Unwanted emissions testing of Raymarine Quantum radar system

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Administration page

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Abstract

A measurement programme was undertaken at QinetiQ Funtington to assess the unwanted emissions of a marine navigation radar system supplied by Raymarine UK Ltd. The radiated emissions were measured using the direct method with the radar operating in its shortest range transmission setting. The shortest pulse was characterised to enable the emission data to be plotted with the corresponding emission masks in the spurious emission domain. The unwanted emissions from the system under test did not exceed the applied specification mask from IEC 62388.

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1 Introduction

A measurement programme was undertaken at QinetiQ Funtington, against Raymarine UK Ltd. purchase order 1310014150, to assess the unwanted emissions of a marine navigation radar system as supplied.

The equipment under test was tested against annex B of the international standard IEC 62388 (Maritime navigation and radiocommunication equipment and systems – Shipborne radar – Performance requirements, methods of testing and required test results) [1]. The measurement method used in the programme was based on the ITU recommendation M.1177 [2].

For the radar system tested this report presents:

- A measurement of the shortest radar pulse employed during testing
- A radiated emission chart demonstrating the emission spectrum of the shortest pulse width transmission
- A radiated spurious emission (SE) chart with corresponding mask

Out-of-band (OOB) emission limits as specified in ITU-R SM.1541-5 [3] (Annex 8) do not apply to pulsed radars with rated peak power of 1kW or less.

2 Equipment under test

Table 2-1 below, summarises the radar system tested in the measurement programme.

Item for test	Model	Serial number
Radar system	20W Solid State Quantum Radar	0750109
Display unit	Hybrid Touch display unit, model number E70023	0620215

Table 2-1 – Equipment under test

Figures 2-1 to 2-4 show photos of both the radar system and display during the testing and the corresponding information plate.

Figure 2-1 – Radar system during test within the anechoic chamber at QinetiQ Funtington

Figure 2-2 – Radar system information plate

Figure 2-3 – Display unit

Figure 2-4 – Display unit information plate

3 Measurement method

3.1 Pulse characteristic measurement

The pulse characteristics of the short pulse from the radar system were measured using a peak power analyser directly connected to a standard gain horn at approximately 13m from the radar antenna. The parameters of interest were:

- Rise time
- Pulse width
- Fall time

The rise time of a pulse is the time taken for the voltage across the detector to rise from 10% of the peak recorded voltage to 90% of the peak. The pulse width is the width of the pulse measured between the 50% peak voltage points. The fall time of a pulse is the time taken for the voltage across the detector diode to fall from 90% of the peak recorded voltage to 10% of the peak (Figure 3-1).

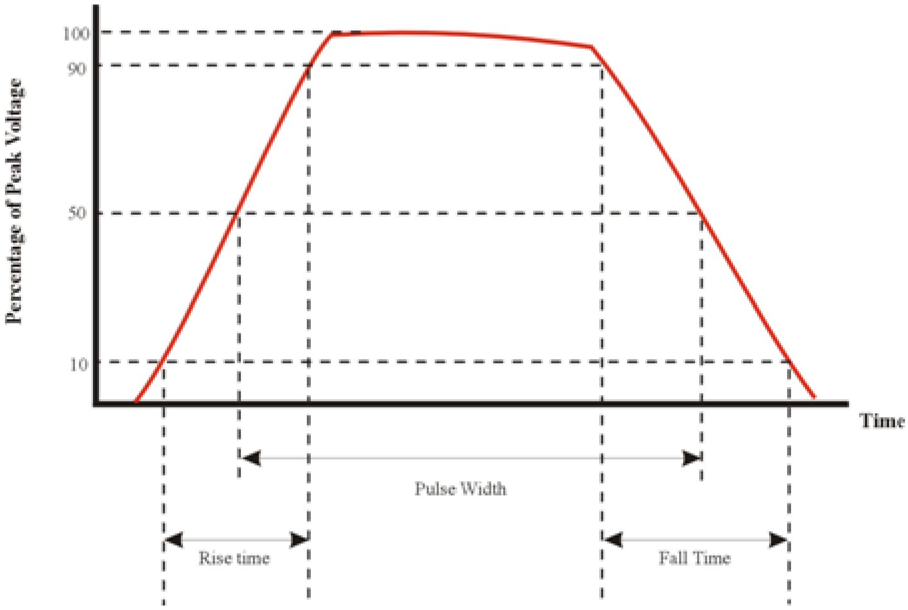

Figure 3-1 – Pulse characteristics

The pulse characteristic measurements are carried out with the radar transmitting as normal but with the turning unit motor disabled, allowing the radar antenna to be aligned to the measurement system antenna to ensure maximum power transfer and minimal fluctuations due to any perturbations in the radar antenna position.

3.2 Unwanted emissions measurement

The technique employed at QinetiQ Funtington for the measurement of unwanted emissions is based on the direct method described in the ITU recommendation M.1177 [2]. This method allows the accurate measurement of the spectral emissions from a complete radar system; however, it does require a large facility, typically an open site or large anechoic chamber to achieve a satisfactory far field distance. A photograph of the QinetiQ Funtington ranges is shown below in Figure 3-2.

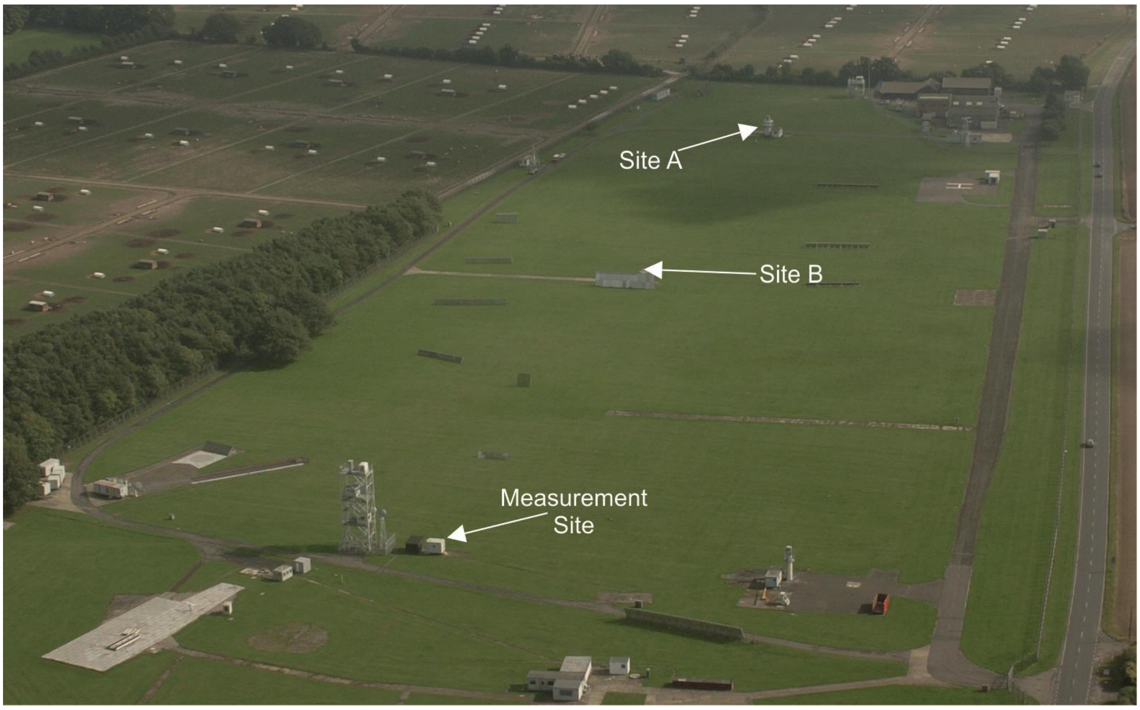

Figure 3-2 – Photo of the QinetiQ Funtington rangesshowing radar test sites A & B

The separation requirement for the measurement system and the equipment under test is given by Equation 3-1 where *D* is the largest dimension of the antenna under test, and λ is the wavelength at the highest measurement frequency. It is not always possible to achieve the required separation with large antennas and very wide band measurements and in these cases a calculation of the gain reduction due to the reduced range is required.

$$R \geq {D^2}/{\lambda}$$

Equation 3-1 – Range separation requirement equation

Measurements of smaller, lower power systems including the Raymarine Quantum radar are measured in one of two anechoic facilities at Funtington, the larger of which is shown below shown in Figure 3-3.

Figure 3-3 – Quantum radar system on test in the large anechoic chamber facility at QinetiQ Funtington

In the anechoic test facility standard gain horns are used as the receive antennas, and several are required to cover the measurement band. The horns used for the assessment of the EUT are shown below in Figure 3-4.

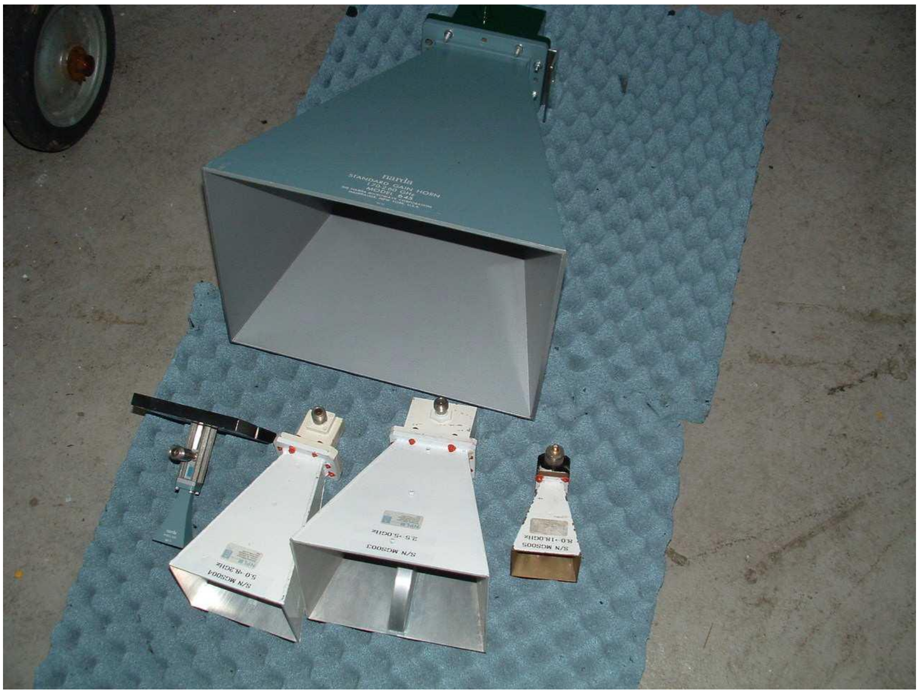

Figure 3-4 – Standard gain horns used for the testing of the Quantum radar system

The test cable from the receive antenna connects to the RF front end box containing the programmable stepped attenuators, YIG filter and preamplifier. A further RF cable and control cables run from this box to the spectrum analyser and PC respectively.

The measurement system for this testing comprised:

- standard gain horns covering 1.7 to 26.5GHz in waveguide bands
- Integrated 0 – 90dB and 0 – 11dB attenuators
- Omni-YiG 2 – 26.5GHz band-pass filter
- Miteq 100MHz – 26.5GHz low noise pre-amplifier
- Hewlett Packard 26.5GHz Modular Measurement System (MMS) spectrum analyser
- Personal computer
- 2GHz – 40GHz synthesised calibration source
- Hewlett Packard 18GHz Peak Power Analyser

All test equipment is calibrated in accordance with standard QinetiQ policy (ENG/Pol/QQ/5.0).

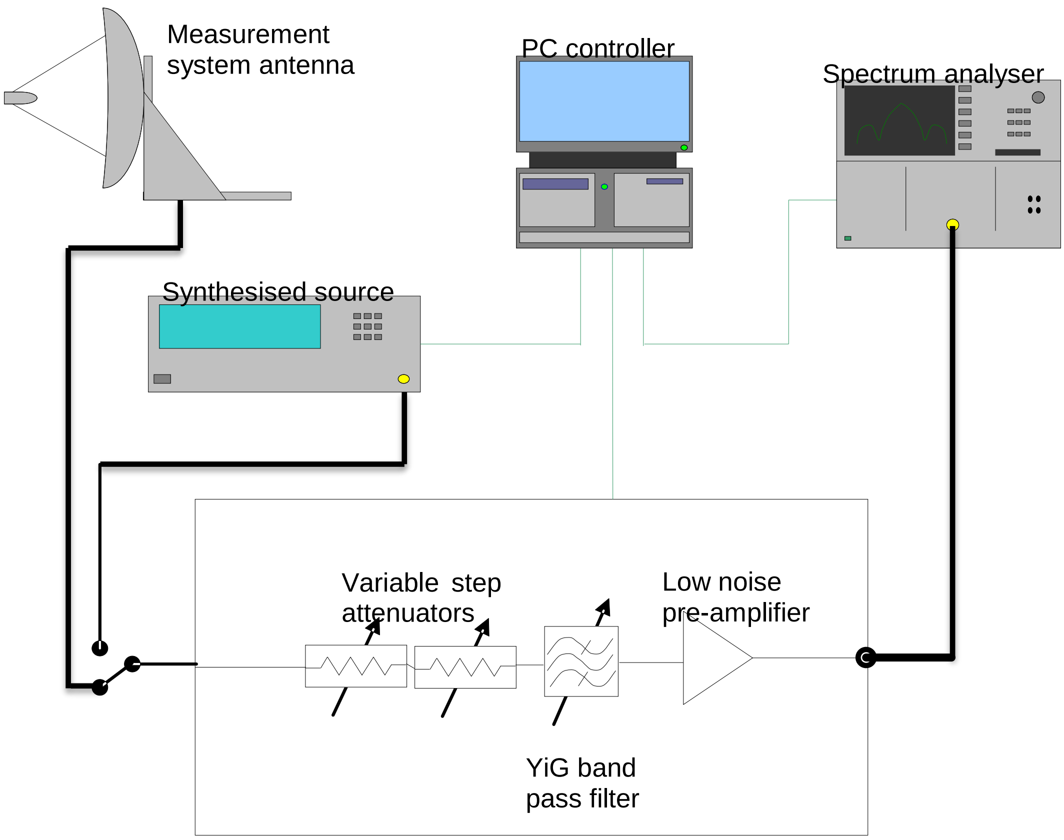

Figure 3-5 – Measurement system schematic diagram

To measure the unwanted emissions of the equipment under test the measurement system is required to measure the worst case power spectrum. The measurement bandwidth (BW_M) is set to a value matching the pulse width of the equipment under test up to a maximum value of 1MHz. The impulse bandwidth (BW_I) of the spectrum analyser is 1.6 times its resolution bandwidth (BW_R); to achieve the 1MHz measurement bandwidth this is set to an inherent value of 0.681MHz.

To adequately measure the peak power of a pulsed spectrum the impulse bandwidth of the receiver must be sufficiently wide to sum the power contained in the majority of the spectral components. In the case of simple non-modulated pulsed radar the required receiver impulse bandwidth is given by Equation 3-2 where τ is the pulse width.

$$BW_I = {}^{1}/_{\tau}$$

Equation 3-2 – Impulse bandwidth calculation

$1/\tau$ is equal to the 3dB bandwidth of the main lobe of the pulse spectrum. The impulse bandwidth is equal to the bandwidth of an ideal rectangular filter with the same pulse response as the receiver.

The most recent version of the ITU recommendation M.1177 [2] states that the spurious emissions region should be measured with a maximum impulse bandwidth of 1MHz although there is no upper limit for the out-of-band region. Consequently when measuring radar systems with short pulse modes there is insufficient bandwidth to correctly measure the peak power. The value measured is reduced by the pulse desensitisation figure (PDF) which may be calculated from Equation 3-3.

$$PDF\ (dB) \approx 20 \times \log(\tau \times 1.6 \times BW_R)$$

Equation 3-3 – Pulse desensitisation figure calculation

The PDF lowers the measured value of all spectra that are a direct result of the pulsed RF. Other non-pulsed signals, for example the continuous wave (CW) local oscillator leakage, are not affected by different receiver bandwidths and are therefore high relative to the pulsed signals and noise floor, which are both a function of the measurement bandwidth.

When assessing the spurious emission performance of the equipment with the application of a mask, the value of the mask should be raised by the PDF to compensate for the difference in relative levels between the pulsed and CW signals.

The spurious emission level as defined by IEC 62388 shall be more than either 60dB or (43 + 10 × log PEP (Peak Envelope Power)) dB below the carrier power as measured in the far field of the radar, whichever is the least stringent case.

A summary of the measurement uncertainties for the unwanted emission measurements are included in Appendix A.

4 Measurement results

The unwanted emissions measurement for the Quantum radar system was carried out with the test equipment listed in Appendix B. The far-field distance of the 0.44m patch array antenna at 20GHz is 13m, above this frequency there may be some gain compression due to near field effects. This gain reduction has been calculated using the programme in M1177-4 Appendix 4 to Annex 1 [2]. The maximum gain compression due to near field effects has been calculated for this radar system as being 0.4dB at 26GHz.

For the radar system tested, this section presents:

- A measurement of the shortest radar pulse
- An emission chart demonstrating the primary emission spectrum for the shortest range setting
- A spurious emission (SE) chart
- The pulse desensitisation factor (PDF)

An out-of-band (OOB) mask is not included as the OOB emission limits in ITU-R SM.1541-5 (Annex 8) [3] do not apply to pulsed radars with rated peak power of 1kW or less. The application of the SE mask has been carried out in accordance with the guidance given in IEC 62388 (Annex B) [1].

4.1 Quantum radar system unwanted emissions measurements

Figure 4-1 presents the normalised voltage for the short pulse of Quantum radar system at 9.4GHz. The pulse characteristics are:

- Rise time: 27.9ns
- Pulse width: 53.4ns
- Fall time: 26ns
- PDF: -24.7dB (53.4ns × 1.6 × 0.681MHz)

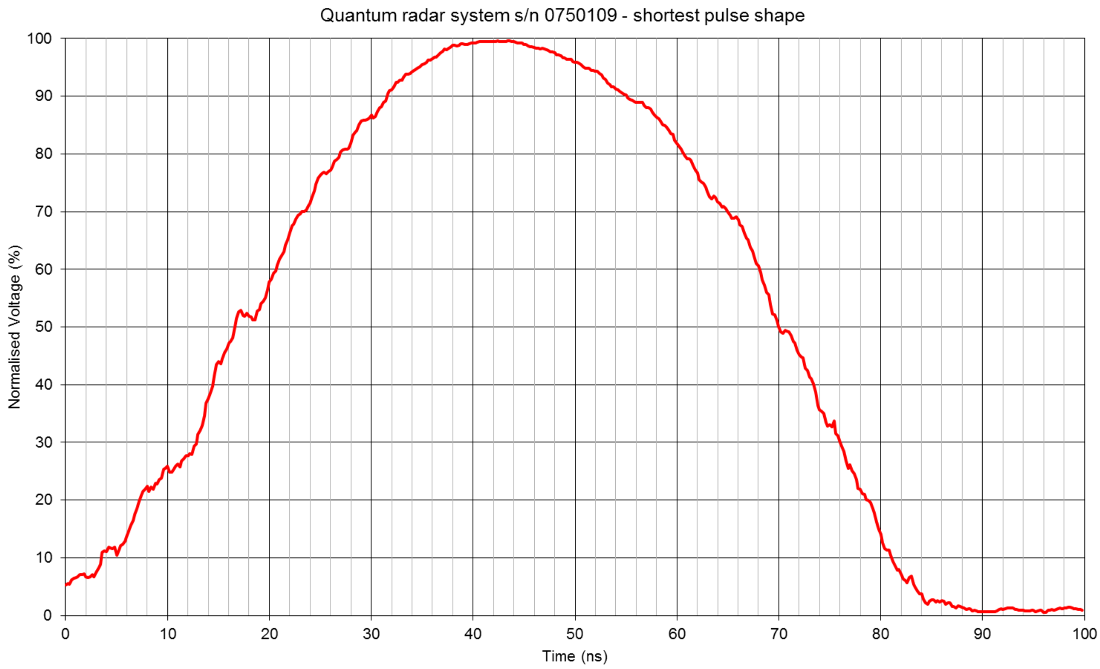

Figure 4-1 – Quantum radar system shortest pulse normalised voltage

Figure 4-2 presents the primary emission spectrum for the shortest pulse width of the Quantum radar system. The SE boundary has been calculated from the B_{-40} bandwidth of the shortest radar pulse transmitted which generates the largest B_{-40} bandwidth. The SE level calculated from the quoted PEP (20W) and the PDF is -31.3dB. 30dB and 40dB OOB masks have been included for information only.

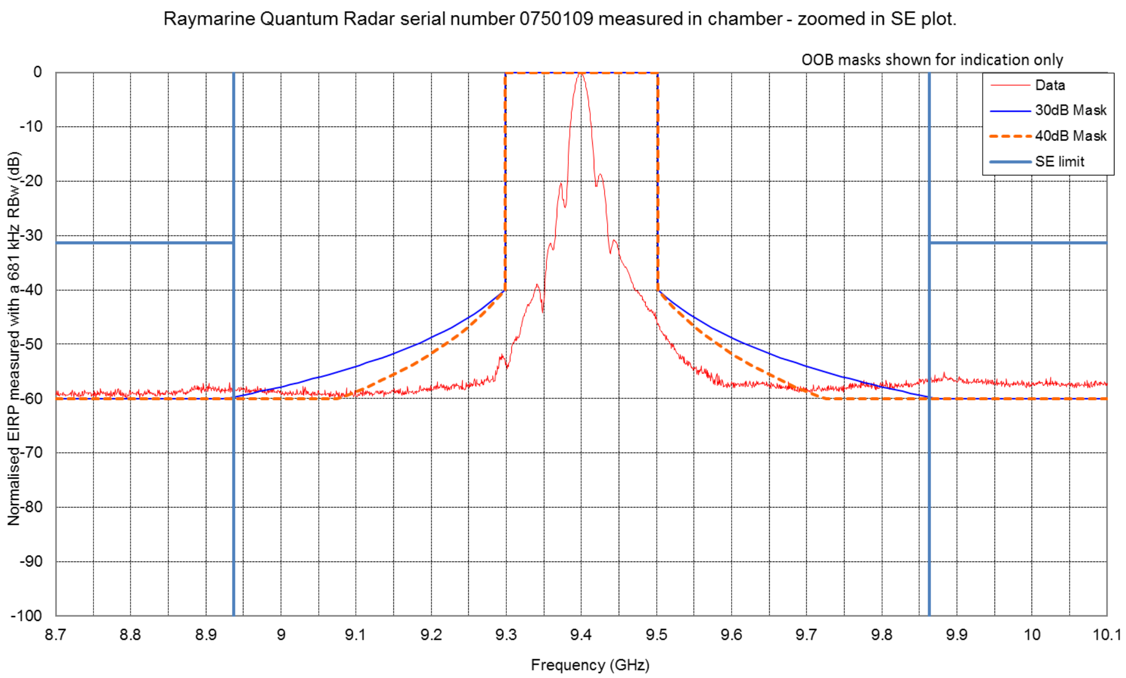

Figure 4-2 – Quantum radar system primary emission spectrum including SE region boundary

Figure 4-3 presents the spurious emission region for the shortest pulse width for the Quantum radar system. The emission at 2.5GHz is generated by the Wi-Fi link within the radar system. The plot shows that the radiated emission spectrum of the Quantum radar system falls below the SE mask excluding the Wi-Fi region.

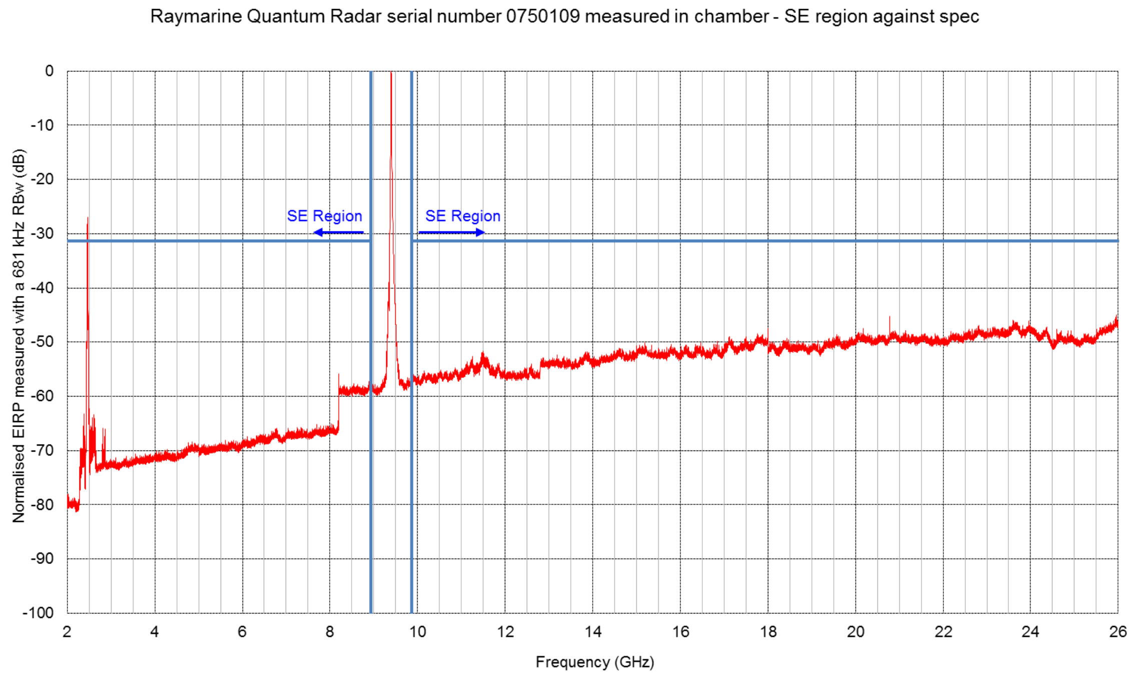

Figure 4-3 – Quantum radar system shortest pulse full spurious emission region

Figure 4-4 shows the emission spectrum of the radar centred at 2.5GHz, also overlaid is the Wi-Fi frequency limits taken from the ETSI EN specification [4].

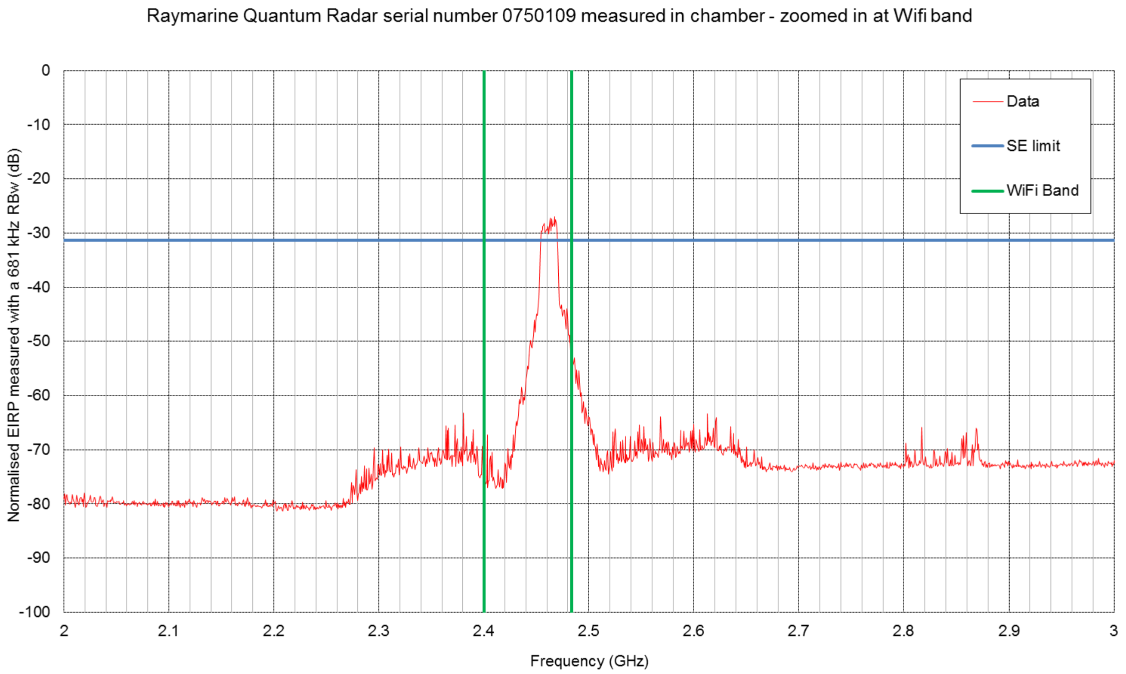

Figure 4-4 Quantum radar system emission spectrum zoomed in at 2.5GHz

5 Conclusions

Unwanted emissions from the radar system tested do not exceed the mask applied in the spurious emission regions.

There are no OOB limits for this system.

The Wi-Fi emission has not been assessed against any specification including ESTI EN 300 328 [4].

6 References / Bibliography

[1] IEC 62388 Edition 2.0 : 2013 Annex B. Maritime navigation and radiocommunication equipment and systems – Shipborne radar – Performance requirements, methods of testing and required test results.

[2] Recommendation ITU-R M.1177-4 – Techniques for Measurement of Unwanted Emissions of Radar Systems. (04/2011).

[3] ITU Recommendation SM.1541-5 – Unwanted emissions in the Out of Band domain. (08/2013).

[4] ETSI EN 300 328 V1.9.1 (2015-02) - Electromagnetic compatibility and Radio spectrum Matters (ERM); Wideband transmission systems; Data transmission equipment operating in the 2,4 GHz ISM band and using wide band modulation techniques; Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive

A Appendix A

A.1 Measurement uncertainties

A summary of the measurement uncertainties for the unwanted emission measurements are presented in Table A–1.

Measurement uncertainty	**Value (dB)**
Range multipath	±0.5
Receive antenna and cable gain	±0.5
Calibration source uncertainty	±0.5
11 dB attenuator value	±0.5
90 dB attenuator value	±1.0
YiG filter pass band ripple	±0.5
Amplifier gain	±0.23
Spectrum analyser frequency response	±1.0
Spectrum analyser marker resolution	±0.03
Spectrum analyser scale fidelity	±0.2

Table A-1– Measurement uncertainties

Combining these values by assuming each to have a rectangular probability distribution the 95% expanded uncertainty for the measurement becomes:

- Expanded uncertainty ±2.54dB

The uncertainties associated with the pulse width and rise-time measurements are ±1.5% of the measured value, which leads to an associated uncertainty in the pulse desensitisation figure of:

- Pulse desensitisation figure uncertainty ±1.0dB

The reduction in antenna gain due to not being in the infinite far field is small. For the 0.44m antenna the gain reduction from the infinite far field is approximately 0.4dB at 26GHz.

The following chart (Figure A-6-1) has been generated to illustrate the variation in uncertainty over the range of the normalised power levels for Quantum radar system. Above -30dBm the power level presented to the spectrum analyser is consistent to within a few decibels due to the front end attenuators, so the uncertainty is constant (the linear region). Beneath -30dBm the power level measured drops and approaches the noise floor, hence the measurements become more uncertain (the non-linear region). The discontinuity in the chart is an artefact of the uncertainty contribution of the attenuators. This uncertainty is not present below -30dBm as the equipment is calibrated with the attenuators set to 0dB.

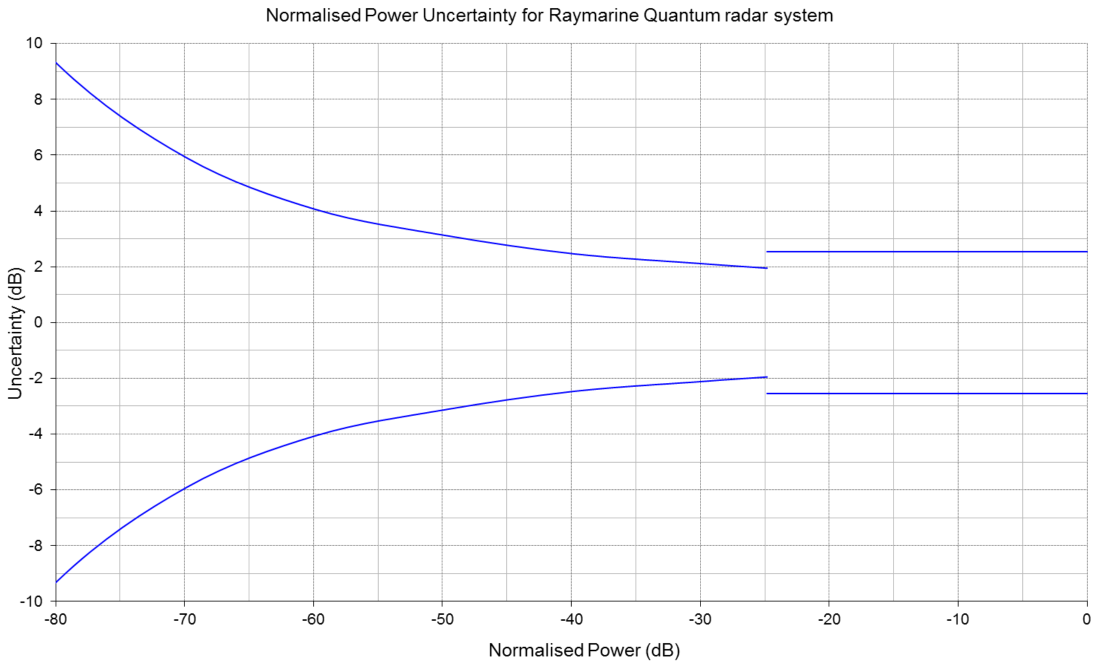

Figure A-6-1 – Quantum radar system, shortest pulse width setting, normalised power uncertainty

B Appendix B

B.1 Test equipment

Item	Manufacturer	Model number	Serial number	Calibration due date
MMS spectrum analyser display unit	Hewlett Packard	HP7004A	3746A05772	29/01/16
MMS spectrum analyser IF section (RBw 10Hz-300kHz)	Hewlett Packard	HP70902A	3530A05386	29/01/16
MMS spectrum analyser IF section (RBw 100kHz-3 MHz)	Hewlett Packard	HP70903A	3533A03511	29/01/16
MMS spectrum analyser wide band IF section (RBw 10 MHz-100 MHz)	Hewlett Packard	HP70911A	3446A00534	29/01/16
MMS spectrum analyser local oscillator	Hewlett Packard	HP70900B	3647A03148	29/01/16
MMS spectrum analyser precision frequency reference	Hewlett Packard	HP70310A	3732A03583	29/01/16
MMS spectrum analyser RF section (100 Hz-26.5 GHz)	Hewlett Packard	HP70910A	3822A00628	29/01/16
MMS spectrum analyser pre-amplifier (unused) (1 GHz-26.5 GHz)	Hewlett Packard	HP70620B	3550A00769	29/01/16
MMS spectrum analyser mainframe	Hewlett Packard	HP70001A	3801A08870	29/01/16
Synthesised sweep source	Hewlett Packard	HP83642A	3119A00123	20/08/16
90 dB programmable step attenuator	Agilent Technologies	84906K	US42140218	N/A
11 dB programmable step attenuator	Agilent Technologies	84904K	US42140310	N/A
YIG band-pass filter	Omniyig	M982D	3109	N/A
Low noise pre-amplifier (100 MHz-26.5 GHz)	Miteq	AFS42-00102650-42-10P-42	957590	N/A
Peak power analyser	Hewlett Packard	HP 8990A	3621A01313	22/01/16
Peak power sensor	Hewlett Packard	HP 84812A	3130A00283	22/01/16
PC control card	National Instruments	PCI-6221	-	N/A
Narda standard gain horns (1.7-2.6GHz & 18-26.5GHz)	Narda	645 & 638		N/A
MGS standard gain horns (covering 2.5-18GHz)	MGS	MGS3, MGS4 & MGS 5	-	N/A

Table B-1 – Unwanted emissions test equipment

Initial distribution list

External	
Andy Little	Raymarine UK Ltd

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QinetiQ Information Warehouse

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Abstract

A measurement programme was undertaken at QinetiQ Funtington to assess the unwanted emissions of a marine navigation radar system supplied by Raymarine UK Ltd. The radiated emissions were measured using the direct method with the radar operating in its shortest range transmission setting. The shortest pulse was characterised to enable the emission data to be plotted with the corresponding emission masks in the spurious emission domain. Unwanted emissions from the system under test did not exceed the applied mask.

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