COSPAS-SARSAT
METEOSAT SECOND GENERATION (MSG)
GEOSAR PERFORMANCE
EVALUATION REPORT

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MSG PERFORMANCE EVALUATION REPORT

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1. INTRODUCTION

The European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) provides 406 MHz Search and Rescue (SAR) repeaters on their Meteosat Second Generation (MSG) meteorological satellites. The first of the MSG satellites was launched in August 2002 and following payload testing the SAR instrument was made available for use by Cospas-Sarsat Ground Segment operators from October 2002. However, because MSG satellites were under development when the original Cospas-Sarsat GEOSAR demonstration and evaluation programme was conducted, its performance had not been tested operationally. In view of this the Cospas-Sarsat Council directed that prior to formal inclusion as part of the operational Cospas-Sarsat System, a MSG GEOSAR performance evaluation programme should be conducted to:

a. measure MSG GEOSAR / GEOLUT performance; and

b. establish specification and commissioning requirements for GEOLUTs which operate with the MSG GEOSAR payload.

1.1 Background

From 1996 to 1998 Cospas-Sarsat conducted a demonstration and evaluation programme to determine the suitability of using satellites in geostationary orbit equipped with SAR instruments to process the signals from Cospas-Sarsat 406 MHz distress beacons. This programme, hereafter referred to as the GEOSAR D & E, was implemented using the GOES series of satellites provided by the USA, the Insat-2 satellites provided by India, and experimental ground segment equipment provided by Canada, Chile, India, Spain and the United Kingdom. The GEOSAR D & E demonstrated that GEOSAR satellites provided a significant enhancement to the Cospas-Sarsat system. Following from this conclusion, in October 1998 the Cospas-Sarsat Council decided that the 406 MHz GEOSAR system components should be incorporated into the Cospas-Sarsat System as soon as possible. A summary report of the Cospas-Sarsat GEOSAR D&E is available from the Cospas-Sarsat web site as document C/S R.009. The complete report is also available from the Cospas-Sarsat Secretariat on request.

1.2 MSG GEOSAR Performance Evaluation

During the period that the GEOSAR D & E was being conducted, EUMETSAT was developing a 406 MHz repeater for their MSG satellites that would be capable of relaying the signals from Cospas-Sarsat 406 MHz distress beacons.

Because the technical characteristics of the MSG SAR instrument are different from SAR instruments on the GOES and the Insat-2 satellites, the tests reported herein were conducted to establish MSG GEOSAR / GEOLUT performance, and any specific GEOLUT specification and commissioning requirements.

The administrations of France, Spain and the United Kingdom provided and operated the GEOLUTs that participated in the MSG performance evaluation.

The tests reported herein were performed while the MSG-1 satellite was at its final operating position of 3.4° W. France's 406 MHz beacon simulator with a linearly polarised whip antenna was used to transmit the uplink signals developed specifically for the testing.

- END OF SECTION 1 -

2. MSG GEOSAR PERFORMANCE EVALUATION GOALS AND OBJECTIVES

2.1 Performance Evaluation Goals

The goals of the performance evaluation programme were to:

a. characterize the technical performance of the MSG GEOSAR / GEOLUT system and confirm whether MSG GEOSAR satellite / GEOLUT systems would be effective for providing useful 406 MHz alert data; and

b. validate specification and commissioning requirements for GEOLUTs which would operate with the MSG satellite.

2.2 Objectives

The programme was subdivided into specific technical objectives. Each objective was addressed by conducting tests and analysing the results. The tests were similar to the technical tests conducted in the previous GEOSAR D&E. Where necessary the procedures were modified to gain additional information that would be necessary to develop MSG GEOLUT specification and commissioning requirements. Most of the tests required a beacon simulator whose power output and message could be accurately controlled.

An overview of each objective is listed below:

T-1 Processing Threshold, System Margin, and Beacon Message Processing Performance
Determine the processing threshold, processing performance, system margin and the performance in respect of long format beacon messages for GEOLUTs which operate with the MSG payload. The beacon test signals used to assess these parameters do not include beacon messages that collide with each other.

T-2 Time to Produce Valid and Confirmed Messages
Determine the statistical distribution of the time required for the GEOLUT to produce valid and confirmed beacon messages. The beacon test signals used to assess this parameter do not include beacon messages which collide with each other.

T-3 Carrier Frequency Measurement Accuracy
Determine how accurately the beacon carrier frequency can be determined by the MSG GEOSAR / GEOLUT system. The beacon test signals used to assess this parameter do not include beacon messages which collide with each other.

T-4 MSG GEOLUT Channel Capacity
Assess the capability of the GEOSAR system to handle multiple simultaneously active distress beacons in a single 406 MHz channel. This parameter is assessed by

generating traffic loads which include beacon messages which collide with each other.

T-5 Impact of Interference
Monitor the band for the presence of interference while the tests are being performed, in order to understand any anomalies in the results and to illustrate the ability of the GEOSAR system to provide valid messages in the presence of interference and noise in the frequency bands used by the MSG GEOSAR system.

T-6 Impact of Interference From LEOSAR Satellites
Assess the impact of interference from LEOSAR satellite downlink signals on the ability of the GEOLUT to produce valid and confirmed alert messages.

T-7 MSG GEOLUT Network Performance
Determine if at a given time some GEOLUTs are affected by interference from the LEOSAR system, the expected GEOSAR alerts would continue to be reliably provided by other GEOLUTs in the MSG ground segment.

T-8 Processing Anomalies
Assess the performance of the GEOLUT in respect of the production of processing anomalies.

T-9 MSG Coverage
Estimate the geographic coverage of the MSG GEOSAR system.

- END OF SECTION 2 -

3. MSG PERFORMANCE EVALUATION RESULTS

3.1 T-1: Processing Threshold, System Margin, and Beacon Message Processing Performance

The processing threshold, processing performance and the system margin are "figures of merit" of the GEOLUT, as defined below.

Processing Threshold
The processing threshold is the value of the minimum carrier to noise density ratio (C/N0) at the GEOLUT processor for which the GEOLUT is able to produce a valid message for a beacon event 99% of the time (the lower this value the more sensitive the GEOLUT). Equally the processing threshold can be expressed in terms of the minimum beacon effective isotropic radiated power (EIRP) for which the GEOLUT is able to produce a valid message 99% of the time.

System Margin
The system margin is the difference between a nominal beacon (which by definition is a beacon with an EIRP of 37 dBm) and a beacon operating at the GEOLUT threshold.

Valid Message Processing Performance
Valid message processing performance is the minimum EIRP for which the MSG GEOLUT can produce a valid message for the beacon event within 5 minutes of beacon activation 95% of the time. The valid message processing performance can also be expressed in terms of the C/N0 at the GEOLUT that produces this level of performance.

Long Message Processing Performance
At present Cospas-Sarsat does not have a GEOLUT specification requirement for producing complete and confirmed long messages. Nevertheless, with the increased use of location protocol beacons using the long message format, it is necessary to assess the MSG system performance in this regard.

3.1.1 Methodology and Data Collection

A beacon simulator with a linearly polarised whip antenna was used to replicate distress beacons that transmit long format messages at specific EIRPs. 20 bursts were transmitted for each beacon identification which simulated a beacon being active for approximately 17 minutes. Hereafter the term “beacon event” is used to describe a beacon being active for a period of time. Schedule constraints and equipment availability required the test to be conducted in three parts, two parts comprising 25 beacon events each and the other comprising 50 beacon events. In total 100 beacon events for each EIRP were transmitted, whilst ensuring that signals from individual beacon events did not overlap in time and frequency with the signals from other beacon events. The uplink EIRP of the test signals were calibrated to within +/- 1 dB. The output of the GEOLUT was monitored and the time required to produce valid, complete and complete confirmed messages for each beacon event was captured. The procedure was repeated at EIRP values ranging from 38 dBm to 29 dBm, in one dB increments.

The UK and Spanish GEOLUTs were still under development during some of the testing, and were not available to participate in all 100 beacon events that were transmitted. Consequently the UK and Spanish performance was evaluated based on a reduced sample set of 75 and 50 beacon events respectively.

3.1.2 Processing Threshold and System Margin

The processing threshold and system margin as evaluated by the French, Spanish and UK GEOLUTs are provided at Table 3.1 below. The detailed results are provided at Annex A.

Table 3.1: Processing Threshold and System Margin

GEOLUT	THRESHOLD EIRP (dBm)	THRESHOLD GEOLUT C/N0 (dB-Hz)	SYSTEM MARGIN (dB)	NUMBER OF BEACON EVENTS USED
France	30	26.4*	7	100
Spain	31	30.9	6	50
UK	30	26.9*	7	75

* During the test period, the French and UK GEOLUTs had an error with their C/N0 calculations that caused them to systematically report C/N0 4 dB too low. When this anomaly is taken into account all three GEOLUTs had very similar processing performance.

The results indicated that beacon signals greater than 31 dBm will be reliably detected by the MSG GEOSAR system. Below the threshold of 31 dBm the system performance degrades rapidly, with only a small percentage of the signals being detected with uplink EIRP values less than 30 dBm.

3.1.3 Valid Message Processing Performance

The valid message processing performance is a measure of the GEOSAR system's ability to provide a valid message within 5 minutes of beacon activation 95% of the time.

The minimum uplink EIRP required for the GEOLUTs to provide valid messages within 5 minutes is provided at Table 3.2 below. The detailed results are provided at Annex B.

Table 3.2: Valid Message Processing Performance

GEOLUT	THRESHOLD EIRP (dBm)	THRESHOLD GEOLUT C/N0 (dB-Hz)	NUMBER OF BEACON EVENTS USED
France	31	27.0	100
Spain	31	30.9	50
UK	31	26.9	75

The 3 GEOLUTs satisfied the message processing requirement for uplink signals with an EIRP of 31 dBm. The results for the Toulouse GEOLUT dropped slightly below the 95th percentile (i.e. 93%) for the test signals at 32 dBm. However, subsequent tests confirmed the GEOLUT message processing performance at this level. This seems to indicate that the anomaly, which was experienced to a lesser degree by the Maspalomas GEOLUT, was probably caused by interference during the test.

3.1.4 Complete and Confirmed Complete Message Performance

The performance of the French, Spanish and UK GEOLUTs to produce complete and confirmed complete messages for beacons with uplink signals at the system threshold level of 30 dBm is provided at Table 3.3 below. The detailed performance of each GEOLUT at all measured uplink signals is provided at Annex C.

Table 3.3: Complete and Confirmed Complete Message Performance at Processing Threshold (31 dBm Uplink)

GEOLUT	COMPLETE MESSAGE PROBABILITY	CONFIRMED COMPLETE MESSAGE PROBABILITY	NUMBER OF BEACON EVENTS USED
France	0.99	0.96	100
Spain	1.00	1.00	50
UK	1.00	0.97	75

3.2 T-2: Time to Produce Valid, Complete and Confirmed Messages

This test assesses how long it takes GEOLUTs operating with the MSG satellite to produce valid beacon messages, complete long messages, and confirmed complete long messages.

3.2.1 Methodology and Data Collection

For simplicity this test was conducted by analysing the data collected for test T-1 (Threshold). Note that the T-1 test scenario is specifically designed not to generate beacon bursts which overlap in time and frequency. Consequently, for operational beacon events, the times to produce valid, complete, and the time to confirm complete messages may differ from those determined during this test.

3.2.2 Time to Produce Valid, Complete and Confirmed Complete Messages at Threshold

Table 3.4 provides statistics in respect of the average time required for the French, Spanish and UK GEOLUTs to produce valid, complete and confirmed complete messages for beacon signals at threshold.

Table 3.4: Time to Produce Messages at Processing Threshold (31 dBm Uplink)

GEOLUT	VALID MESSAGES Avg / Standard Deviation (Seconds)	COMPLETE MESSAGES Avg / Standard Deviation (Seconds)	CONFIRMED COMPLETE MESSAGES Avg / Standard Deviation (Seconds)
France	67 / 106*	166 / 189*	376 / 217*
Spain	36 / 55	97 / 143	223 / 198
UK	29.3 / 50.7	70.3 / 184.5	300.7 / 204.9

* Statistics calculated from 50 beacon events (not 100 as reported at tables 3.1, 3.2 and 3.3)

Table 3.5 provides statistics in respect of the time required to produce valid, complete and confirmed complete messages for the 95th percentile, in respect of beacon signals that transmit at the processing threshold of 30 dBm.

Table 3.5: Time to Produce Messages at Processing Threshold for the 95th Percentile (31 dBm Uplink)

GEOLUT	VALID MESSAGES (Seconds)	COMPLETE MESSAGES (Seconds)	CONFIRMED COMPLETE MESSAGES (Seconds)
France	252*	552*	852*
Spain	202	415	607
UK	115	565	690

* Statistics calculated from 50 beacon events (not 100 as reported at tables 3.1, 3.2 and 3.3)

The detailed data providing the time required for the GEOLUTs to produce valid, complete and confirmed complete messages for signals with different transmit EIRPs are provided at Annex D.

3.3 T-3: Carrier Frequency Measurement Accuracy

This test assessed how accurately MSG GEOSAR / GEOLUTs could measure the beacon transmit frequency. For each valid message produced by the GEOLUT the frequency measured was compared against the known transmit frequency provided by the beacon simulator operator.

3.3.1 Methodology and Data Collection

For simplicity, this test was conducted by analysing the data collected for test T-1. For each beacon event the frequency measurement provided by the GEOLUT for the first valid message produced was recorded.

The GEOLUT measured frequency included any calibration that would normally be performed during actual GEOLUT operations (e.g. if the GEOLUT includes features for assessing and correcting frequency measurements by applying calibration correction factors and using reference beacons, these features should be activated).

3.3.2 Frequency Measurement Accuracy Results

The detailed results for the frequency measurement accuracy testing is provided at Annex E. In summary the French, Spanish and UK GEOLUTs reliably measured the frequency to within the Cospas-Sarsat GEOLUT specification of 2 Hz for all signals at or above the processing threshold. However, given the impact that periods of solar eclipse has on the satellite frequency stability, this level of performance might not be experienced at all times.

All the GEOLUTs needed at least two reference beacons in the MSG satellite footprint for frequency measurement calibration to accommodate frequency variations during the eclipse period. At other times the Toulouse reference beacon alone was sufficient for frequency calibration. Since both the Toulouse time calibration beacon and the UK reference beacon are within the MSG satellite footprint, no additional reference beacons are required for this function.

3.4 T-4: MSG GEOLUT Channel Capacity

The definition of capacity in Cospas-Sarsat GEOSAR systems is the number of 406 MHz distress beacons operating simultaneously in the field of view of a GEOSAR satellite that can be successfully processed by the System to provide a valid beacon message, under nominal conditions, within 5 minutes of beacon activation 95% of the time.

3.4.1 Methodology and Data Collection

The MSG GEOSAR channel capacity was assessed by generating traffic loads equivalent to known numbers of simultaneously active long format beacons in a Cospas-Sarsat 406 MHz channel. The time required for the GEOLUT to produce a valid beacon message, complete message and confirm a complete message for each beacon event was recorded. The number of simultaneously active beacon events was changed and the time required for the GEOLUT to produce valid, complete and complete confirmed messages was calculated and recorded for the new 406 MHz traffic load.

The test scripts transmitted by the beacon simulator conformed to the nominal conditions detailed in the Cospas-Sarsat 406 MHz frequency management plan (document C/S T.012), with the exception that the uplink EIRP was selected to be 35 dBm rather than 32 dBm. The test replicated a number of beacon messages overlapping in time and frequency commensurate with the number of simultaneously active beacons. Further, the beacon events used in the test script also replicated the beacon burst repetition period defined in document C/S T.001 (406 MHz beacon specification). The test was scheduled to avoid any potential interference caused by Cospas-Sarsat LEOSAR satellite downlink transmissions.

To obtain a sufficient sample size 10 different test scripts were transmitted for each simulated beacon traffic load. For example 10 scripts simulating 15 simultaneously active beacons were transmitted, which resulted in a sample size of 150 active beacons for this traffic load.

3.4.2 Capacity Results

This test was performed by the French and the Spanish GEOLUTs, and the resulting performance statistics are provided at Tables 3.6 and 3.7 respectively.

Table 3.6: Capacity Performance Results Measured by French GEOLUT

NUMBER OF ACTIVE BEACONS	PROBABILITY OF VALID MESSAGE WITHIN 5 MIN	PROBABILITY OF VALID MESSAGE WITHIN 10 MIN	PROBABILITY OF VALID MESSAGE WITHIN 15 MIN	PROBABILITY OF CONFIRMED COMPLETE MESSAGE WITHIN 15 MIN
15	0.98	0.99	1.00	0.99
20	0.97	1.00	1.00	0.98
25	0.87	0.98	1.00	0.94
30	0.93	1.00	1.00	0.98

Table 3.7: Capacity Performance Results Measured by Spanish GEOLUT

NUMBER OF ACTIVE BEACONS	PROBABILITY OF VALID MESSAGE WITHIN 5 MIN	PROBABILITY OF VALID MESSAGE WITHIN 10 MIN	PROBABILITY OF VALID MESSAGE WITHIN 15 MIN	PROBABILITY OF CONFIRMED COMPLETE MESSAGE WITHIN 15 MIN
15	1.00	1.00	1.00	1.00
20	0.99	1.00	1.00	1.00
25	0.99	1.00	1.00	0.95
30	0.99	1.00	1.00	0.99

The results indicate that for beacon populations with uplink EIRP values exceeding 35 dBm, the capacity would exceed 20 simultaneously active beacons, and that at this load the MSG GEOSAR system would reliably provide complete confirmed beacon messages.

3.5 T-8: Processing Anomaly Performance

A processing anomaly is an alert generated by the system that does not correspond to a real beacon. Processing anomalies may occur when bit errors cause a real beacon transmission to be received garbled in a manner such that the corrupted message passes BCH error checking.

The beacon message content validation checks at the MCC are able to identify most processing anomalies, thereby preventing their further distribution as false alerts.

Two different tests were conducted to evaluate the processing anomaly characteristics of the MSG system. One test measured the processing anomaly rate as a function of the number of beacon bursts seen by the satellite, and the other test evaluated a processing anomaly rate as a ratio of the number of processing anomalies sent to the MCC in comparison to the total number of alerts transmitted by the GEOLUT.

3.5.1 Processing Anomaly as a Function of Number of Beacon Bursts

This test was conducted by monitoring the 406 MHz channel (406.022 MHz) used by Cospas-Sarsat reference beacons, and noting instances where the GEOLUT produced valid beacon messages which did not correspond to any of the reference beacons in the coverage area of the MSG satellite. Since the identification (IDs) of all reference beacons in view of the MSG satellite are known, it was inferred that beacons detected in the 406.022 MHz channel that did not correspond to known reference beacons were processing anomalies.

The time of each processing anomaly was noted and correlated against LEOSAR passes over the GEOLUT to determine whether interference from LEOSAR satellite downlinks influenced the processing anomaly performance. The testing took place over 30 days and the results are summarised in the table below.

Table 3.8: Processing Anomaly Performance as Function of Received Beacon Bursts (Measured by Maspalomas GEOLUT)

	Number of Bursts	Number of Processing Anomalies	Processing Anomaly Rate
All Data	224,640	68	0.030%
GEOLUT in LEOSAR Footprint	56,160	17	0.030%

The results provided by the Spanish GEOLUT indicate that that 3 processing anomalies were produced for every 10,000 beacon bursts, and that possible interference from LEOSAR satellite downlinks did not appear to affect performance in respect of processing anomalies.

3.5.2 Processing Anomaly as Percentage of Alerts Transmitted by GEOLUT

This test was conducted by monitoring the alert messages sent by the Toulouse GEOLUT to the French MCC, and noting those alerts that failed message validation checks at the MCC. It was assumed that:

a. the alerts failing beacon message validation were processing anomalies; and

b. given the robust validation checks at the MCC for most beacon message protocols, very few processing anomalies were not detected by the MCC checks. The data was collected over a two month period from 27 March 2004 to 27 May 2004. For comparison purposes processing anomaly data was also collected from the two Toulouse LEOLUTs.

Table 3.9: Processing Anomaly Performance as Function of Number of Alert Messages Sent to MCC (Measured by Toulouse GEOLUT)

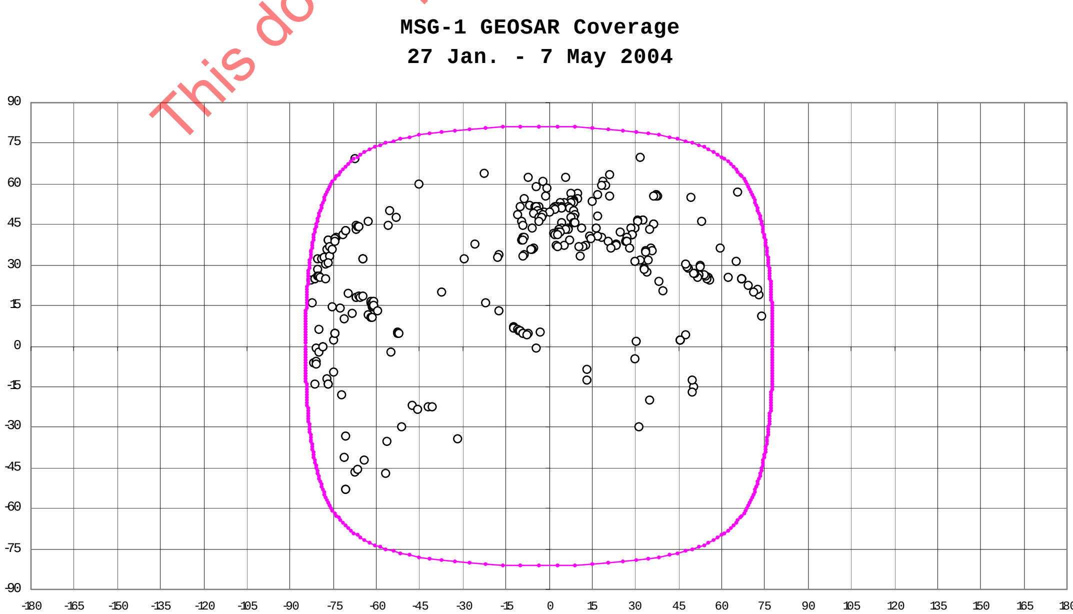
	Alerts Transmitted to MCC	Processing Anomalies Transmitted to MCC	Processing Anomaly Rate
Toulouse MSG GEOLUT 2273	6,904	210	3.04%
LEOLUT 2271	7,352	94	1.28%
LEOLUT 2272	7,605	101	1.33%

3.6 T-9: MSG Coverage

Two methods were used to evaluate the coverage of the MSG satellite. One method involved plotting the location of alerts received by the MSG system. The location information was provided in most cases by the LEOSAR system. The second method involved placing a beacon on a ship that was travelling through the MSG coverage boundaries.

The location of alerts that were detected by the MSG system over a 101 day period is provided at Figure 3.1 below. The footprint circle indicated on Figure 3.1 represents a 0° elevation from the earth to the satellite.

Figure 3.1: Location of MSG Alerts



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The results of the test with the beacon mounted on the ship are provided at Figure 3.2. The findings demonstrate reception throughout the MSG satellite footprint for elevation angles greater than 7.7°, except for a gap between 37° and 52° East. Investigation into this gap revealed the presence of a strong interfering signal, which disrupted reception. As indicated at Figure 3.3 the MSG was able to detect the beacon down to the horizon, although reliable coverage at the Eastern boundary was achieved for elevation angles greater than 7.7°.

Figure 3.2: MSG Footprint Boundary

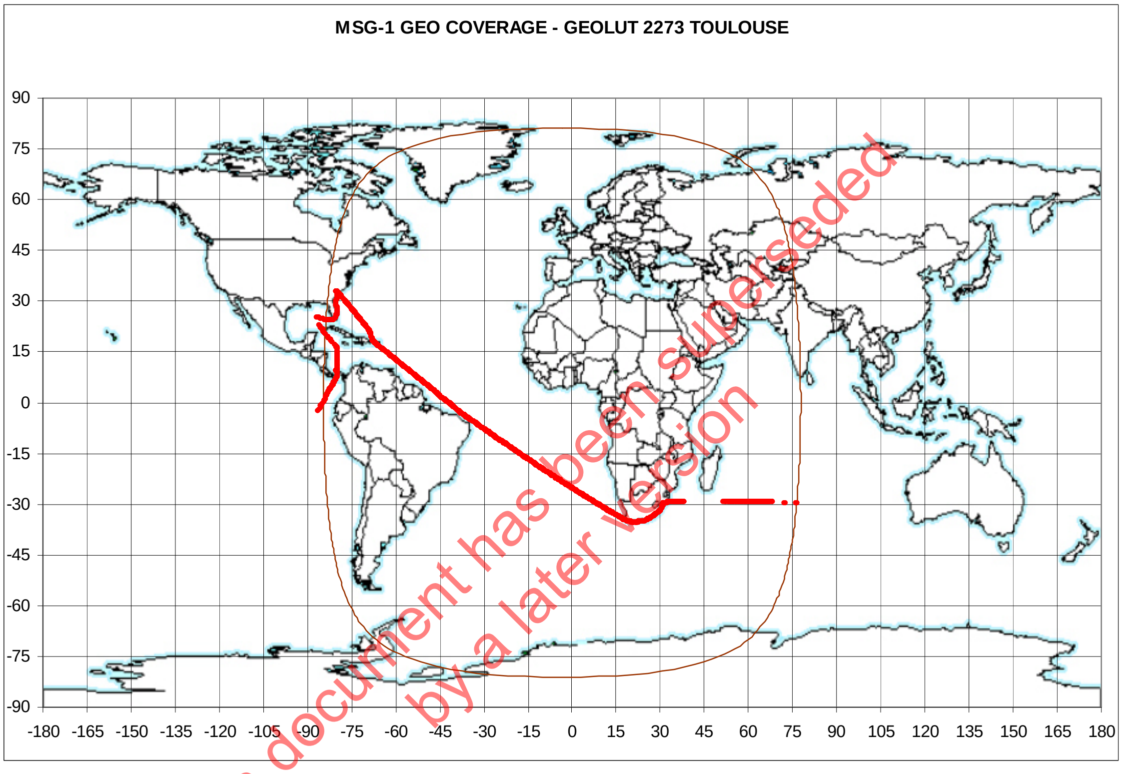
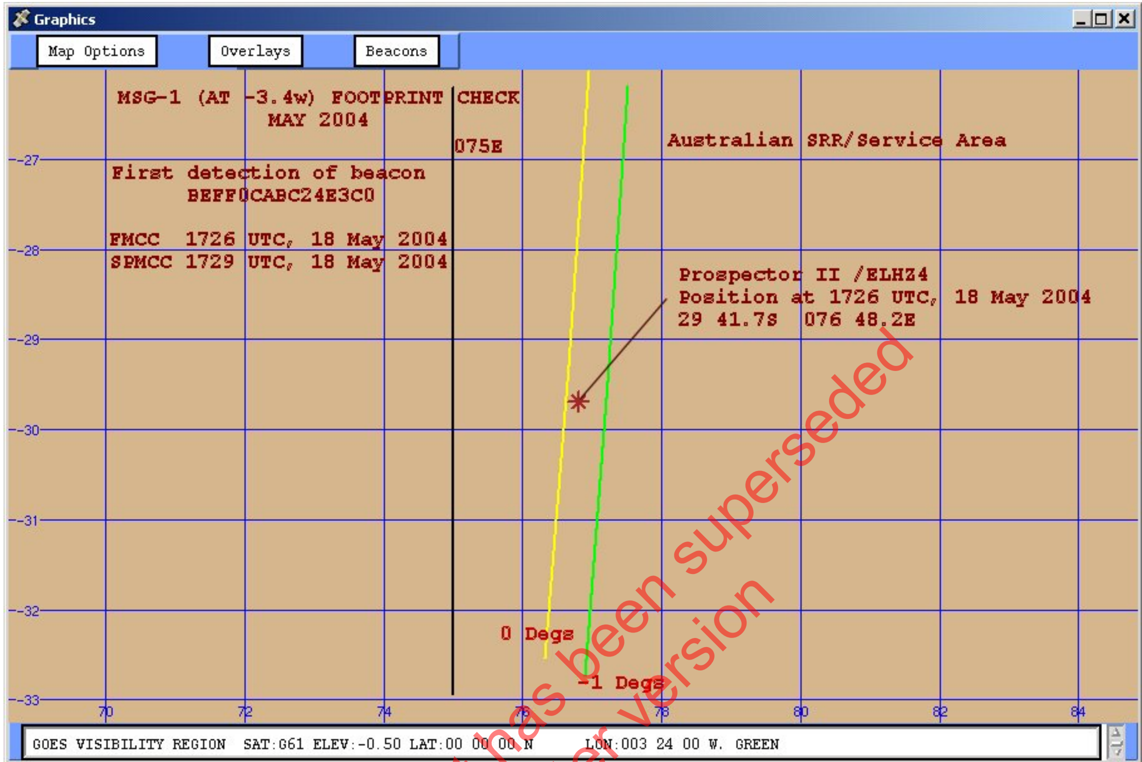


Figure 3.3: Eastern Footprint Boundary



3.7 Complementarity and Effectiveness of the GEOSAR/LEOSAR Systems

The complementarity and effectiveness of GEOSAR/LEOSAR systems is an assessment of the percentage of 406 MHz beacon transmissions, within the coverage area of a particular geostationary satellite, that are detected by only the GEOSAR system, only the LEOSAR System, or by both systems. This analysis measures the ability of the GEOSAR system to detect beacons within the satellite coverage area using confirmed detections by the LEOSAR System as a reference. GEOSAR data for this analysis was provided from the Toulouse MSG GEOLUT.

Table 3.10: Complementarity and Effectiveness of MSG GEOSAR/LEOSAR Systems

	Feb. 2004	%	April 2004	%
Total number of C/S 406 MHz Beacon Activations (BA) within the FMCC Service Area of the MSG-1 footprint (Position confirmed by LEO satellite passes, or by RCC feedback):	78		78	
Number of BA that were detected using the MSG-1 SAR signal:	59	76 %	57	73 %
Number of BA for which the MSG-1 detection was the only means of alert:	8	10 %	10	13 %
Number of BA for which the MSG-1 detection was the first means of alert:	42	54 %	32	41 %
Number of BA for which the MSG-1 detection was the first OR only Alert:	50	64 %	42	54 %
Number of BA not detected by the MSG-1 GEOLUT 2273:	19	24 %	20	26 %

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4. CONCLUSIONS

The MSG GEOSAR performance evaluation test results show that the MSG GEOSAR system reliably detects beacons with uplink EIRPs greater than 30 dBm. Furthermore at the 31 dBm threshold the system also reliably provides confirmed complete beacon messages. The ability to provide confirmed complete messages indicates that the MSG GEOSAR system will effectively provide MCCs with precise encoded location information when this data is transmitted in location protocol beacons.

The results achieved by the French, Spanish and United Kingdom GEOLUTs were consistent with each other. Prior to conducting the testing the design and configuration of the MSG GEOLUTs had been optimised for overall system performance. Consequently, further major improvements to GEOLUT performance should not be expected, and the results obtained during the system evaluation were suitable for developing MSG GEOLUT specification and commissioning requirements.

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ANNEXES TO THE COSPAS-SARSAT METEOSAT SECOND GENERATION (MSG) GEOSAR PERFORMANCE EVALUATION REPORT

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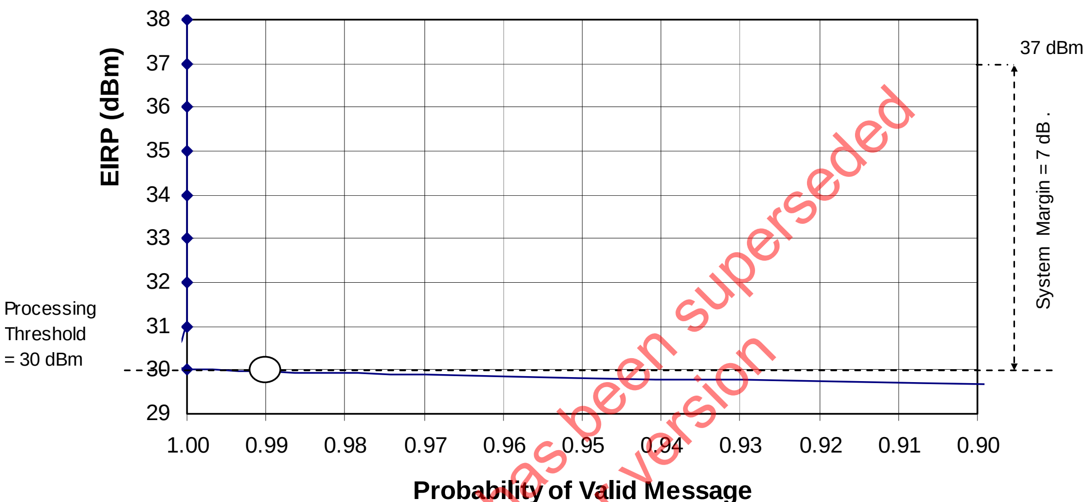
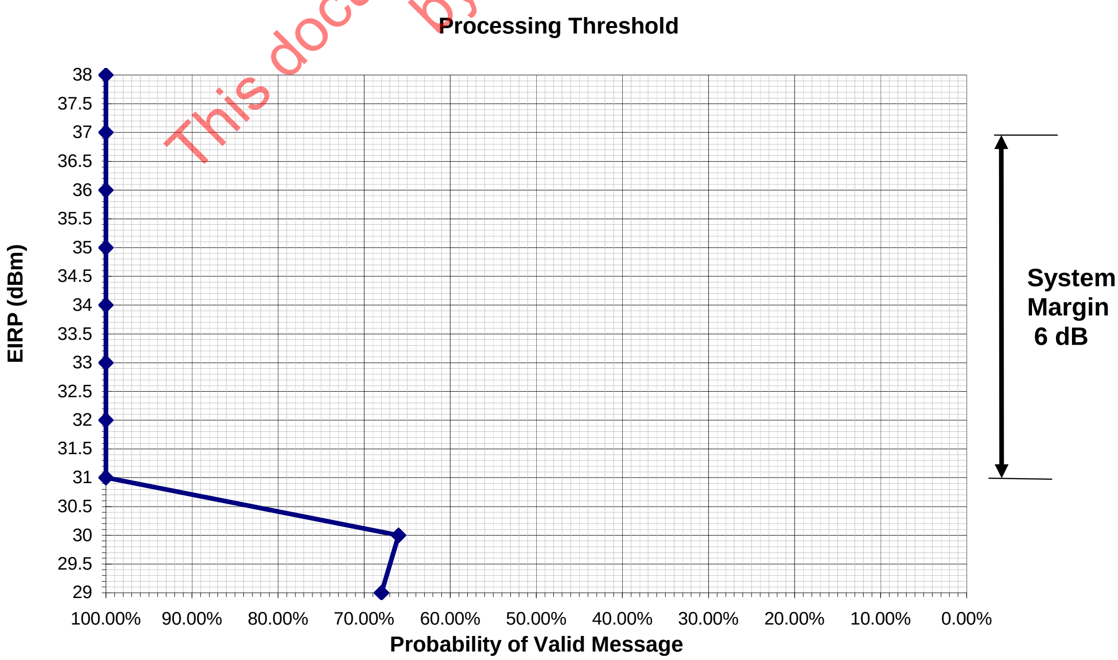
ANNEX A

PROCESSING THRESHOLD AND SYSTEM MARGIN TEST RESULTS

1.0 Processing Threshold and System Margin Test Results Measured by France's GEOLUT



2.0 Processing Threshold and System Margin Test Results Measured by Spain's GEOLUT



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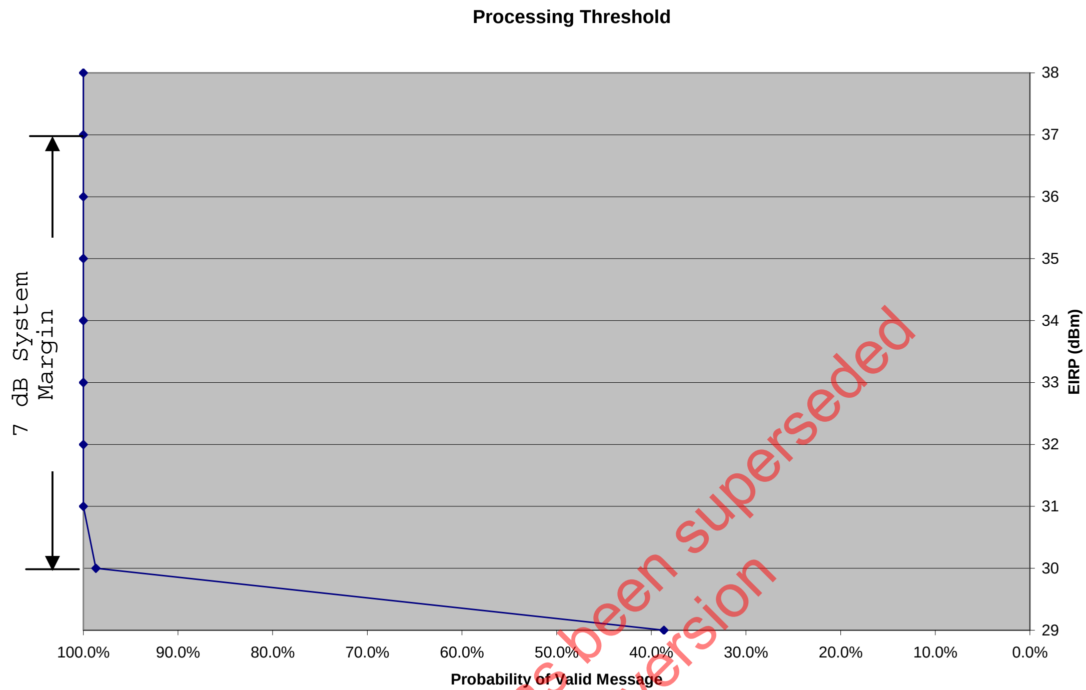
3.0 Processing Threshold and System Margin Test Results Measured by UK's GEOLUT



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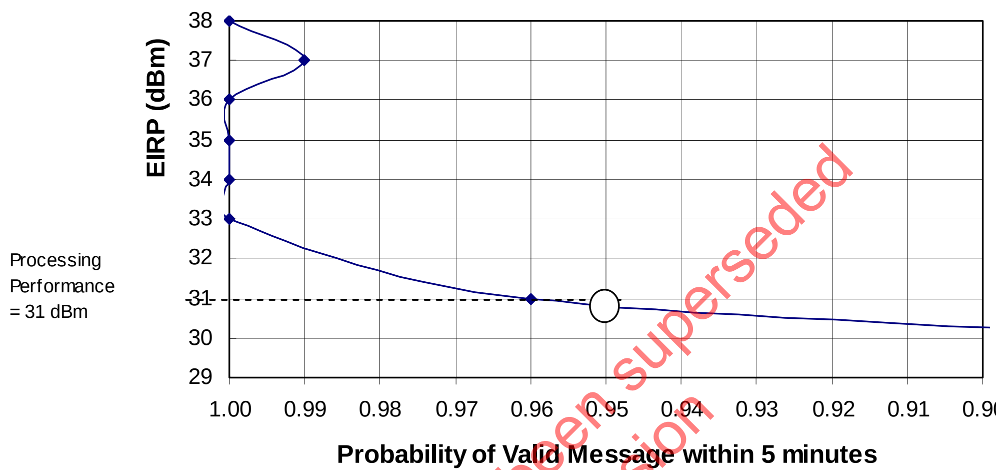
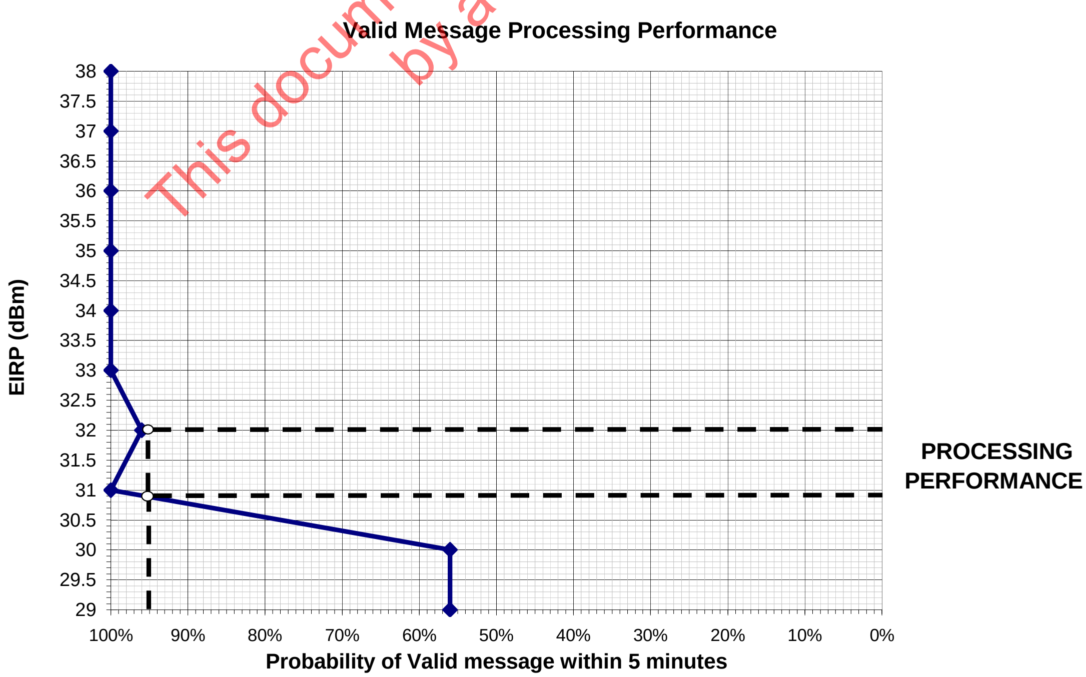
ANNEX B

VALID MESSAGE PROCESSING PERFORMANCE

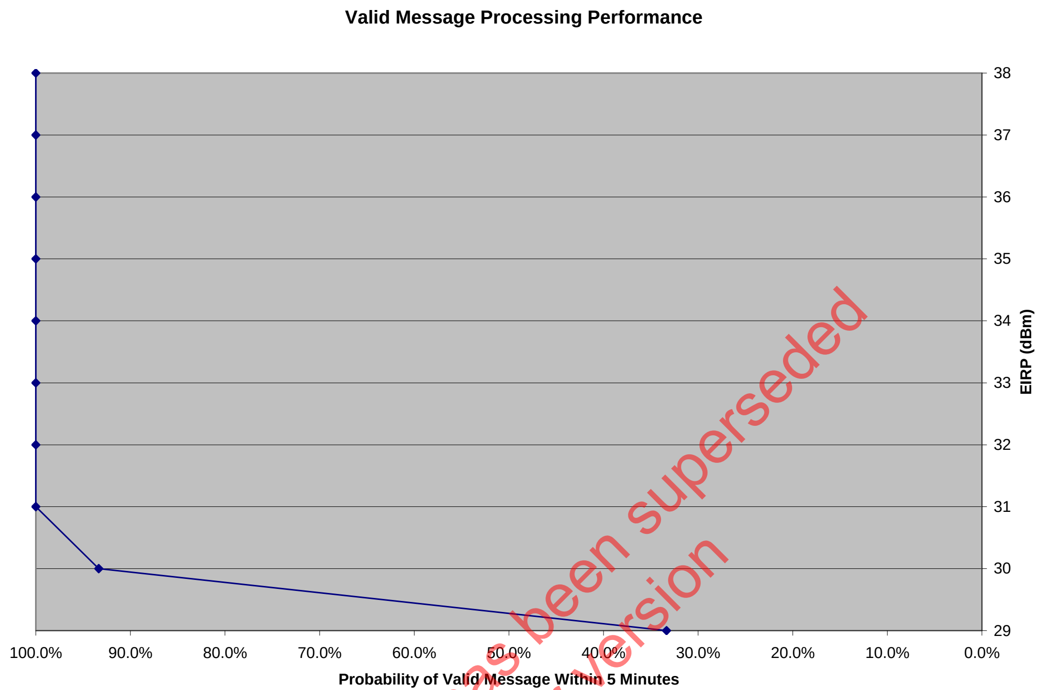
1.0 Valid Message Processing Performance Test Results Measured by France's GEOLUT



2.0 Valid Message Processing Performance Test Results Measured by Spain's GEOLUT



3.0 Valid Message Processing Performance Test Results Measured by UK GEOLUT



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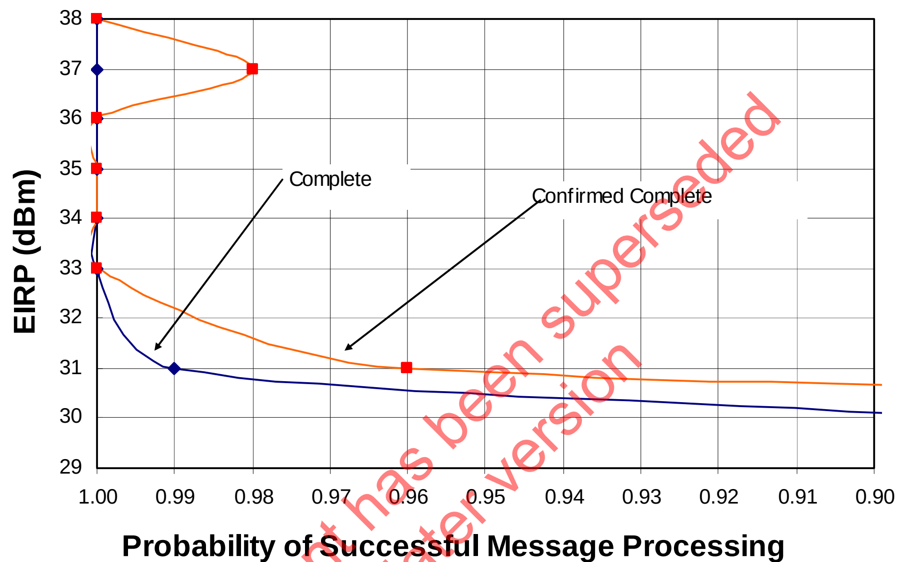
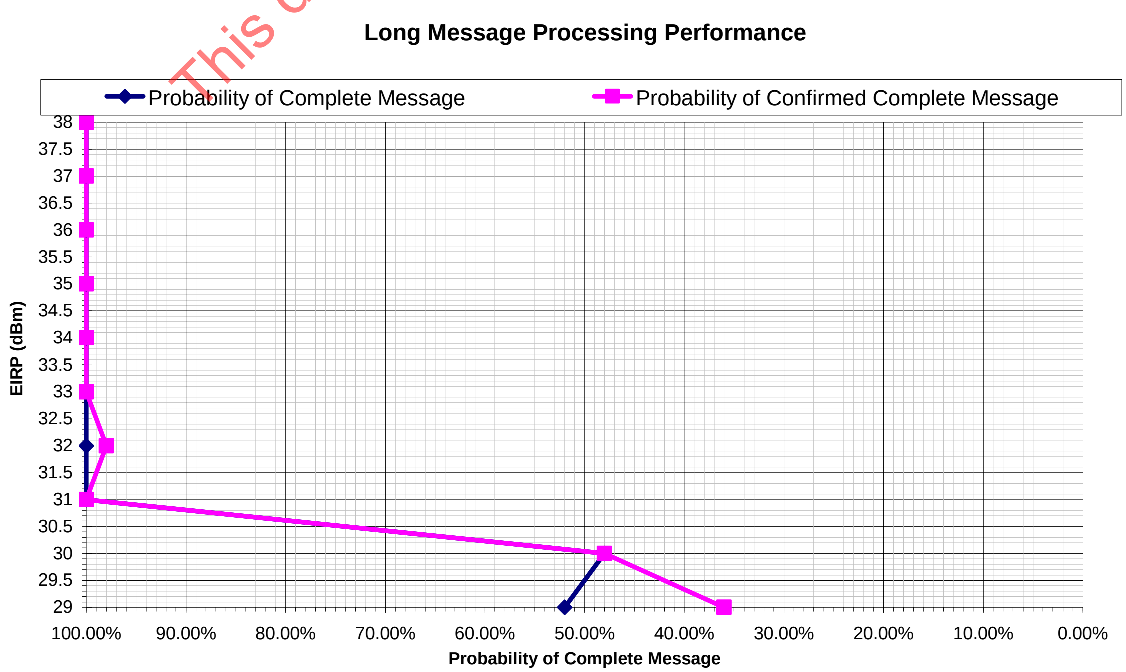
ANNEX C

COMPLETE AND CONFIRMED COMPLETE MESSAGE PERFORMANCE TEST RESULTS

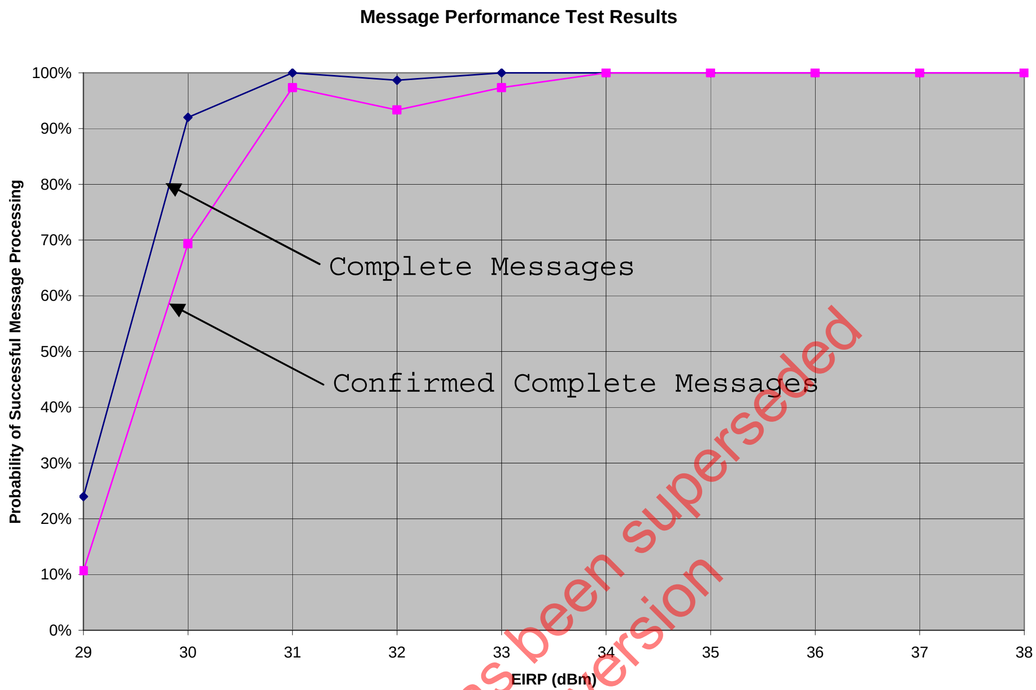
1.0 Complete and Confirmed Complete Performance Test Results Measured by France's GEOLUT



2.0 Complete and Confirmed Complete Performance Test Results Measured by Spain's GEOLUT



3.0 Confirmed Complete Performance Test Results Measured by UK's GEOLUT



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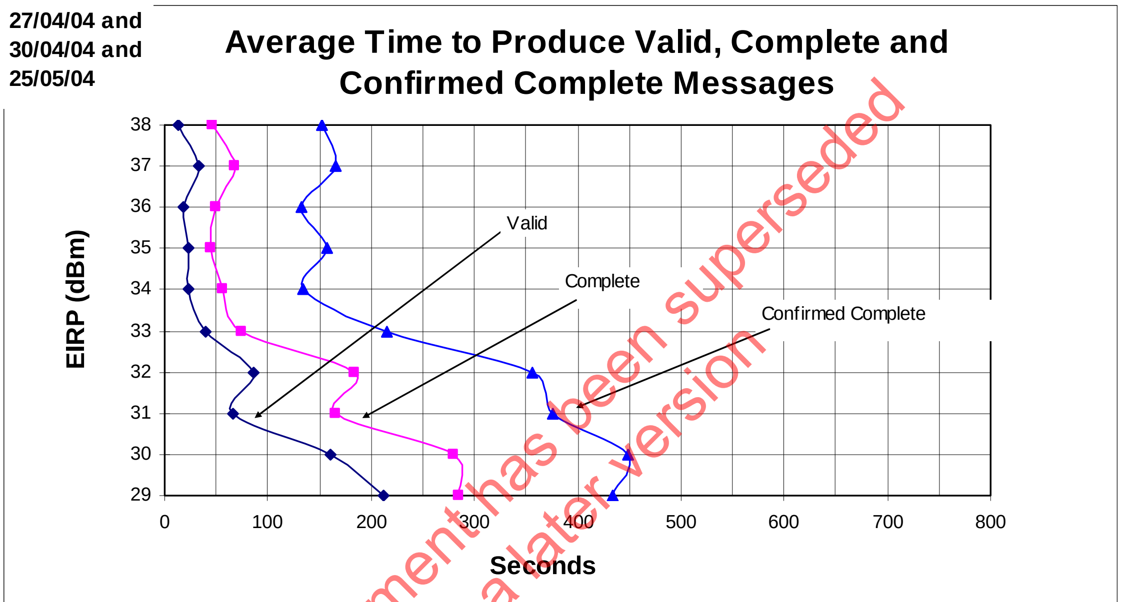
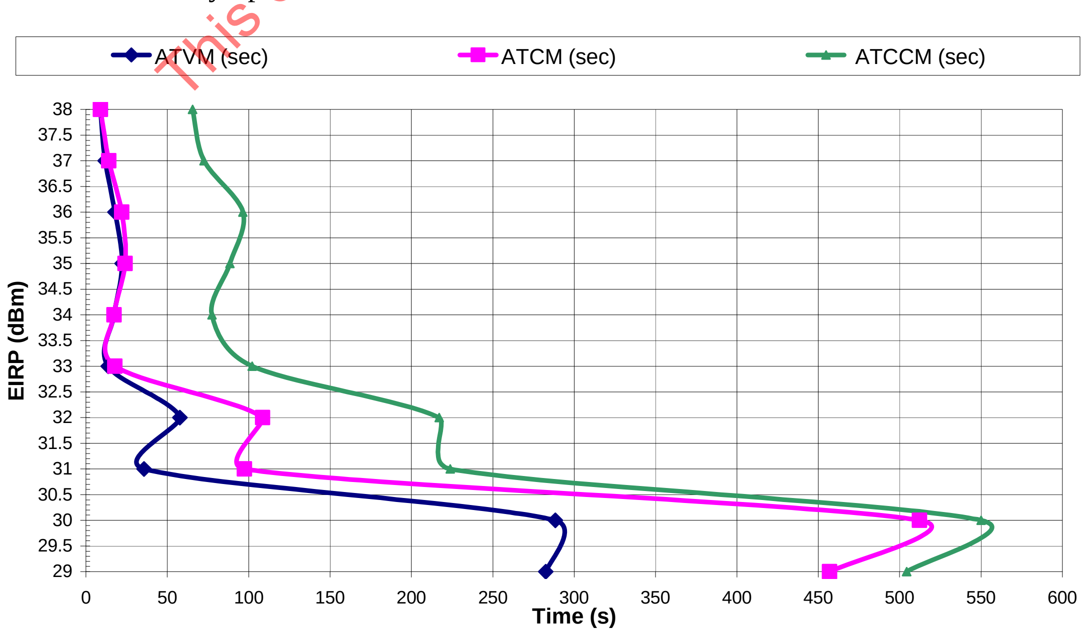
ANNEX D

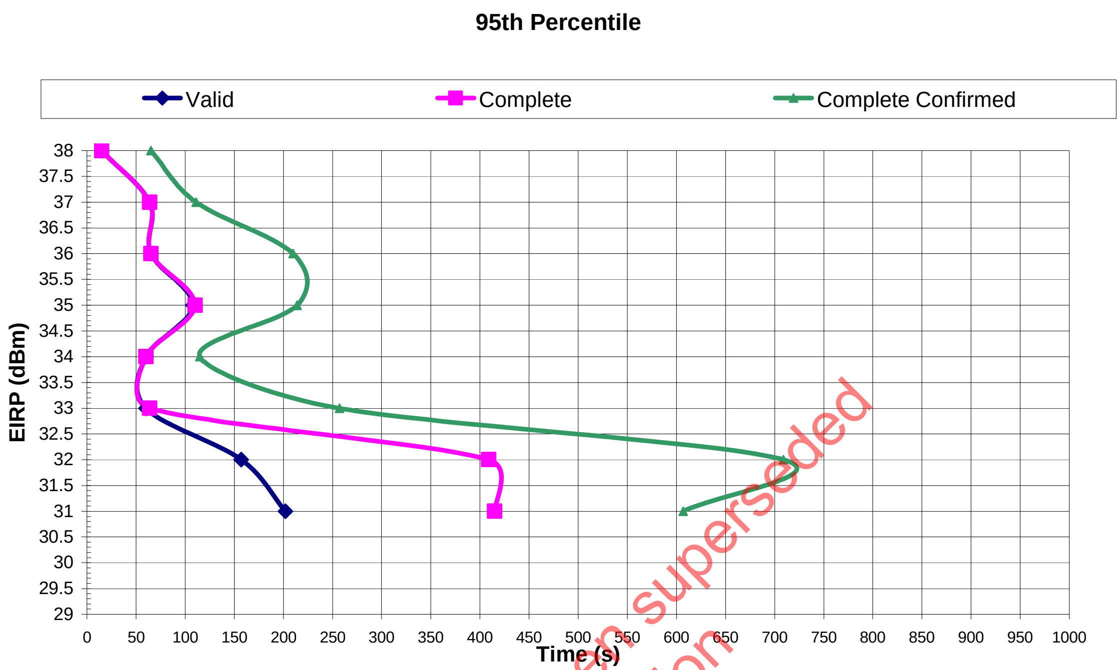
TIME TO PRODUCE VALID, COMPLETE AND CONFIRMED COMPLETE MESSAGES TEST RESULTS

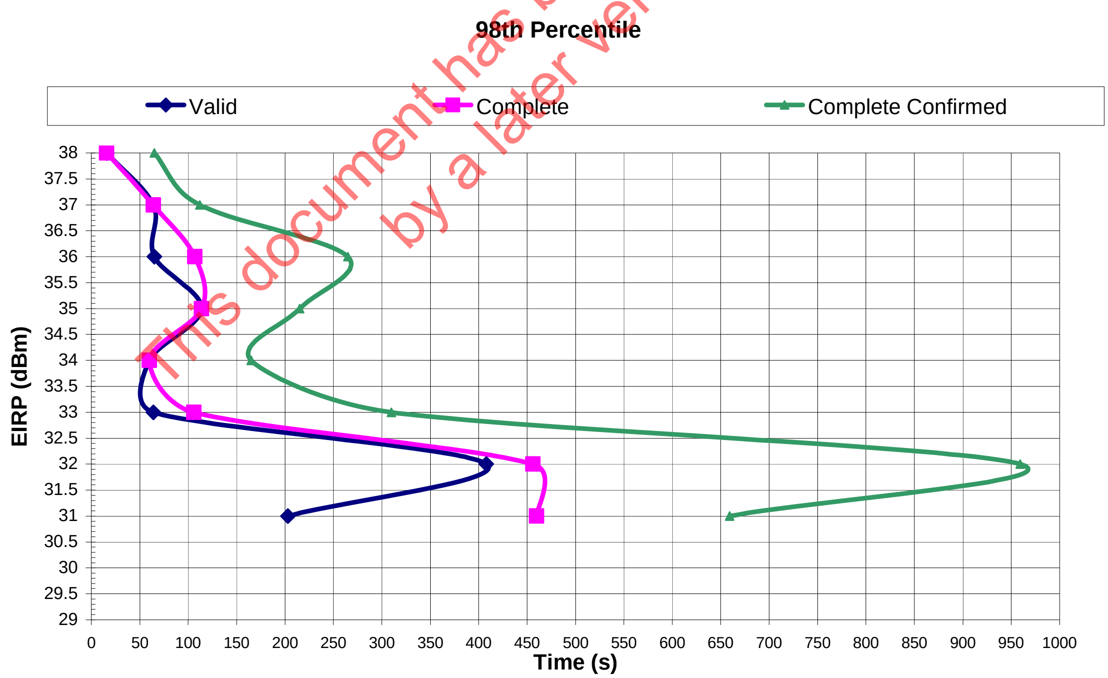
1.0 Time to Produce Valid, Complete and Confirmed Complete Message Test Results Measured by France's GEOLUT



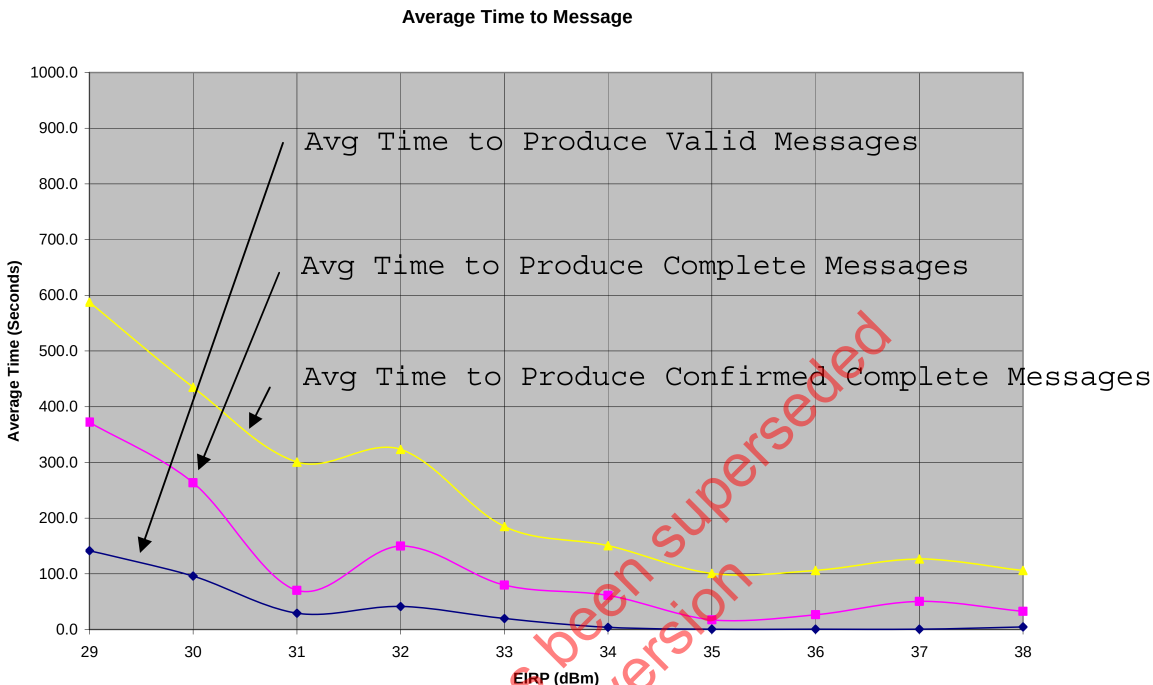
2.0 Time to Produce Valid, Complete and Confirmed Complete Message Test Results Measured by Spain's GEOLUT

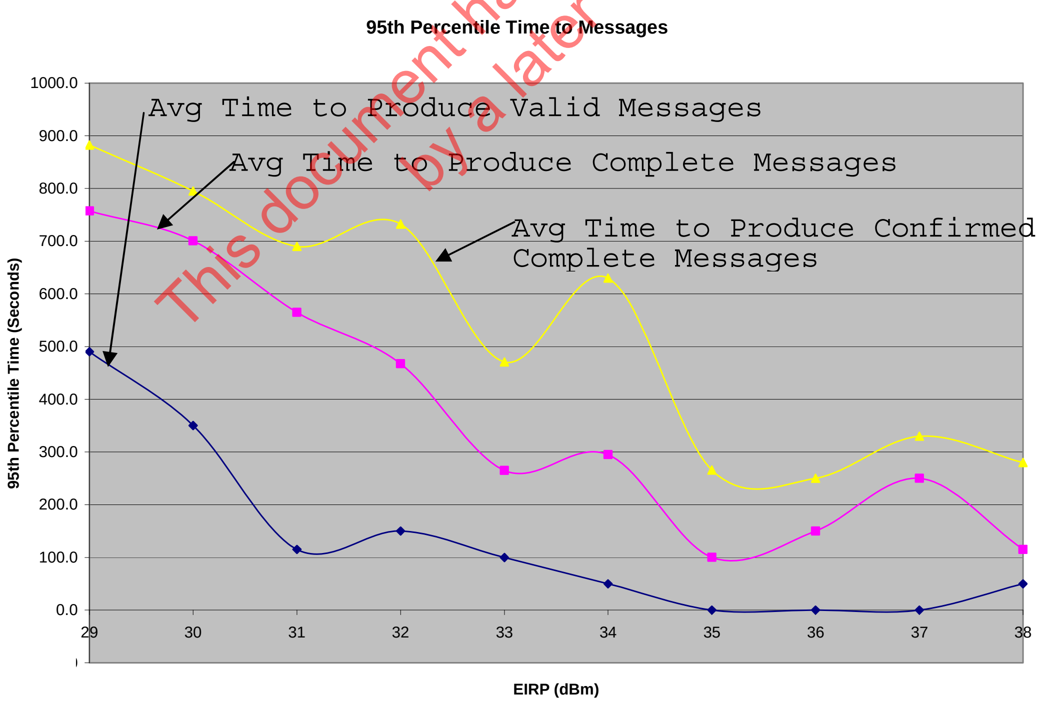


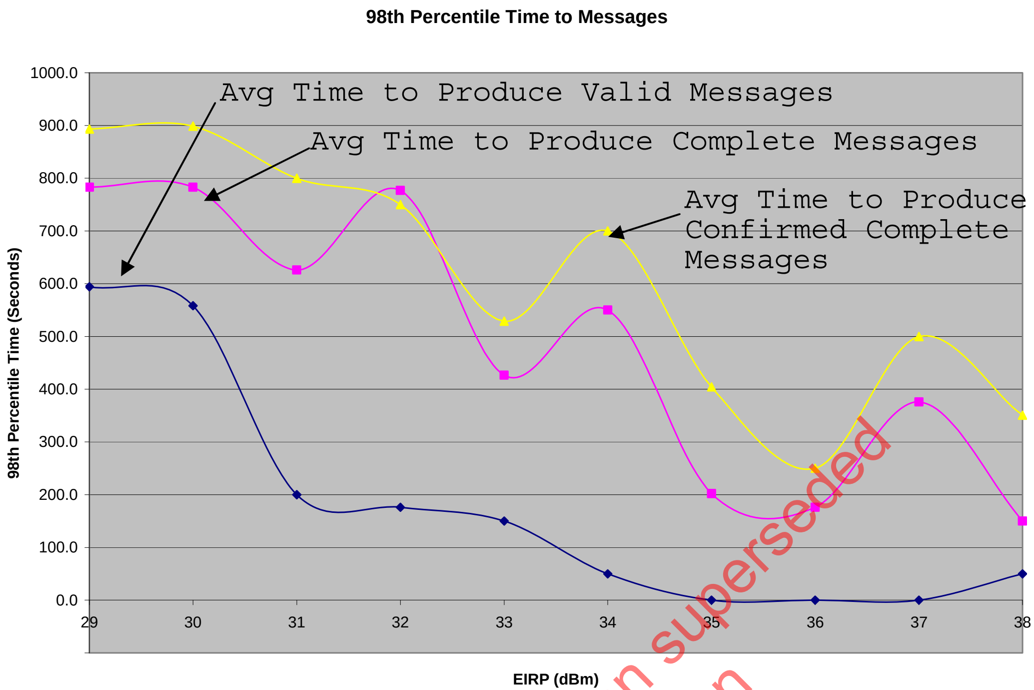

95th Percentile
Valid
Complete
Complete Confirmed
EIRP (dBm)
38
37.5
37
36.5
36
35.5
35
34.5
34
33.5
33
32.5
32
31.5
31
30.5
30
29.5
29
0 50 100 150 200 250 300 350 400 450 500 550 600 650 700 750 800 850 900 950 1000
Time (s)


98th Percentile
Valid
Complete
Complete Confirmed
EIRP (dBm)
38
37.5
37
36.5
36
35.5
35
34.5
34
33.5
33
32.5
32
31.5
31
30.5
30
29.5
29
0 50 100 150 200 250 300 350 400 450 500 550 600 650 700 750 800 850 900 950 1000
Time (s)

3.0 Time to Produce Valid, Complete and Confirmed Complete Message Test Results Measured by UK's GEOLUT





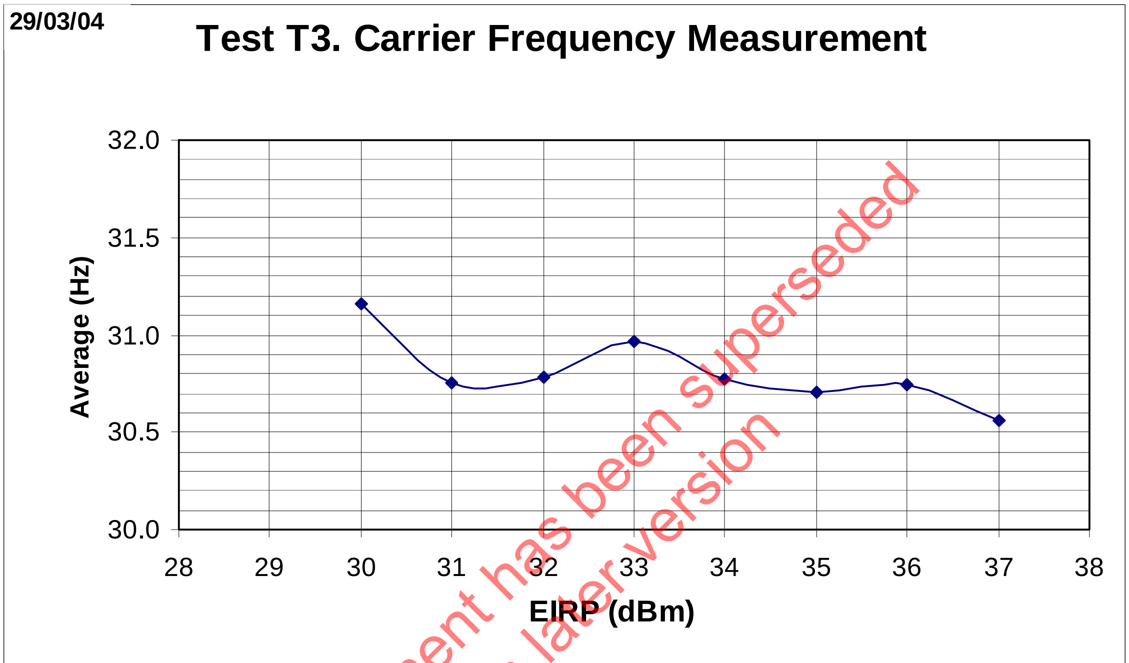


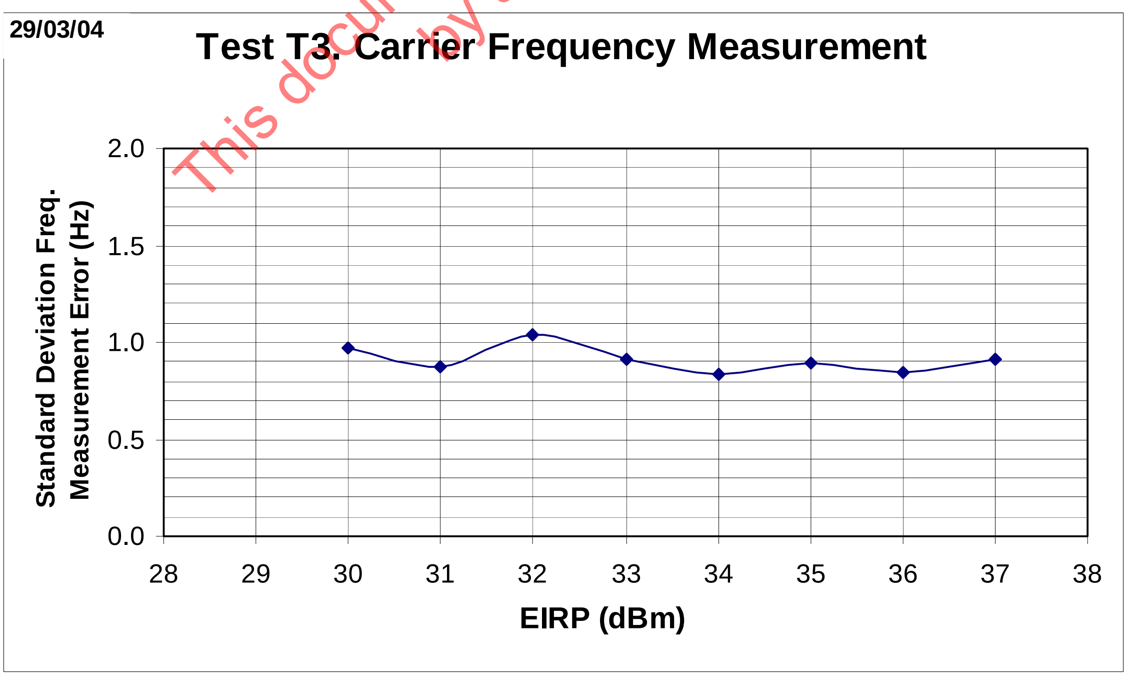
- END OF ANNEX D -

ANNEX E

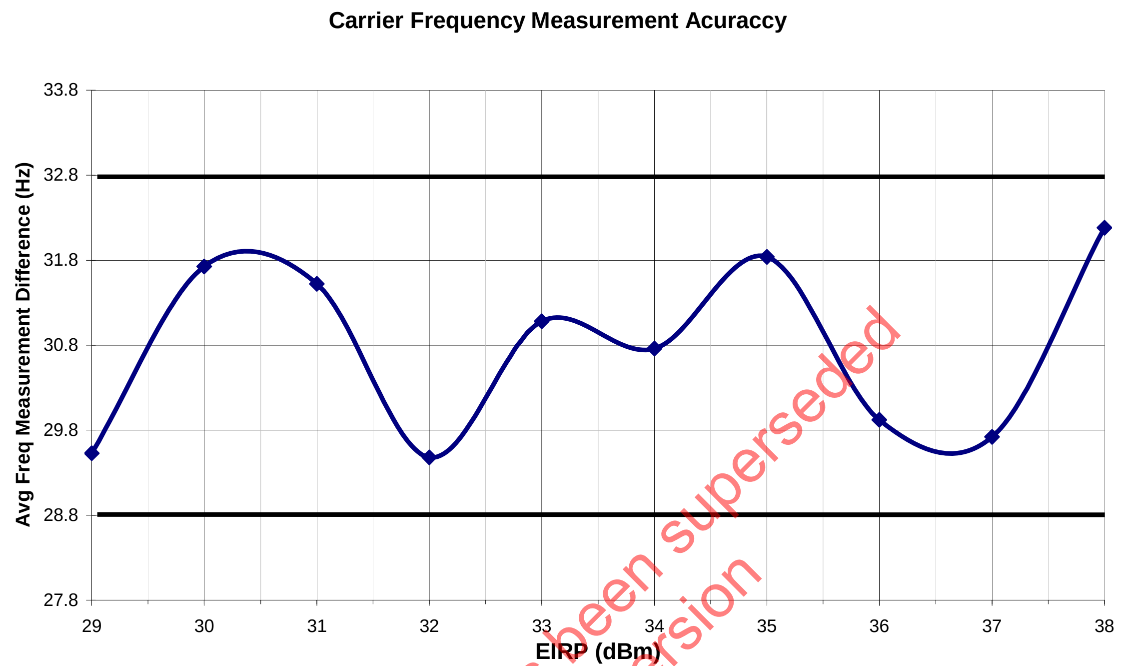
FREQUENCY MEASUREMENT ACCURACY TEST RESULTS

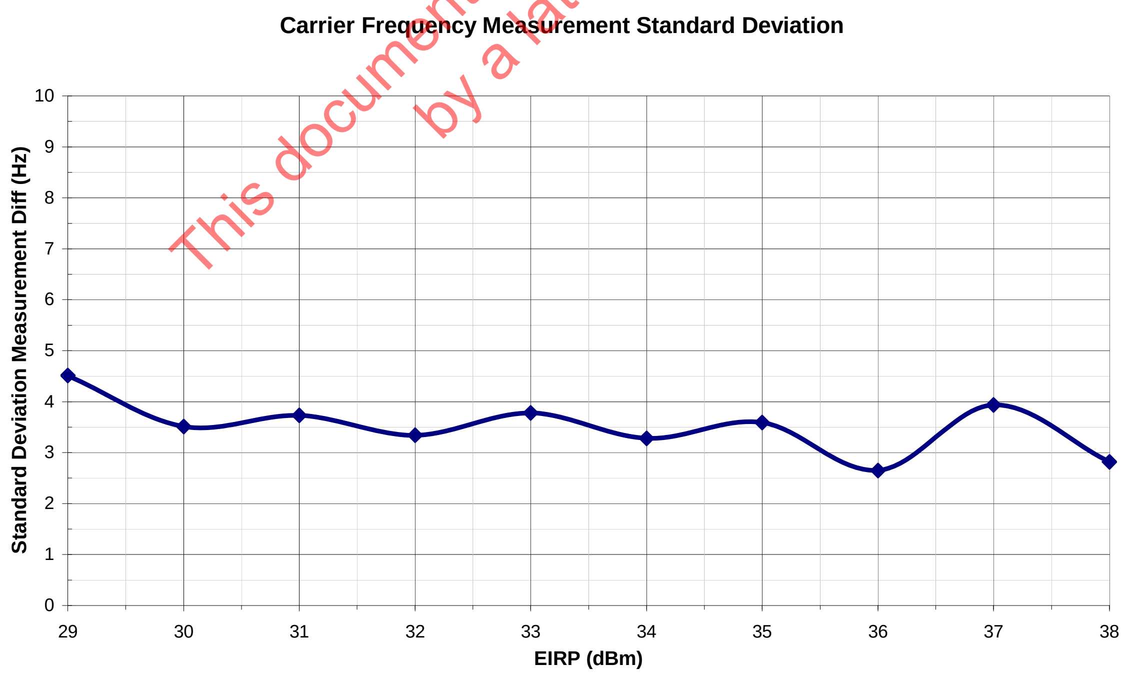
1.0 Frequency Measurement Accuracy Test Results Measured by France's GEOLUT



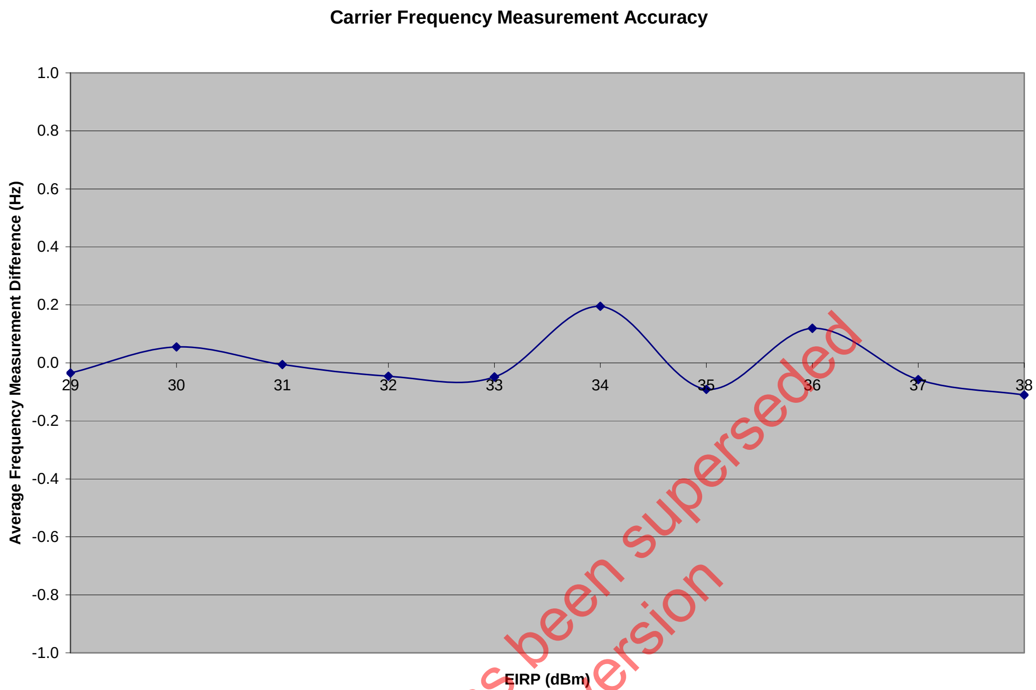


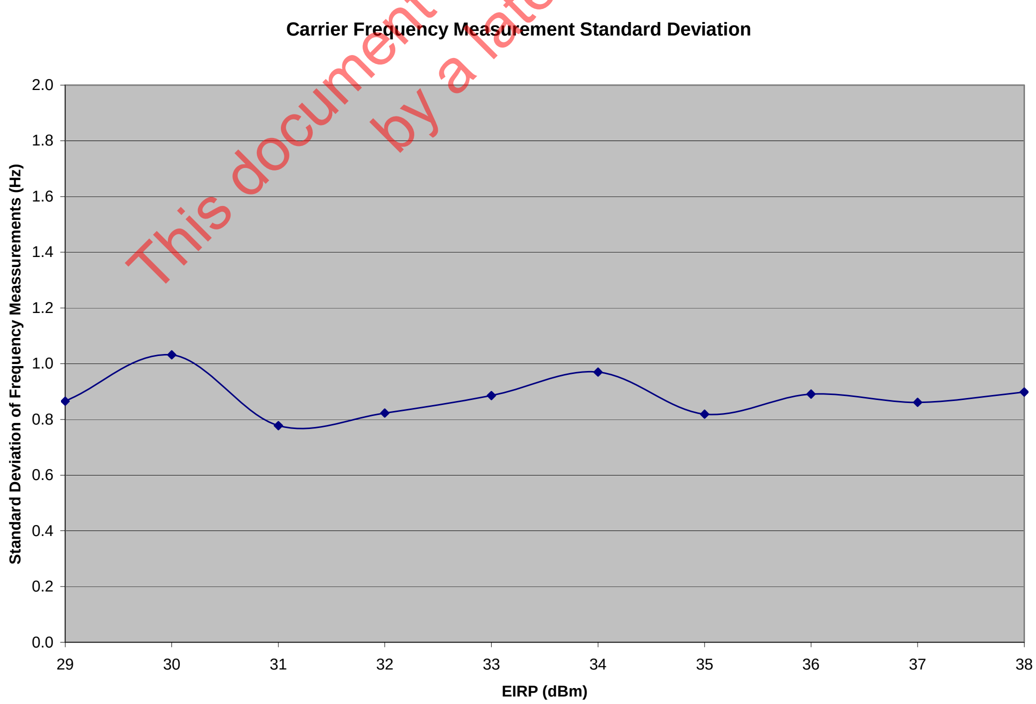
2.0 Frequency Measurement Accuracy Test Results Measured by Spain's GEOLUT





3.0 Frequency Measurement Accuracy Test Results Measured by the UK's GEOLUT





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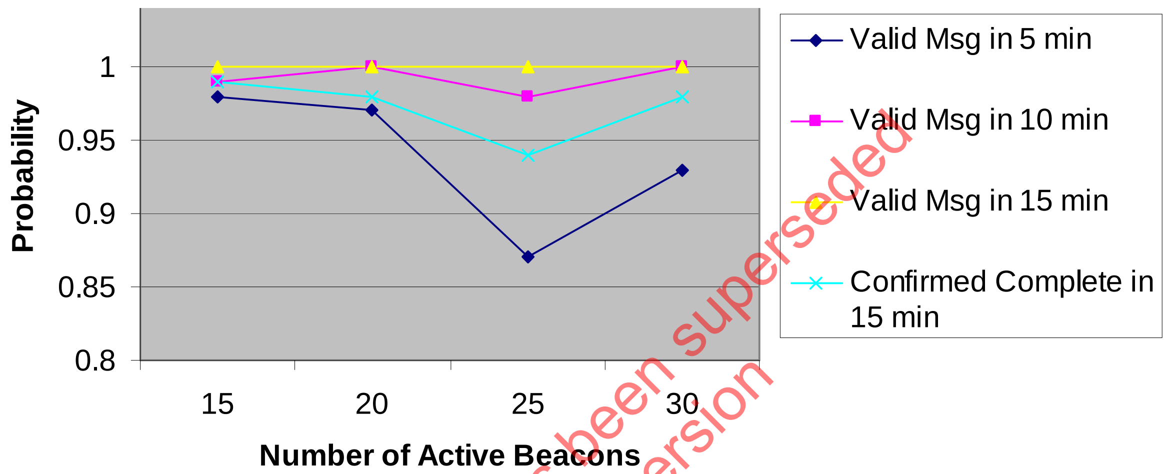
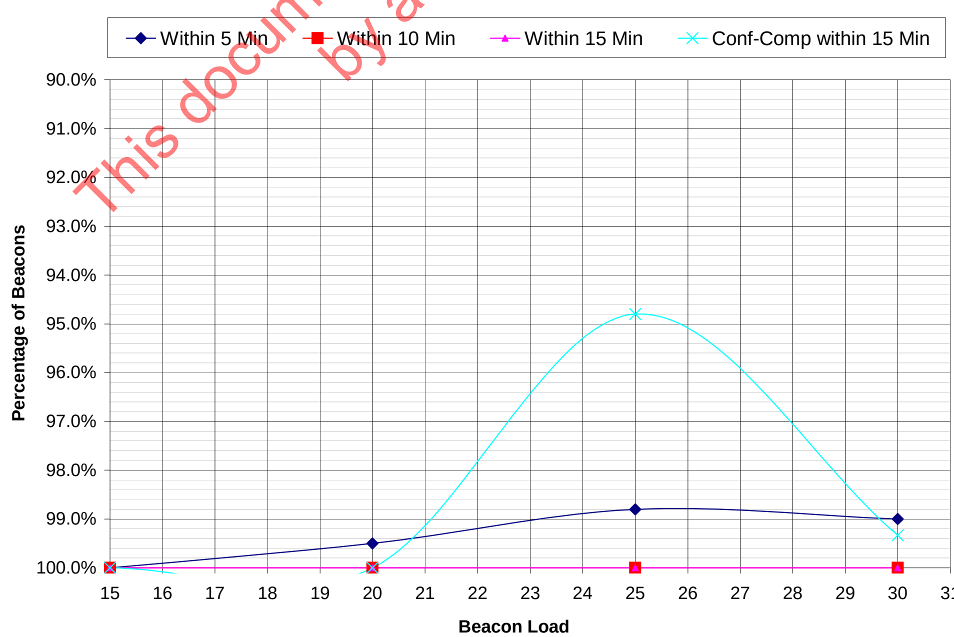
ANNEX F

CAPACITY TEST RESULTS

1.0 Capacity Test Results Measured by France's GEOLUT



2.0 Capacity Test Results Measured by Spain's GEOLUT



- END OF ANNEX F –

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