 2 PMSE into MSS GSPS Test Setup

The satellite used for the testing was the Imarsat I-4 EMEA (Europe, Middle East and Africa), at 25 degrees East. The parabolic dish antenna azimuth and inclination was sited for maximum signal level from the satellite. The parabolic dish azimuth had a bearing of 154° with and inclination of 23°.

There are three beam types, global, regional and narrow beams in use by the Inmarsat satellite each providing a different service to the terminals.

All satellite beams are transmitted with right hand circular polarisation (RHCP). The reference parabolic antenna was vertically polarised so a 3 dB correction has been included in the measurement results.

The global beam provides a wide area coverage, approximately 1/3 of the Earth's circumfrance. The beam operates with a single broadcast channel which occupies a 12.5 kHz channel.

The single global beam footprint is occupied by 19 regional beams (or sometimes refered to wide spot beams) which operate with a number of channels occupying a 50 kHz channel bandwidth.

The single global beam footprint is occupied by 200 narrow beams (or sometimes refered to spot beams) which operate with a number of channels occupying a 200 kHz channel bandwidth.

The channels used for testing are as follows:

1. GSPS
    a. Regional Beam Channel: - RBC $f1$
    b. Narrow Beam Channel: - NBC $f2$
2. BGAN
    a. Global Beam Channel: - GBC $f3$
    b. Regional Beam Channel 1: - RBC $f4$
    c. Regional Beam Channel 2: - RBC $f5$
    d. Narrow Beam Channel: - NBC $f6$

The satellite signals were measured using the Rohde and Schwarz, FSW spectrum analyser, via a parabolic dish antenna, using a log periodic receive antenna as the feed. The gain of the antenna at RBC $f4$ was 15 dB. The gain of the antenna was sufficient to provide a measurable signal into the spectrum analyser without the use of active amplification of the forward signal.

The satellite signals were measured daily prior to the commencement of the testing. It was noted that the global and regional beam channels where consistently measured to be within ±0.5 dB day to day. The narrow beam channel did vary by about 6 dB.

3.2 Interfering Signals

The PMSE interferer was generated using an Anritsu MG3695A signal generator with the output from the signal generator set to 0 dBm. The carrier wave was modulated with an FM signal with a deviation of 24 kHz, utilising a 1 kHz tone. The level was controlled using a stepped attenuator, capable of applying up to 121 dB of attenuation, which ensures that output of the signal gereator changes linearly. The testing was a radiated test with a seperation of the two antennas (PMSE and MSS UE) of 10 m.

Where possible all PMSE test signals where measured using the Rohde and Schwarz FSW analyser and the levels recorded. An offset was applied to the FSW readings to account for losses between the FSW input and the system reference point, at the input to the antennas. Please refer to Figures 1 and 2 which show the reference point.

During co-channel interference testing of the BGAN terminal it was found that the PMSE level would not attenuate sufficiently and the output of the signal generator had to be reduced by up to 30 dB and with all attenuation switched in, to ensure that no interference was present at the beginning of the test. By reducing the signal generator level and having full attenuation switched in, it was not possible to measure the received value at the reference point, on the spectrum analyser and the value had to be calculated.

The calculation was made by decreasing the attenuator by an amount X, until a signal of greater than 6 dB above the noise floor could be measured on the FSW. The value X was subtracted from the measured value, which provided the absolute value at the FSW. An adjustment was then made to take the value reference point.

The level at which interference occurred was below the performance characteristics and noise floor of the test equipment and are not consistent with the overall test methodology and are included for completeness only and should not be considered representative.

The PMSE used a Schwarzbeck SBA9113 bi-conical antenna as its source, as this provided a close representation of the antenna used with PMSE equipment.

4 System Calibration and Measurements

4.1 System Calibration

The system was calibrated to provide a common reference point for all measurements within the system. The reference point used was the input to the parbolic dish, Schwarzbeck DRG antenna and the UE antennas. Refer to figures 1 and 2 for the diagramatical representation of the reference point.

The PMSE antenna was positioned 10m from the reference point and two calibrated antennas were used to determine the PMSE level at the reference point. Using the spectrum analyser in conjuction with the known gain and losses of the antennas and connecting cables the following levels were calculated at the input of the antennas:

1. Schwarzbeck BBHA 9120D (DRG): PMSE Rx level -58.44 dBm

   FSW level = -53.34 dBm

   Cable loss = -4 dB

   Antenna gain = +9.1 dB

   Therefore level at reference point = ${}^{-}53.34 - {}^{-}4 - {}^{+}9.1 = -58.44$ dBm

Therefore the FSW offset to the reference point for the DRG antenna is -5.1 dB

2. Schwarzbeck STLP 9149: PMSE: PMSE Rx level -58.65 dBm

   FSW level = -52.45 dBm

   Cable loss = -4 dB

   Antenna gain = +10.2 dB

   Therefore level at reference point = ${}^{-}52.45 - {}^{-}4 - {}^{+}10.2 = -58.65$ dBm

The STLP antenna was not used in testing only for calibrating the system.

With similar results from the two calibrated antennas, it was then possible to substitute the parabolic dish antenna using the same PMSE signal.

FSW level for Q-Par Parbolic dish antenna = -47.66 dBm

PMSE Rx Level = -58.65 dBm (From 2 above)

Cable loss = -4 dB

Therefore Parabolic Antenna gain = ${}^{-}47.66 - {}^{-}58.65 - {}^{-}4 = 15$ dB.

Therefore the FSW offset to the reference point for the parabolic antenna is -11 dB for a vertically polarised signal. For RHCP the offset is -8 dB to the reference point.

4.2 Signal Measurement

All signal measurements were taken using a Rohde and Schwarz FSW spectrum analyser. The FSW with its pre-amp in operation, and noise cancellation active, has a Display Average Noise Level (DANL) of approximately -171 dBm/Hz.

The measurement of all signals used a spectrum analyser span set for a value of 104% of the channel bandwidth being measered. The use of a 104% span allows the marker boundaries for the channel to be seen. The signals from the satellite and the PMSE were measured using a marker band power functionality which allows for a marker to be positioned on the centre frequency of a signal and then record the power in a specific channel bandwidth. The set up for the analyser measuring a 50 kHz signal can be seen in Figure 3 below.

Note that all measurements have been taken as channel power within the operational bandwidths shown in Table 2 **and no correction for bandwidth advantage has been applied to the results in section 6.**

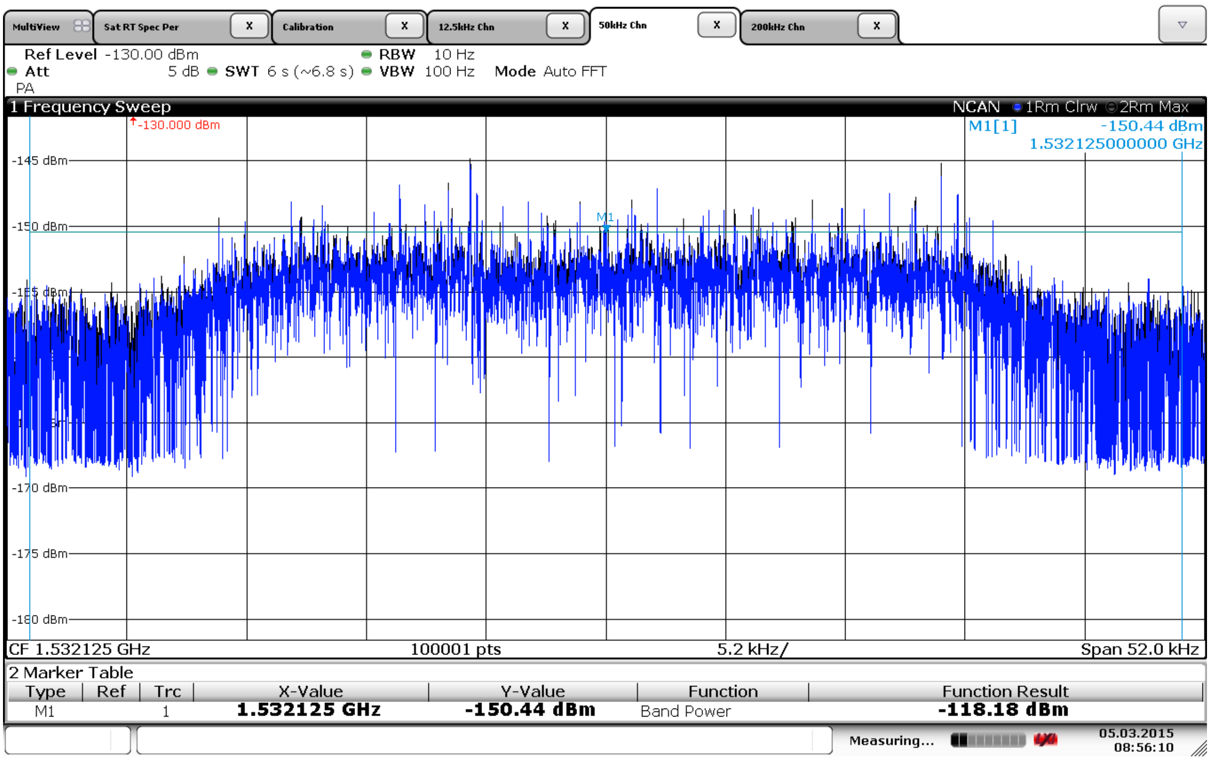

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Figure 3 Sample 50kHz Measurement FSW Screen Shot

Signal	FSW Span (kHz)	Marker BW (kHz)	RBW (Hz)	VBW (Hz)
PMSE	104	100	10	100
Global Beam	13	12.5	10	100
Regional Beam	52	50	10	100
Narrow Beam	208	200	10	100

Table 2 FSW Measurement Settings

5 Test Methodology

Prior to the commencement of any daily PMSE testing the satellite channels were measured in a corresponding bandwidth, for each of the channels being tested.

5.1 Operational Failure and C/No Degradation Test of BGAN Terminals

The setup for the BGAN UE testing can be found in Figure 1. Values for the PMSE levels that cause interference to the global, regional and narrow beams for the BGAN terminal were measured for both co-channel and adjacent channel interference, utilising a Rohde and Schwarz FSW spectrum analyser. Failure of the device was determined using software tools and practical usage of the device.

To monitor the UE during testing an engineering Telnet session was initiated with the UE. This allowed the frequency of the channel and the C/No to be monitored using the login commands. These were used to reset the memory blocks used to store and show updated data.

5.1.1 Global Beam Receive Failure Test

This test was carried out on the global beam, and operates in a forward direction only, to provide system information data to the terminal in a 12.5 kHz channel bandwidth. The channel is also used to point the terminal at the satellite using an inbuilt C/No meter, where the terminal is repostioned until the highest reading was obtained. When no decodeable signal is detected the terminal provides a “No Line of Sight” (NLS) indication.

With the terminal correctly positioned a high level PMSE co-channel signal was generated and the terminal was monitored to ensure the terminal provided a NLS indication.

The PMSE signal was gradually reduced until the NLS indication was no longer present and the C/No indication was present. It was observed during testing that there was an unstable period where the terminal would go between 0 dB-Hz and ~40 dB-Hz. During the unstable period the terminal would not reliably decode the satellite signals and hence be able to progress to the registration phase of the satellite connection process. It was found that a 1 dB decrease in the level of the PMSE, would take the terminal from the unstable state to a C/No level that allowed a Minimum Operational Level (MOL)[1], that allows the terminal to decode the broadcast signals and progress to the registration process. The MOL can be different for each of the beams. At the MOL for the global beam the C/No was degraded by about 11 dB, i.e. from 52 dBHz to 41 dBHz.

The test was repeated using the adjacent channel offsets of 200, 400, 600, 800, 1000 and 1200 kHz. Offsets are from centre frequency to centre frequency for each channel.

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[1] MOL or minimum operational level is the level at which the UE was capable of passing and decoding data in a practical operational manner, in the environment under which the testing was completed.

During the 600 kHz offset test an anomally was found with the PMSE level being measured ~8 dB lower than anticipated. This was further investigated and found to be a fault with the test equipment used. Details of this anomaly can be found in Appendix 1.

The results for the global broadcast beam can be found in Section 6.1.

5.1.2 Regional Beam Operational Failure Test

The following test was carried out on the regional beam, which is used primarily for system registration and call/data setup. There are two frequencies used for the registration process and the UE can use either. The regional beam utilises a frequency diverse 50 KHz forward channel and was the only channel under test.

The process of operation is as follows. Once the UE has detected the global beam and decoded the required data, the UE will indicate that it is “Registering” and once registered it will indicate “Ready”. The registration takes place using one of the available frequencies in the regional beam. During testing it was found that the UE could switch between the regional beam channels on a dynamic basis and hence, the frequency needed to be checked on a regular basis to ensure the interference was associated with the correct channel.

The test on the regional beam was carried out with the PMSE signal set to a high level and then incrementally decreased until the UE was able to detect the channel under test and register on the network and indicate that it was ready to accept data.

To ensure that the UE was at a known start condition the UE was forced onto the global beam in the point function using the browser based UE configuation tool. With the PMSE level set, the point function level was accepted and the UE would attempt to use the regional beam to register on the network. The level of the PMSE was gradually reduced until the Telnet tool indicated that the UE could see the beam (and the frequency could be confirmed). The PMSE signal level was further reduced until the C/No level was increasing and the number of errors was decreasing. As the errors decreased to zero, so the UE was able to register on the system.

It was found that the PMSE level would only need to change by 1 dB to switch from not being able to decode the regional beam signal reliably, to one that allowed a MOL, that allows the terminal to register the UE on the network at each attempt.

The test was repeated using adjacent channel offsets of 200, 400, 600, 800 and 1000 kHz.

During testing an anomaly was found with the test using a 600 kHz offset with the PMSE level being ~8 dB lower than anticipated. The anomaly was investigated after the testing and found to be a fault with the test equipment used. Details of the anomaly can be found in Appendix 1.

The results for the regional beam can be found in Section 6.1.

5.1.3 Narrow Beam Operational Failure Test

The following test was carried out on the narrow beam, which is used primarily for data transfer. There are a number of channels allocated to a narrow beam and it is not known which channel will be used during a data transfer. It is also possible that the channel will change dynamically during a data transfer. The narrow beam utilises a frequency diverse 200 kHz forward channel. To ensure that the narrow beam channel was known throughout the testing a dedicated frequency was used, with access to the channel controlled by Inmarsat operations as it was a premium channel which could only be used when not congested. Hence, the channel was only available for use on a limited basis and small set of results were obtained.

With the narrow beam channel available, a PC connected to the UE was set to "Ping"[2] an internet server (IP address 8.8.8.8). With an echo response from the server the PMSE signal was switched on using a high level of signal. The Ping ceased, indentifying that the channel was not available to pass data. The PMSE level was incrementally decreased until the Ping recovered to the remote server. It was found that a 1 dB difference made the difference between the Ping being successful at every attempt and the Ping being intermittent. With the Ping being successful at every attempt (1 dB below being unreliable), a website was browsed to ensure that the service was successful. This was deemed as the MOL level.

The channel was tested using co-channel and adjacent channels with an offset of 200, 300 and 400 kHz

The results for the spot beam can be found in Section 6.1.

5.2 Operational Failure Test of GSPS Terminals

The setup for the GSPS UE testing can be found in Figure 2. Values for the PMSE levels that cause interference to the regional and narrow beams (global beam is not used by the GSPS) for UE were measured for both co-channel and adjacent channel interference, utilising a Rohde and Schwarz FSW spectrum analyser. Failure of the device was determined using software tools and practical usage of the device.

To monitor the UE during testing an engineering modem terminal session was activated and the modem command "AT-CSQ" was used to monitor the signal quality received by the UE.

5.2.1 Regional Beam Operational Failure Test

The following test was carried out on the regional beam, which is used primarily for system identification and system registration. The regional beam utilises a frequency diverse 50 kHz single channel for the forward and return channel. The forward channel was the only channel under test.

The process of operation for the channel is as follows. Registration takes place using a single channel frequency in the regional beam and hence there is no dynamic changes available to the GSPS UE in terms of diverse channels or frequencies.

The test on the regional beam used the following format. The PMSE signal was set to a high level and the level was incrementally decreased until the unit was able to detect the channel under test and register on the network.

[2] Ping is a IP test tool used to check the connectivity of a host computer to other network elements.

To ensure that the UE was at a known start condition the UE was reset by using the fold away antenna to break the RF connection to the satellite. With the PMSE level set, the UE would attempt to use the regional beam to register on the network. The level of the PMSE was gradually reduced until the UE could see a signal from the satellite as indicated by the signal strength meter in the UE display (and the frequency could be confirmed). The PMSE signal level was further reduced until the C/No level was increasing and the number of errors was decreasing. As the errors decreased to zero, so the UE could was able to register on the system.

It was found that the PMSE level would only need to change by 1 dB to switch from not being able to decode the regional beam signal reliably, to one that allowed a MOL, that allows the terminal to register the UE on the network at each attempt.

The test was repeated using adjacent channel offsets of 200, 400, 600, 800 and 1000 kHz.

5.2.2 Narrow Beam Operational Failure Test

The following test was carried out on the narrow beam, which is used primarily for voice communications, although it can also be used as a modem to transfer data. There is a single 200 kHz channel allocated to the narrow beam for in the UK for GSPS voice call use.

To test the GSPS narrow beam channel, calls were made to the Inmarsat test number. With the GSPS registered on the satellite and the PMSE level set to high the GSPS was unable to make a call.

The PMSE level was incrementally decreased until the GSPS was able to setup a call. During the testing it was found that the call could be set up, but no, or very intermittent audio was present. It was found that a 1 dB difference made the difference between the call being setup without audio, and full audio being present. Full audio present was deemed as the MOL level.

The channel was tested using co-channel and adjacent channels with an offset of 200, 300 and 400 kHz

The results for the narrow beam can be found in Section 6.2

6 Test Results

6.1 BGAN Test Results

6.1.1 Satellite RF Levels

The satellite signals were measured every day prior to the commencement of testing. It was found that the Global and regional beams varied by less than 1 dB on day by day basis. However, the narrow beams could change power by up to 6 dB day by day, the values recorded are those at the time of conducting the tests.

The PMSE value recorded is with 0 dB output from the signal generator and 0 dB entered into the variable attenuator.

Beam	Frequency (MHz)	Channel Bandwidth (kHz)	FSW Level dBm[3]	Reference Point Level (dBm)
Global	GBC ƒ3	12.5	-125.04	-133.04
Regional 1	RBC ƒ4	50.0	-118.09	-126.09
Regional 2	RBC ƒ5	50.0	-118.84	-126.84
Narrow	NBC ƒ6	200.0	-105.60	-113.60
PMSE	1542.000	100.0	-52.99	-58.09

Table 3 Pre-test Calibration Measurements

6.1.2 BGAN Channel Minimum Operational Level

The C/No values were recorded to provide an indication of system performance at the point of MOL. The PMSE signals recorded in Table 4 are those for which the BGAN could decode signals and was operational.

[3] Measurement level as per the bandwidth detailed in Section 4.

Beam	Frequency (MHz)	Channel Bandwidth (kHz)	Offset (kHz)	Minimum Operational Level		
				FSW Level[3] (dBm)	Reference Point Level (dBm)	C/No dBHz
Global[4]	GBC ƒ3	12.5	0		-184.00	N/R
Global	GBC ƒ3	12.5	-200	-90.11	-95.21	52.0
Global	GBC ƒ3	12.5	-400	-70.32	-75.42	49.0
Global[5]	GBC ƒ3	12.5	-600	-77.36	-82.46	43.7
Global	GBC ƒ3	12.5	-800	-69.37	-74.47	48.0
Global	GBC ƒ3	12.5	-1000	-68.38	-73.48	51.6
Global	GBC ƒ3	12.5	-1200	-67.35	-72.45	50.6
Regional[4]	RBC ƒ5	50.0	0		-184.00	N/R
Regional	RBC ƒ5	50.0	-200	-90.97	-96.07	57.0
Regional	RBC ƒ5	50.0	-400	-70.32	-75.42	55.0
Regional	RBC ƒ5	50.0	-600	-78.40	-83.50	48.5
Regional	RBC ƒ5	50.0	-800	-69.41	-74.51	51.5
Regional	RBC ƒ5	50.0	-1000	-69.51	-74.61	54.5
Narrow[6]	NBC ƒ6	200.0	0	-109.33	-114.43	N/R
Narrow[6]	NBC ƒ6	200.0	0	-105.38	-110.48	61.0
Narrow[6]	NBC ƒ6	200.0	0	-109.46	-114.56	64.0
Narrow[6]	NBC ƒ6	200.0	-200	-72.90	-78.00	N/R
Narrow	NBC ƒ6	200.0	-300	-68.22	-73.32	65.0
Narrow	NBC ƒ6	200.0	-400	-66.90	-72.00	64.8

Table 4 Test Measurements of PMSE Signal for BGAN UE

6.2 GSPS Test Results

It was found during initial testing that the orientation of the GSPS handset did have an effect on the performance. All tests were completed with the back of the GSPS pointing directly to the satellite, as this was the best case.

6.2.1 Satellite RF Levels

The satellite signals were measured every day prior to the commencement of testing. It was found that the regional beam channel varied by less than 1dB. However, the narrow beams could change power by up to 6dB day by day, the values recorded are those at the time of conducting the tests.

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[4] The level at which interference occurred was below the performance characteristics and noise floor of the test equipment and are not consistent with the overall test methodology. Interference values have been derived as explained in section 3.2 and are included for completeness only and should not be considered representative.

[5] This value was affected by the image frequency generated by the signal generator, see Appendix A in Section 7 for details.

[6] These readings were taken during small windows of opportunity when the channel was available for testing

Beam	Frequency (MHz)	Channel Bandwidth (kHz)	FSW Level[3] (dBm)	Reference Point Level (dBm)
Regional	RBC ƒ1	50.0	-118.74	-129.74
Narrow	NBC ƒ2	200.0	-114.05	-125.05
PMSE	1542.000	100.0	-52.99	-58.09

Table 5 Pre-test Calibration Measurements

6.2.2 GSPS Channel Minimum Operational Level

The PMSE signals recorded in Table 6 are those for which the GSPS could decode signals and was operational.

Beam	Frequency (MHz)	Channel Bandwidth (kHz)	Offset (kHz)	Minimum Operational Level	
				FSW Level[3] (dBm)	Reference Point Level (dBm)
Regional	RBC ƒ1	50.0	0	-89.25	-94.35
Regional	RBC ƒ1	50.0	-200	-60.00	-65.10
Regional	RBC ƒ1	50.0	-400	-55.93	-61.03
Narrow	NBC ƒ2	200.0	0	-103.19	-108.29
Narrow	NBC ƒ2	200.0	-200	-52.73	-57.83
Narrow	NBC ƒ2	200.0	-300	See Note[7]	
Narrow	NBC ƒ2	200.0	-400		

Table 6 Test Measurements of PMSE Signal for GSPS UE

[7] It was found during testing, that it was difficult to interfere with the GSPS narrow beam channel. With offsets of 400 and 600 kHz the GSPS would operate normally with 0 dBm from the signal generator and 0 dB in the attenuator. Increasing the signal generator output by 2 dB a call setup was possible but no audio was available. With the signal generator output set up for 4 dB it was not possible to make a call. With the signal generator output set up for 6 dB, it was not possible to register on the network and the GPS was blocked and hence not allowing the GSPS to fix a location.

7 Appendix A Signal Generator Anomaly

During the testing it was identified that there was an increase in the level that caused interference at 600 kHz from the centre frequency. This was initally put down as an issue with the internal local oscillator of the UE.

Following the completion of testing the issue was followed up and investigated and it was found that image frequencies were being generated by the signal generator.

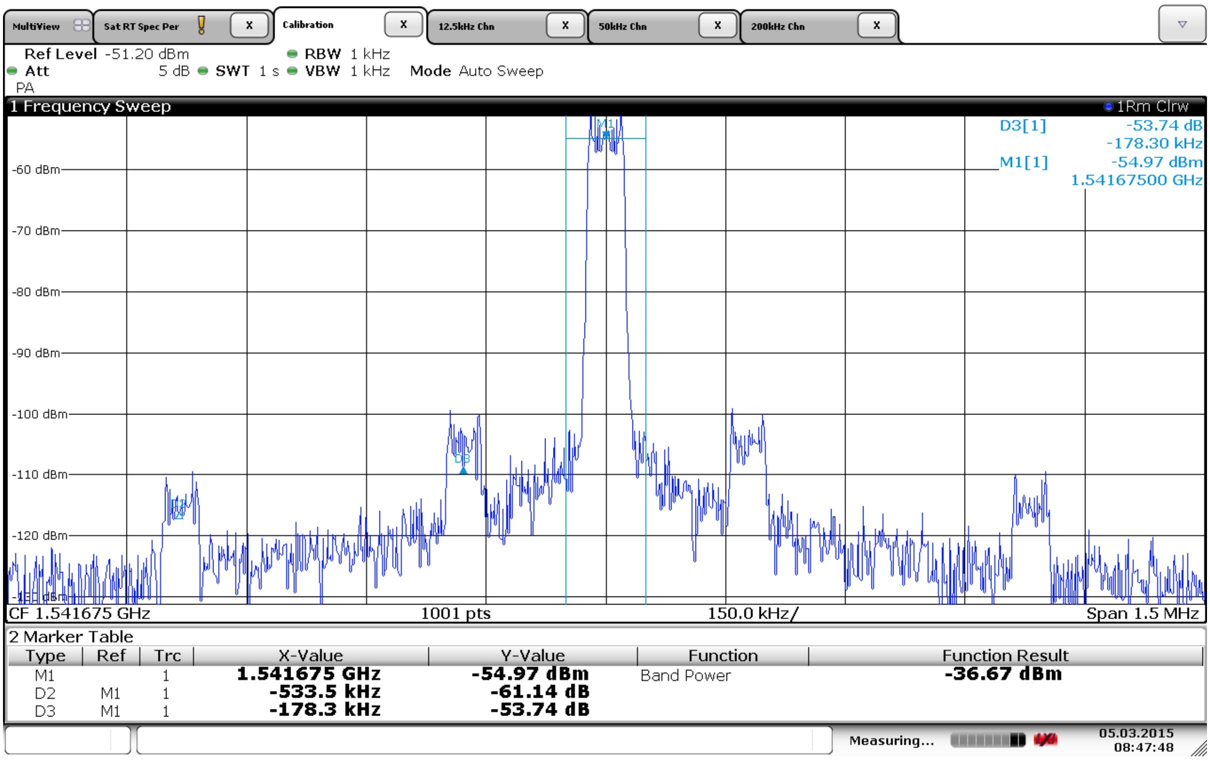

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Figure 4 Signal Generator Image Frequencies

The issue was found to occur across the entire frequency range of the unit with and without modulation applied. See Figure 4 and 5.

The image which caused the issue is approximately 540 kHz from the main carrier and hence the image was approximately -60 kHz offset from the on-channel frequency of the UE. The level of the image was approximately -61 dBc. When changing the amplitude of the carrier it had a 1:1 ratio with the image frequency.

Given the offset measurements made at 400 kHz, 600 kHz and 800 kHz are causing blocking to the receiver, then it is clear that the 600 kHz signal is an outlyer and that the value should be approximately -75 dBm.

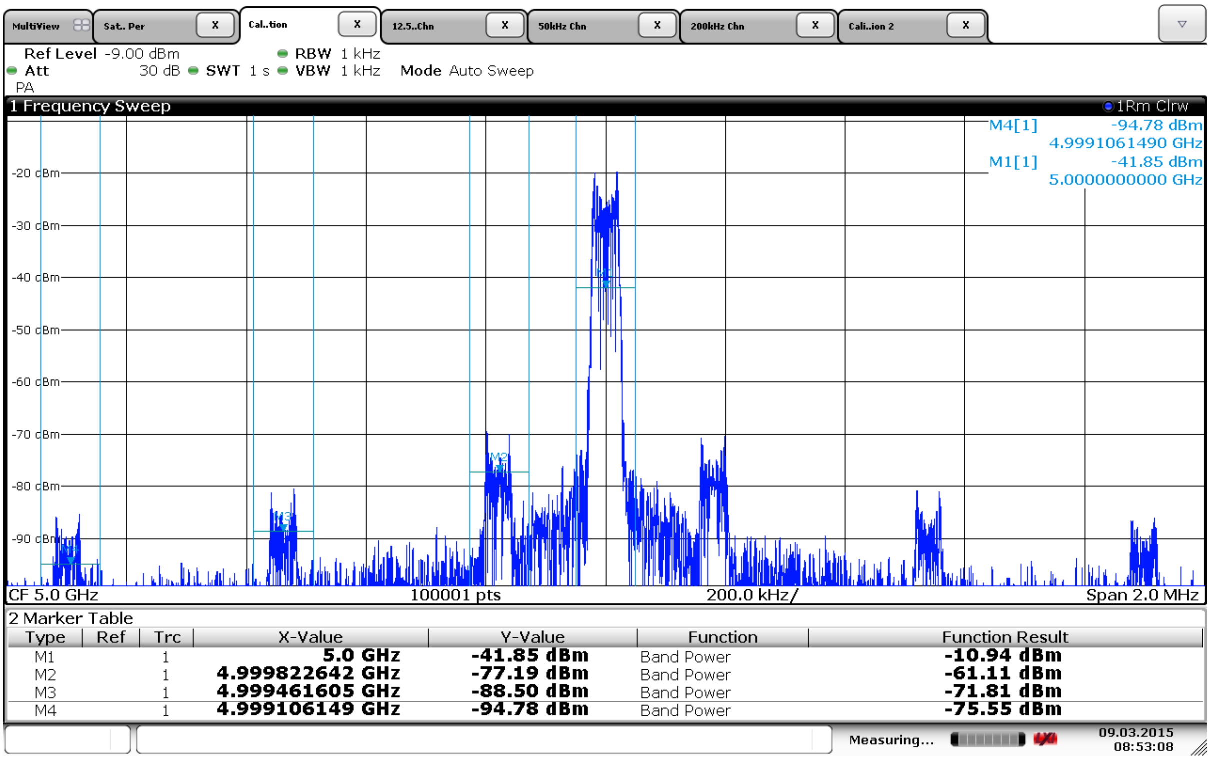

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Figure 5 GHz Image Frequencies