Solid State Radar

Antenna Performance Report

NACOS Platinum - Radar

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1 Revisions

REV.	DATE	CHANGES	NAME	ORGANISATION
00	2020-04-27	First revision	K. Hanisch	WSAM (NHR)
01	2020-04-30	General revision	K. Hanisch	WSAM (NHR)
02	2020-05-04	CATR Schematic, Results Summary, Test Procedure	K. Hanisch	WSAM (NHR)
03	2020-06-17	Results for Harmonics	K. Hanisch	WSAM (NHR)

2 Reference Documents

REF.	DOCUMENT NO.	REV.	SOURCE	DOCUMENT TITLE
[IEC62388]	IEC 62388:2013	Ed.2		Shipborne Radar - Performance requirements, methods of test and required results

Introduction

2.1 Scope of this document

This document is applicable to SSR2018 and effective from 2020-04-27 until a newer version supersedes it.

2.2 Purpose

The purpose of this document is to show compliance of the Wärtsilä NACOS Platinum Radar antenna GR3021G091 with the requirements defined in [IEC62388].

2.3 Intended audience

Development teams, approval authorities as well as other stakeholders in the Wärtsilä SAM Platinum SSR development project are the intended audience of this document.

3 Test facility

Measurements have been conducted at the compact range antenna measurement facility at Thales, Netherlands.

3.1 Facility Street Address

THALES NEDERLAND B.V.

Zuidelijke Havenweg 40

7554 RR HENGELO

www.thalesgroup.com

3.2 Contact Person / Responsible for Measurement

Ronnie Spekhorst

SYSTEM TEST ENGINEER

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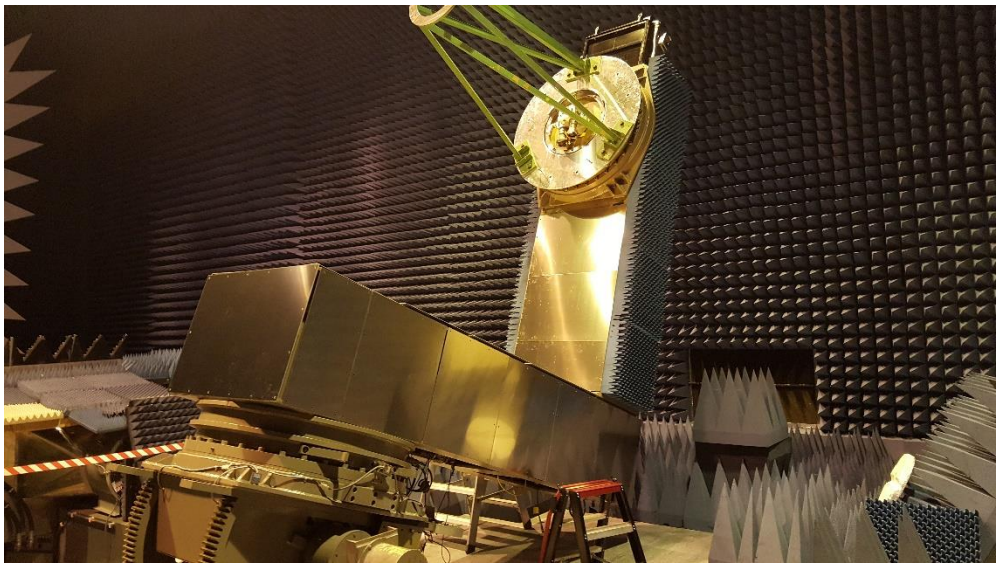

FIGURE 1 THALES ANECHORIC CHAMBER WITH POSITIONER

Simplified CATR test setup

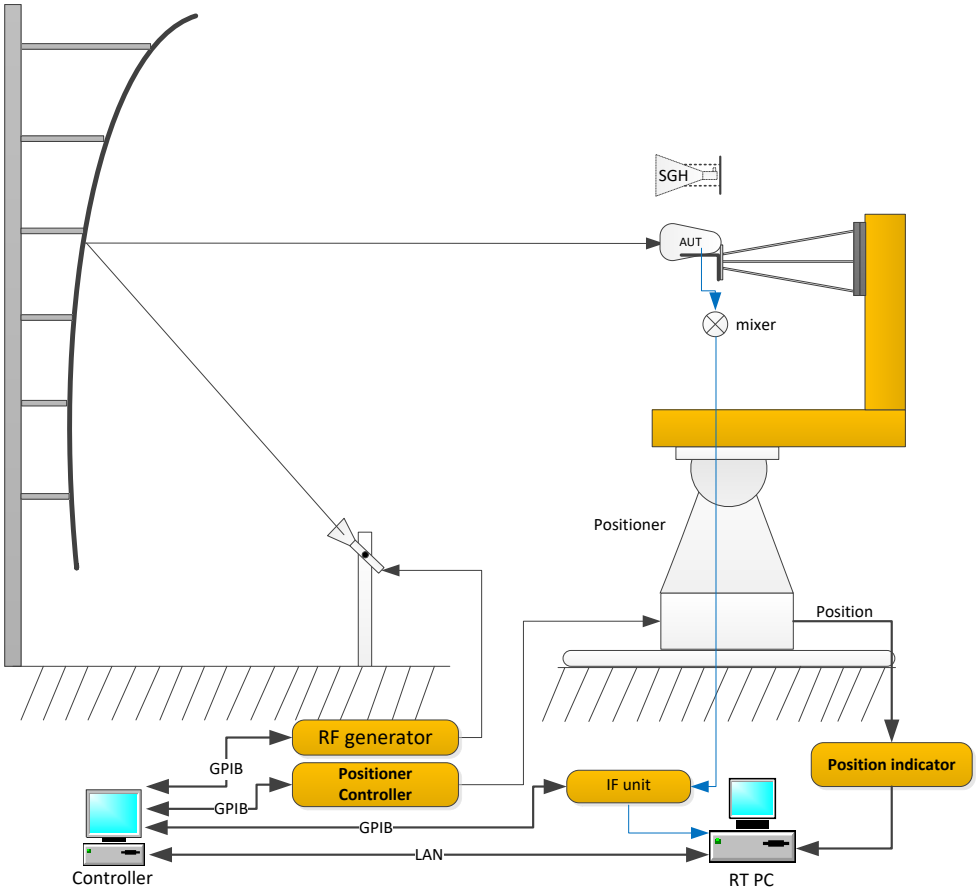

FIGURE 2 SCHEMATIC OF THE COMPACT RANGE MEASUREMENT USED FOR TEST

	2.5-3.5GHz	8.2-12.4GHz	34.5-35.5GHz
Quiet Zone Diameter [m]	4	2	2
Amplitude-ripple (p-p) [dB]	1.0	0.5	0.5
Amplitude-taper [dB]	1.0	0.25	0.25
Phase-ripple (p-p) [deg]	6	3	3

TABLE 1 COMPACT RANGE QUIET ZONE DIMENSIONS

Item	Manufacturer	Model number
Compact Antenna Test Range CATR	MI technologies	57817
X-band SGH	SA	12-8.2
C-band SGH	SA	12-5.8
S-band SGH	SA	12-2.6

TABLE 2 EQUIPMENT USED FOR THE MEASUREMENT

4 Equipment under test

Unit	
Type:	Waveguide antenna, S-Band
Manufacturing date	April 2020
Type No.	GR3021G092
Part No.	XAAB931419
Serial number	2013 70004

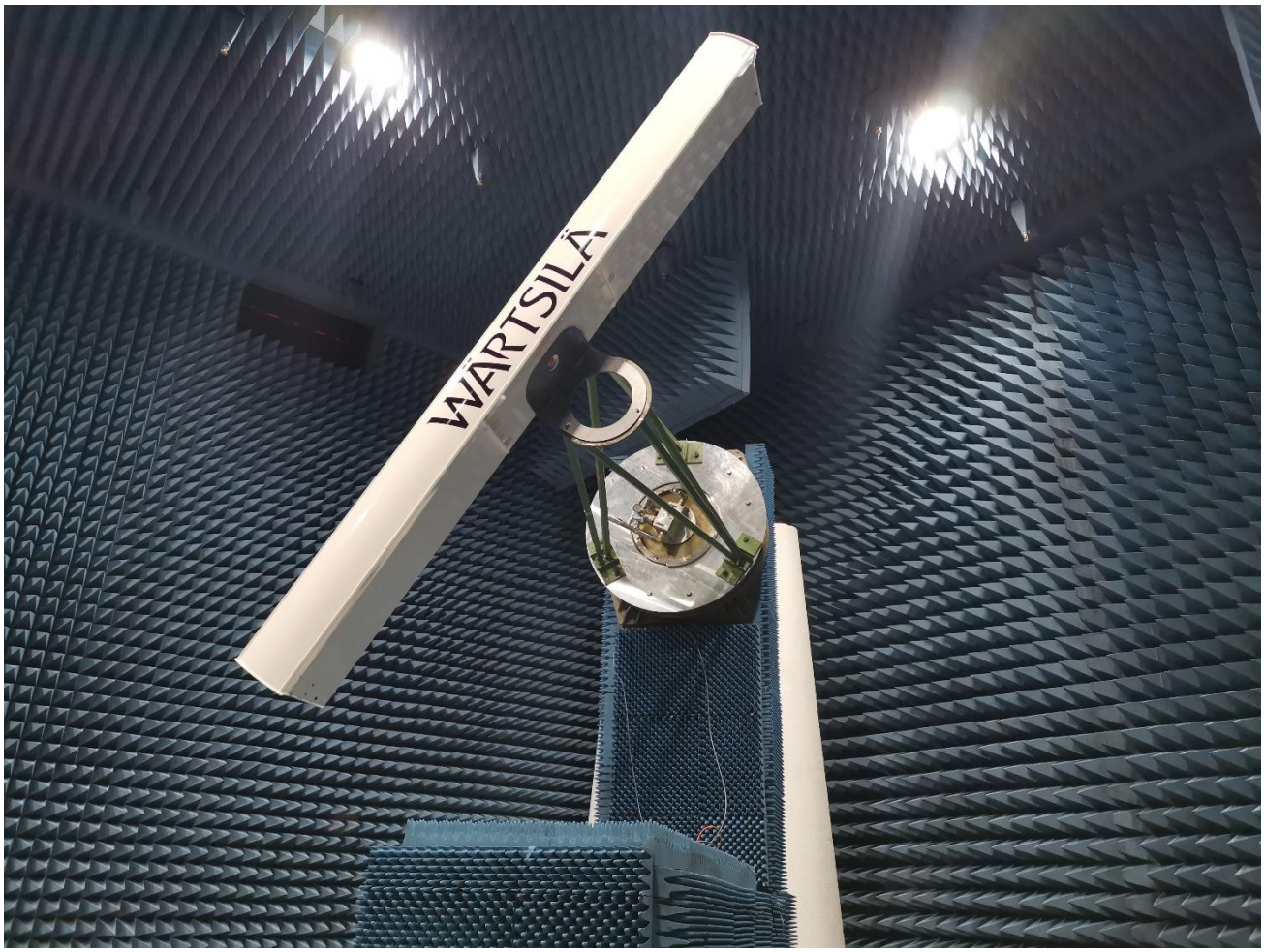

FIGURE 3 ANTENNA MOUNTED ON POSITIONER IN COMPACT RANGE TEST FACILITY

4.1 Contact person at Wärtsilä SAM

Kai Hanisch (Radar Technology, Navigation, Communication and Smart Sensors, WSAM Hamburg)

kai.hanisch@wartsila.com

Phone +49 40 8825 2937

4.2 System Operating Frequencies

The operating frequencies of the Wärtsilä SAM S-Band Solid State Radar transceiver are described in the table below.

Channel	Center Frequency / MHz	Short Pulse / MHz	Medium + Long Pulse /MHz
1	2930	2910	2950
2	2950	2930	2970
3	2970	2950	2990
4	2990	2970	3010
5	3010	2990	3030
6	3030	3010	3050
7	3050	3030	3070
8	3070	3050	3090

TABLE 3 SYSTEM OPERATING FREQUENCIES

5 Test Procedure

23-04-2020

Elevation scan at -5° azimuthal offset, first 360° azimuth scan
08:31:49 >> Creating: C:\wartsilla\data\Elevation_3.dat
08:57:04 >> Creating: C:\wartsilla\data\az _14.dat

Rotate ROLL axis 180° (antenna upside down) for verification, expect “mirrored” result
09:20:30 >> Creating: C:\wartsilla\data\az _15.dat

Gain measurement (maximum search) over frequency at various azimuth angles
10:35:43 >> Creating: C:\wartsilla\data\freq_sw_5.6°_AUT_S_1.dat
10:36:55 >> Creating: C:\wartsilla\data\freq_sw_6.6°_AUT_S_1.dat
10:38:33 >> Creating: C:\wartsilla\data\freq_sw_8.1°_AUT_S_1.dat
10:39:41 >> Creating: C:\wartsilla\data\freq_sw_5.1°_AUT_S_1.dat
10:40:41 >> Creating: C:\wartsilla\data\freq_sw_4.1°_AUT_S_1.dat
10:41:28 >> Creating: C:\wartsilla\data\freq_sw_3.1°_AUT_S_1.dat

Standard Gain Horn (S-Band) Reference Measurement
10:47:17 >> Creating: C:\wartsilla\data\freq_sw_SGH_3.dat
10:48:07 >> Creating: C:\wartsilla\data\freq_sw_SGH_4.dat (Repeat)

Standard Gain Horn (X-Band, Model 12-8.2) Reference Measurement
12:11:17 >> Creating: C:\wartsilla\data\freq_sw_SGH_X_2.dat

3rd Harmonic Gain Measurement, Maximum search at bore sight
12:15:08 >> Creating: C:\wartsilla\data\freq_sw_AUT_X_2.dat

3rd Harmonic Gain Measurement, Maximum search at -5.1° LOAZ offset
12:16:28 >> Creating: C:\wartsilla\data\freq_sw_5.1°_AUT_X_1.dat

3rd Harmonic Gain Measurement, Maximum search at -2.5° LOAZ offset
12:17:39 >> Creating: C:\wartsilla\data\freq_sw_2.5°_AUT_X_1.dat
12:20:38 >> Creating: C:\wartsilla\data\freq_sw_2.5°_AUT_X_2.dat (repeat, higher resolution)

24-4-2020

Standard Gain Horn (C-Band, Model SA 12-5.8) Reference Measurement
07:01:32 >> Creating: C:\wartsilla\data\freq_sw_SGH_C_3.dat

2nd Harmonic Gain Measurement, Maximum search at -5.1° LOAZ axis offset
07:10:02 >> Creating: C:\wartsilla\data\freq_sw_5.1°_aut_C_1.dat

2nd Harmonic Gain Measurement, Maximum search at bore sight
07:10:58 >> Creating: C:\wartsilla\data\freq_sw_aut_C_1.dat
07:13:51 >> Creating: C:\wartsilla\data\freq_sw_aut_C_2.dat (Repeat, higher resolution)

Elevation scan at -6.6° azimuthal offset (S-Band)
09:27:14 >> Creating: C:\wartsilla\data\Elevation_6.6°_1.dat

Elevation scan at -5.1° azimuthal offset (S-Band)
09:31:20 >> Creating: C:\wartsilla\data\Elevation_5.1°_1.dat

Elevation scan at -4.1° azimuthal offset (S-Band)
09:34:55 >> Creating: C:\wartsilla\data\ Elevation_4.1°_1.dat

Elevation scan at -3.1° azimuthal offset (S-Band)
09:38:16 >> Creating: C:\wartsilla\data\ Elevation_3.1°_1.dat

6 Test Results

Test case	Reference IEC62388 Ed. 2	Value	Limit	Remark	Result
Antenna gain		26,7 dBi - 28,2 dBi		For reference	%
Vertical radiation pattern	6.10.2	> (+/- 10°)	+/- 10° (min.)		passed
Horizontal radiation pattern	6.10.3	1,77° - 1,88°	2° / -3 dBn (max.)		passed
Horizontal radiation pattern	6.10.3	see 6.3	10° / -20 dBn (max.)		passed
Antenna sidelobes	6.10.4	see 6.4	-23 dBc / within +/- 10° (max.)		passed
Antenna sidelobes	6.10.4	see 6.4	-30 dBc / outside +/- 10° (max.)		passed
Antenna gain at 2nd Harmonic		+5 dBi (max.)		For reference	%
Antenna gain at 3rd Harmonic		+15 dBi (max.)		For reference	%

TABLE 4 TEST RESULTS SUMMARY

6.1 Antenna Gain at In Band Frequencies

For reference only.

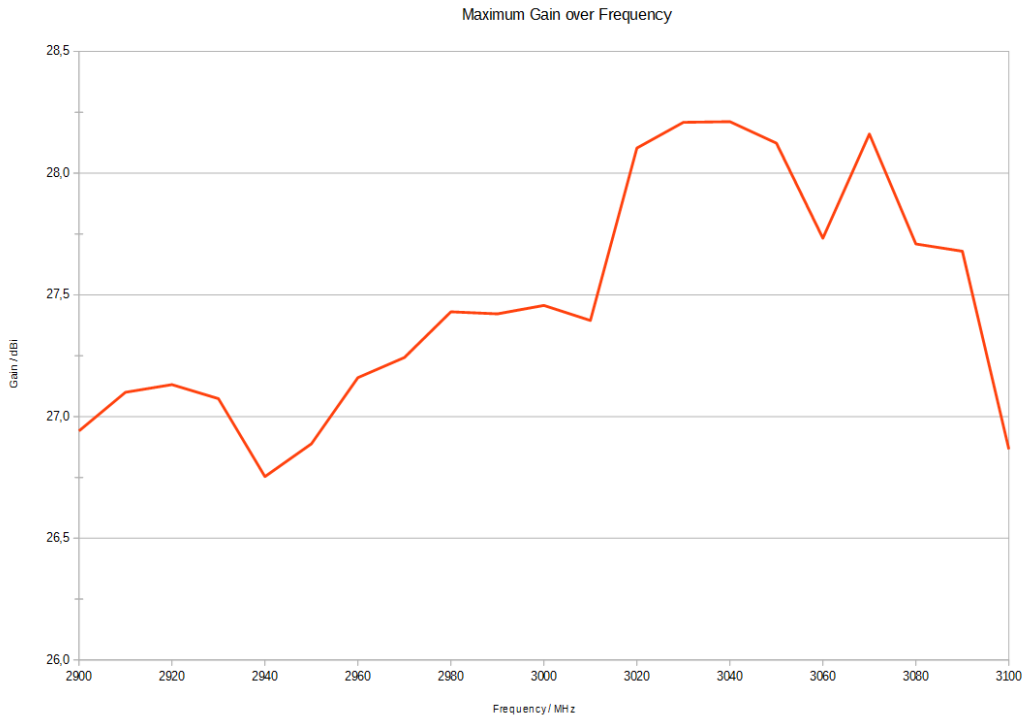

FIGURE 4 ANTENNA GAIN AT 1ST HARMONIC

6.2 3 dB Opening Angle, Azimuth

6.10.3 Antenna horizontal pattern

6.10.3.1 Requirements

The X-band radar shall be capable of operating in a horizontally polarised mode. The far field horizontal pattern for an X-band antenna shall be measured at the upper and lower operational frequencies, as specified by the manufacturer. The measurements provide a performance check at the frequency extremes. The limits of the horizontal beam pattern specified in Table 7 shall be met. The figures relate to one way propagation. The limits in Table 7 shall also apply to an S-band antenna.

Table 7 – Main horizontal beam pattern

Power relative to maximum of main beam dB	Maximum total beam width X-band degrees (°)	Maximum total beam width S-band degrees (°)
–3	2	2
–20	10	10

6.10.3.2 Methods of test and required results

The methods of test and the required results are as follows:

a) confirm by document inspection that horizontal polarisation is available on X-band systems and record any alternative polarisation(s) that may be selected;

b) confirm by measurement in all polarisation modes that the horizontal beam limits given in Table 7 are met at the upper and lower operational frequencies;

c) verify that for the smallest radar antenna, including any design using new technology, meets the bearing discrimination requirement in 6.8.4.

Compliance for alternative tests of meeting the above requirements may be demonstrated by measurements of the antenna radiation pattern and submission of test data documenting the required results. Providing it can be demonstrated that the radar system meets the bearing discrimination requirements of 6.8.4, alternative processing may be used to permit a broader horizontal antenna beam width.

Requirement: Maximum total beam width of 2° at -3 dB power relative to maximum of main beam. Maximum total beam width of 10° at -20 dB power relative to maximum of main beam.

Note: Frequencies outside the used band are shown for information only. Frequency steps do not depict the actual frequency channels used in the system due to the measurement setup. Information about the opening angles at the actual channel frequencies can be derived by interpolation.

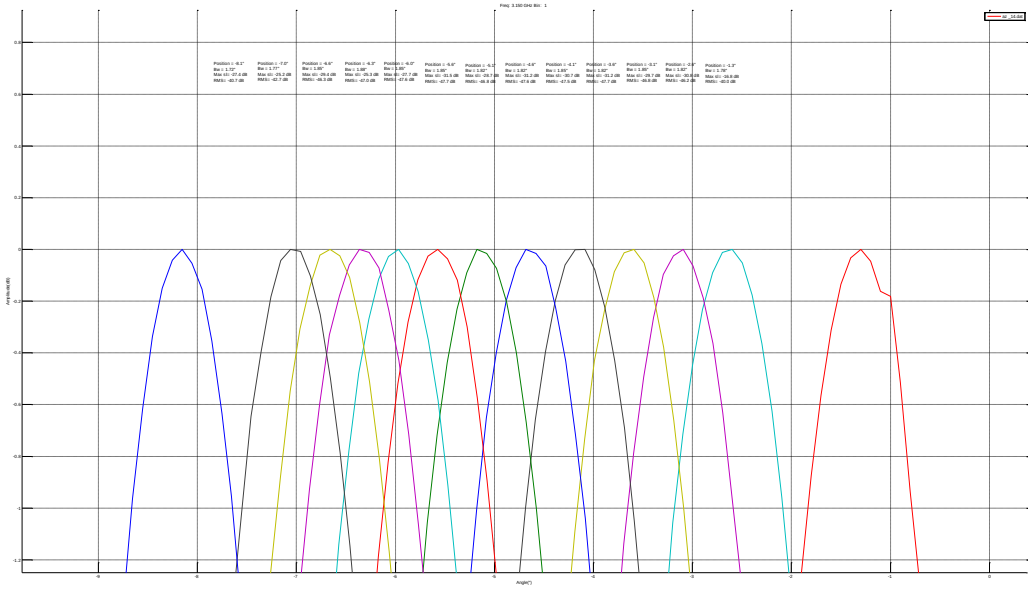

FIGURE 5 PLOT OF 3 DB OPENING ANGLES AT IN BAND FREQUENCIES

Frequency / MHz	3dB opening angle / °	Squint angle / °	Result
2900	1,82	-2,6	passed
2920	1,85	-3,1	passed
2940	1,82	-3,6	passed
2960	1,85	-4,1	passed
2980	1,82	-4,6	passed
3000	1,82	-5,1	passed
3020	1,85	-5,6	passed
3040	1,85	-6	passed
3060	1,88	-6,3	passed
3080	1,85	-6,6	passed
3100	1,77	-7	passed

TABLE 5 3 DB OPENING ANGLE AT IN BAND FREQUENCIES

6.3 3 dB Opening Angle, Elevation

6.10 Radar antenna (including pitch and roll)

6.10.1 General

The radar antenna is fundamental to the radar performance and shall be tested to provide information for specific tests required within this standard.

6.10.2 Vertical radiation pattern/pitch and roll

6.10.2.1 Requirements

(MSC.192/5.6) *The target detection performance of the equipment* shall *not be substantially impaired when own ship is rolling or pitching up to ± 10°*.

The vertical radiation pattern shall be designed to permit the pitch and roll of a ship without undue loss of performance, while providing a main beam pattern to limit degradation in performance due to nearby structures and to reduce the illumination of precipitation.

Providing that the radar system meets the rolling and pitching requirements, alternative methods may be used to permit a narrower vertical antenna beam width. However, the detection performance, bearing accuracy and bearing discrimination shall then be evaluated in the same conditions of ship motion.

6.10.2.2 Methods of test and required results

The methods of test and the required results are as follows:

a) confirm by measurement, the vertical radiation pattern (one way) of the radar antenna, measured either in the far field region or in a region that can be referenced to it. The measurement shall be carried out at the upper and lower frequency band declared by the manufacturer. The vertical plots shall be recorded;

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b) confirm by document inspection of the measured result in a), that the –3 dB beam width encompasses ± 10° in elevation.

c) compliance of alternative methods shall be demonstrated by measurements of the antenna radiation pattern at the upper and lower frequency band declared by the manufacturer and submission of test evidence documenting that requirements for detection performance, bearing accuracy and bearing discrimination are achieved in dynamic conditions with the specified rolling and pitching ship motion and that a warning alert to the operator is provided of a degradation in performance of the alternative methods implemented.

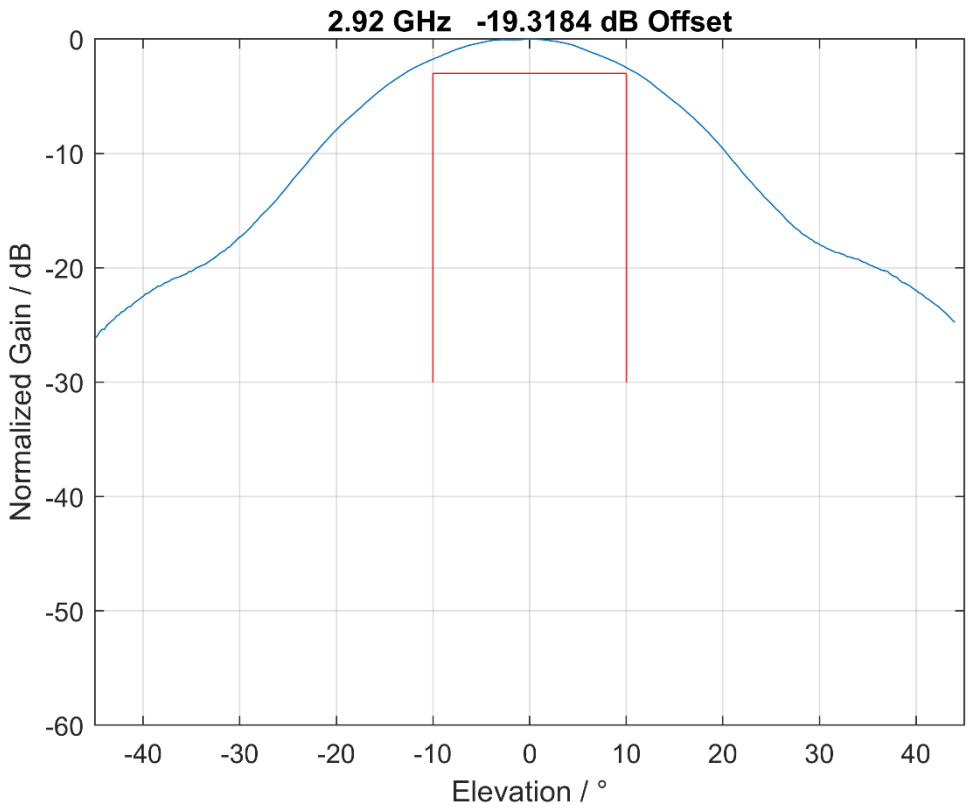

FIGURE 6 ELEVATION OPENING ANGLE, 3.1° OFFSET

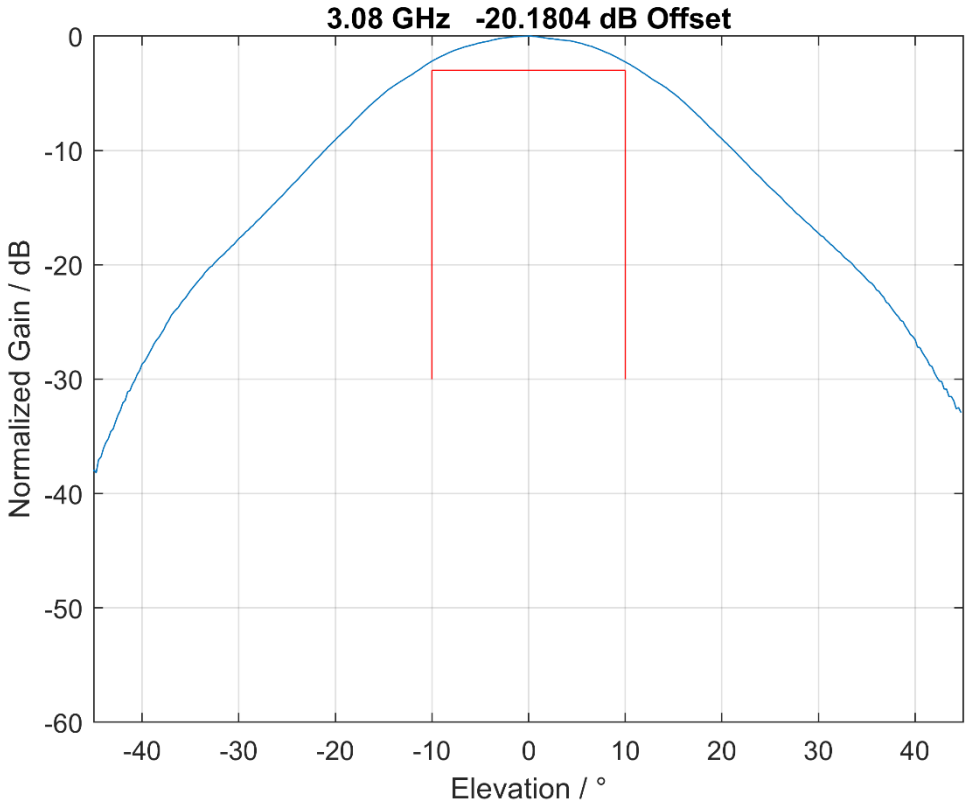

FIGURE 7 ELEVATION OPENING ANGLE, 6.6° OFFSET

Frequency / MHz	Result
2920	passed
3080	passed

TABLE 6 ELEVATION 3DB OPENING ANGLE; RESULTS

According to the requirements, only the lower and upper frequencies of the used band are relevant to determine compliance.

6.4 Azimuth Sidelobes

6.10.4 Antenna side lobes

6.10.4.1 Requirements

(MSC.192/7.4.3) *The antenna side lobes* shall *be consistent with satisfying the system performance as defined in this standard.*

As far as is practical, the design shall minimise the antenna side lobes. The measured side lobes shall be within the limits defined in Table 8.

Table 8 – Effective side-lobes

Position relative to maximum of main beam degrees (°)	**Maximum power relative to maximum of main beam** dB
Within ± 10	*– 23*
Outside ± 10	*– 30*

6.10.4.2 Methods of test and required results

The far-field horizontal radiation pattern of the radar antenna shall be determined either by direct measurement in the far field or by transforming an intermediate range measurement in the far field. This test shall be carried out at the upper and lower operating radio frequency limits of the nominal radio frequency declared by the manufacturer:

a) confirm by measurement that the far field horizontal radiation pattern conforms to Table 8, noting that the figures relate to one-way propagation only. The measured horizontal pattern (plot) of the antenna shall be recorded in the test report;

b) confirm by analytical evaluation that no significant side lobes exceed the limits defined in Table 8. The antenna horizontal radiation pattern shows the relative response of the antenna plotted against angular displacement in the horizontal plane. A significant side-lobe is defined as any positive excursion from the monotonically decreasing main beam pattern of more than 2 dB.

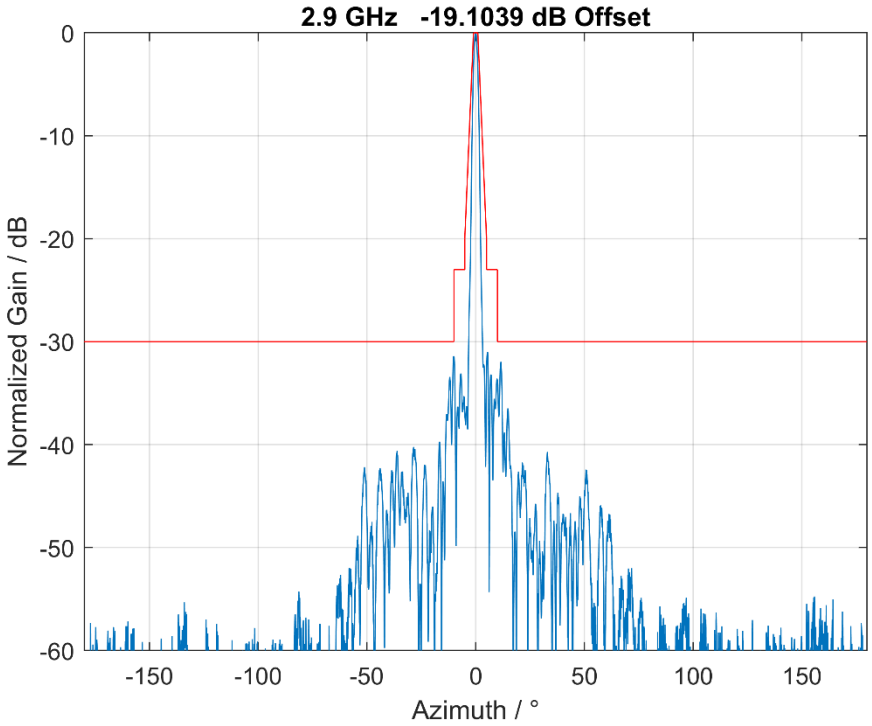

FIGURE 8 PLOT OF AZIMUTH SIDELOBES

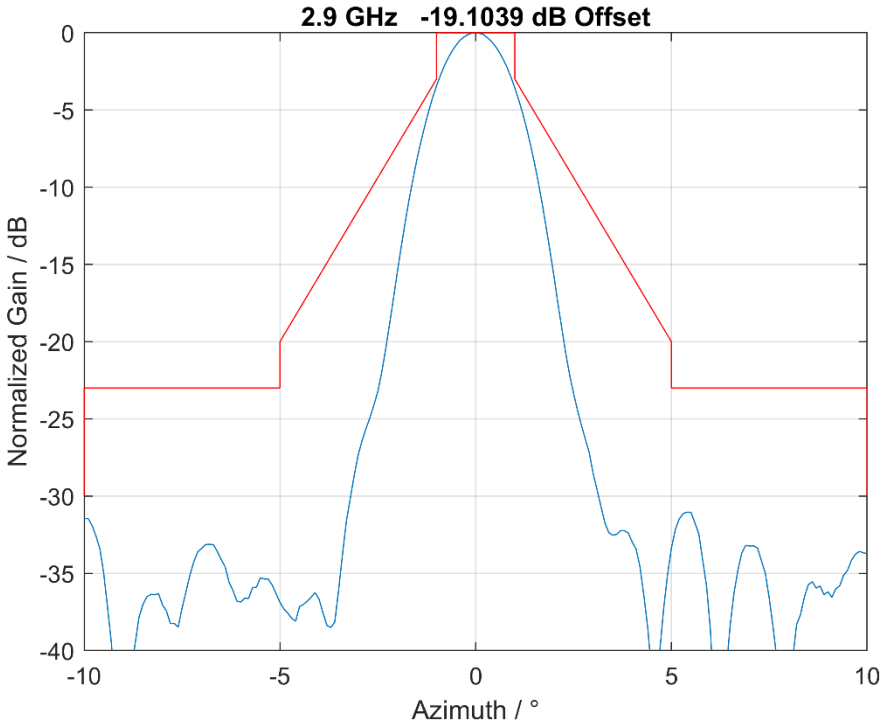

FIGURE 9 PLOT OF AZIMUTH SIDELOBES; DETAIL

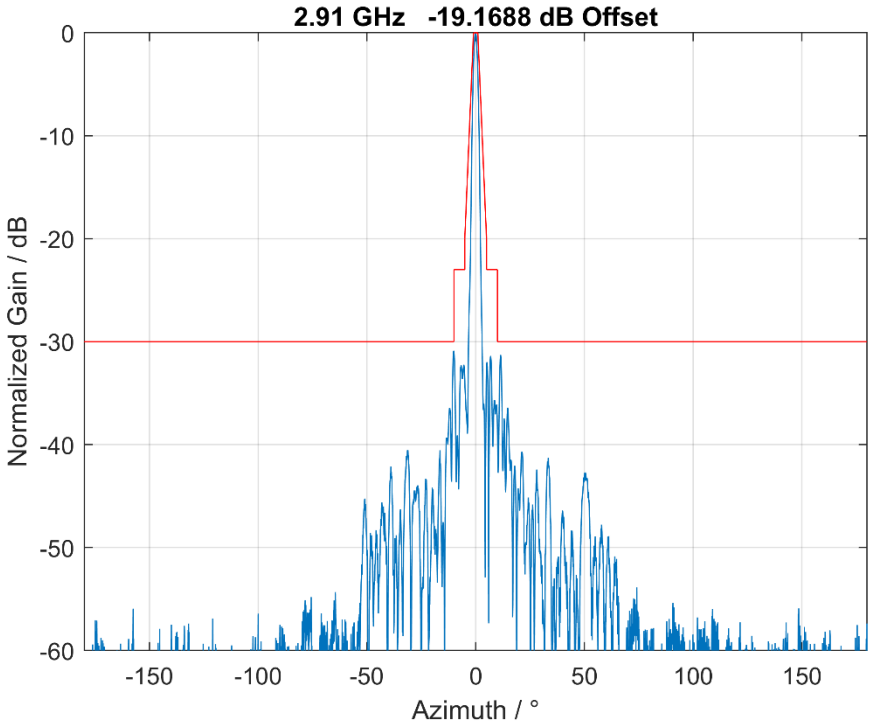

FIGURE 10 PLOT OF AZIMUTH SIDELOBES

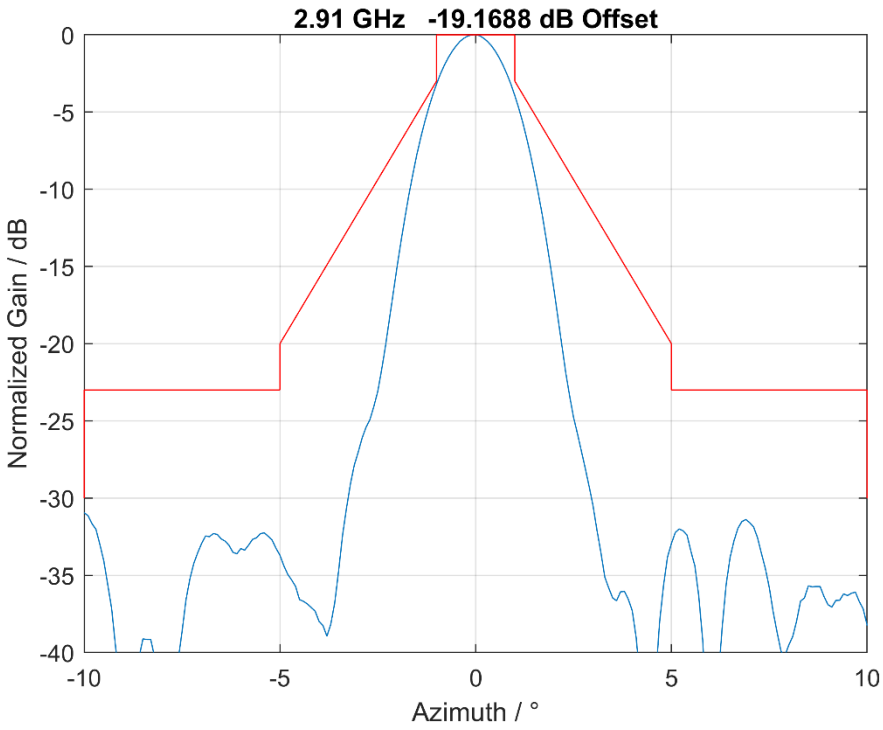

FIGURE 11 PLOT OF AZIMUTH SIDELOBES; DETAIL

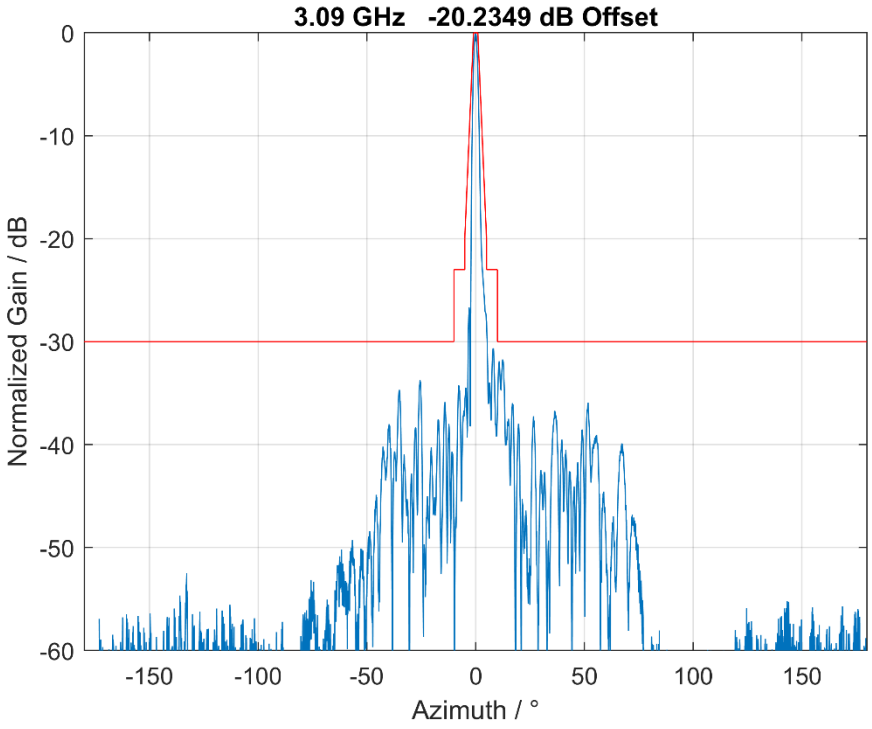

FIGURE 12 PLOT OF AZIMUTH SIDELOBES

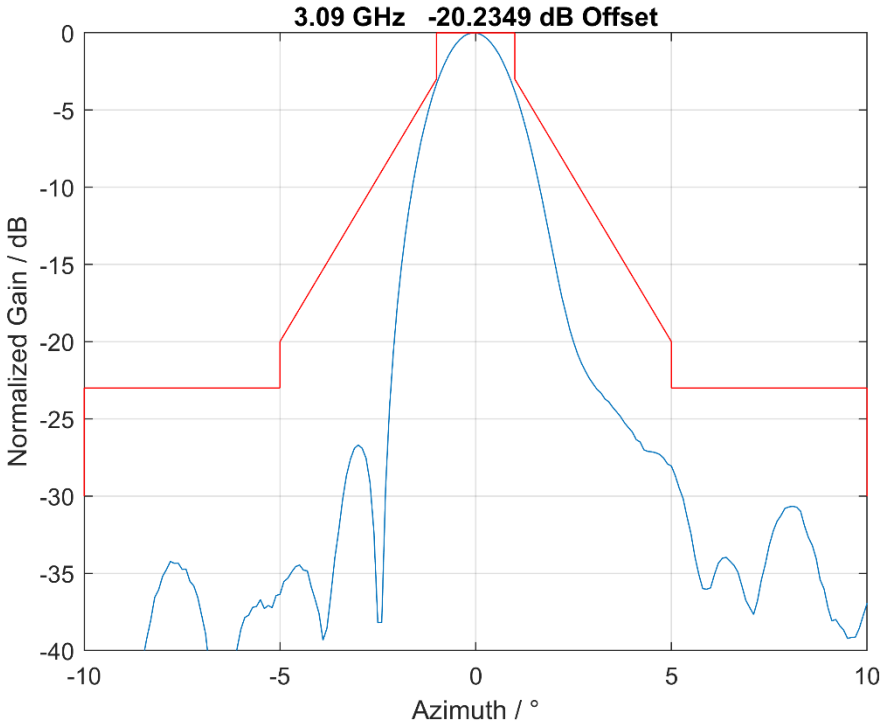

FIGURE 13 PLOT OF AZIMUTH SIDELOBES; DETAIL

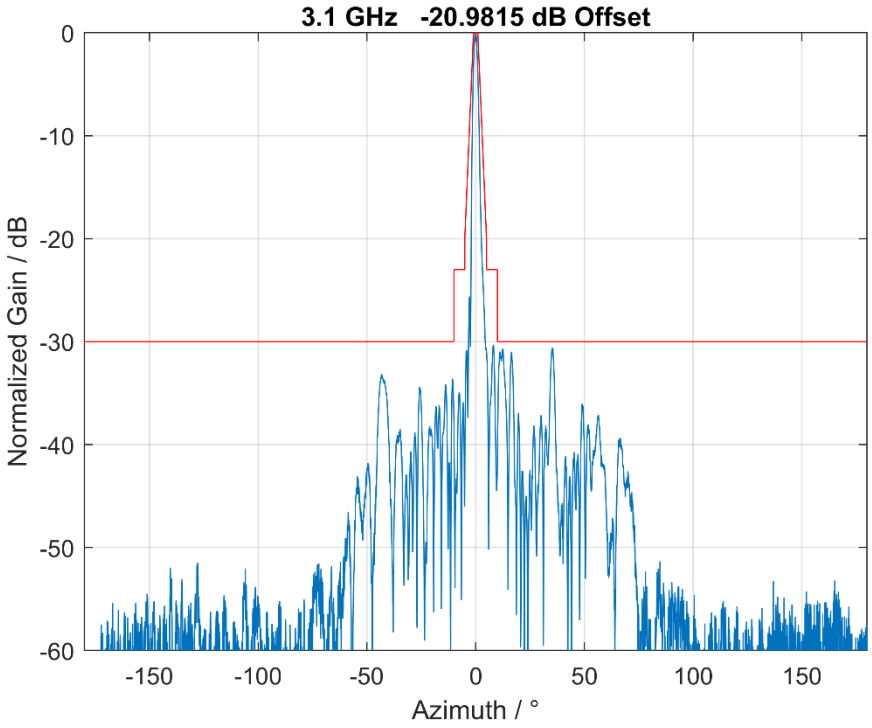

FIGURE 14 PLOT OF AZIMUTH SIDELOBES

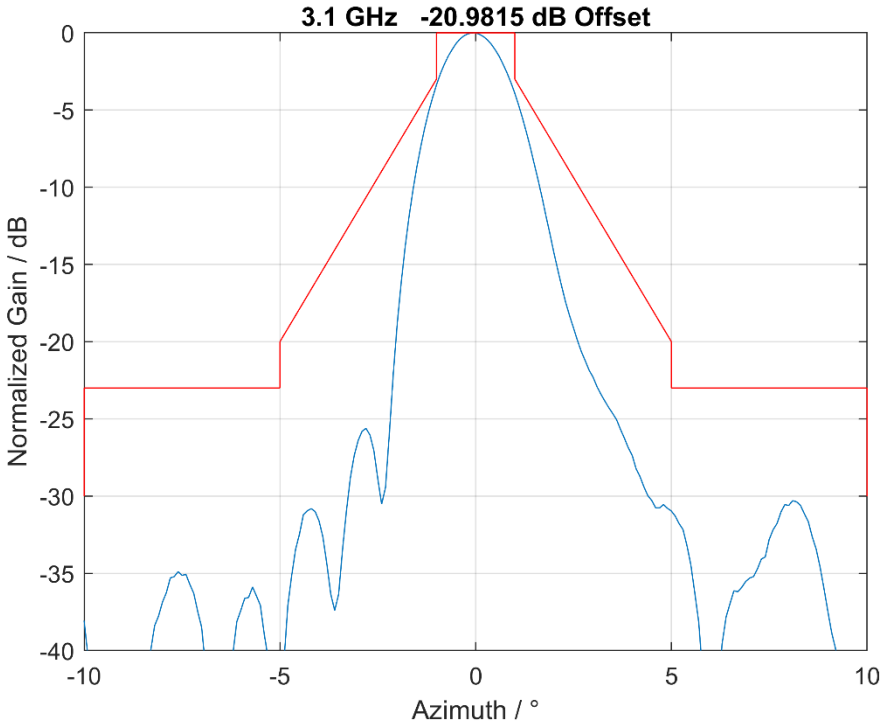

FIGURE 15 PLOT OF AZIMUTH SIDELOBES; DETAIL

Frequency / MHz	Result
2900	passed
2910	passed
3090	passed
3100	passed

TABLE 7 AZIMUTH SIDELOBE PERFORMANCE; RESULTS

According to the requirements, only the lower and upper frequencies of the used band are relevant to determine compliance.

6.5 Second Harmonic Antenna Gain (5.8 GHz to 6.2 GHz)

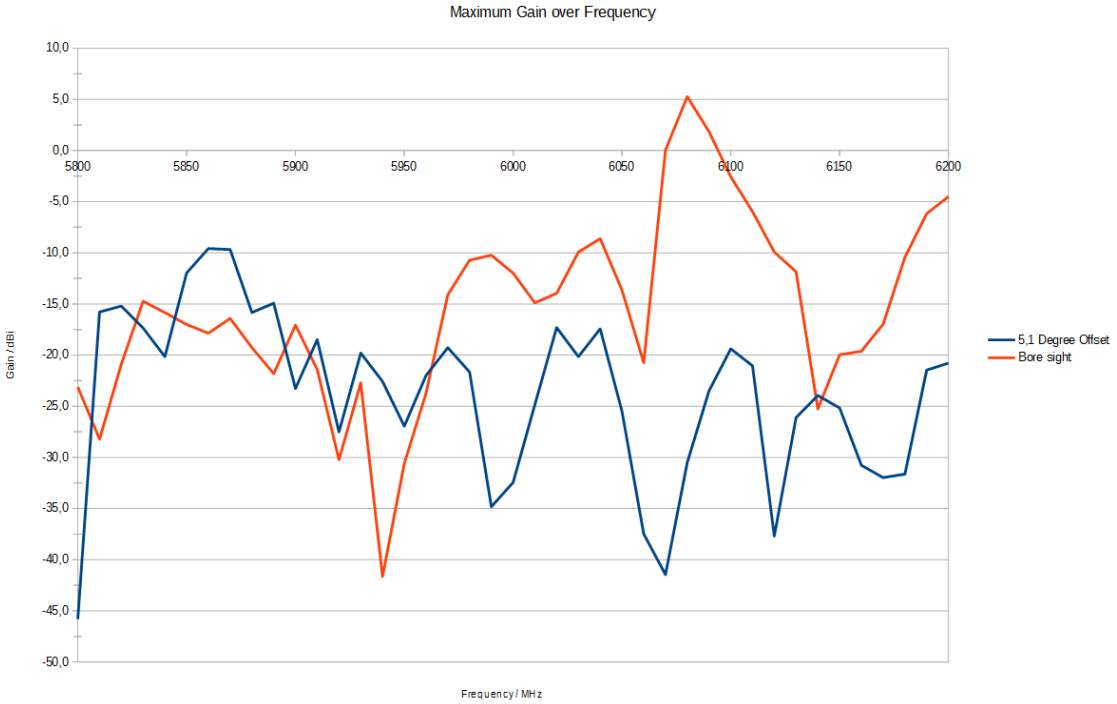

FIGURE 16 MAXIMUM GAIN OVER FREQUENCY, 2ND HARMONIC

6.6 Third Harmonic Antenna Gain (8.7 GHz to 9.3 GHz)

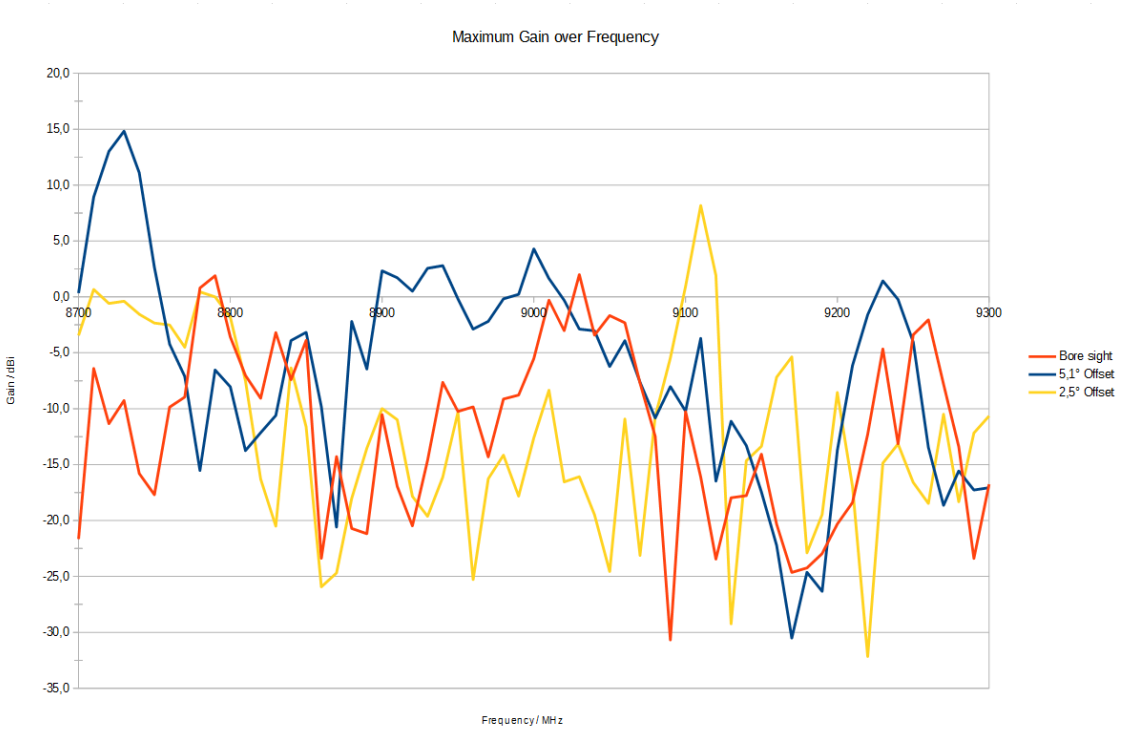

FIGURE 17 MAXIMUM GAIN OVER FREQUENCY, 3RD HARMONIC

6.7 Standard Gain Horn Reference Data

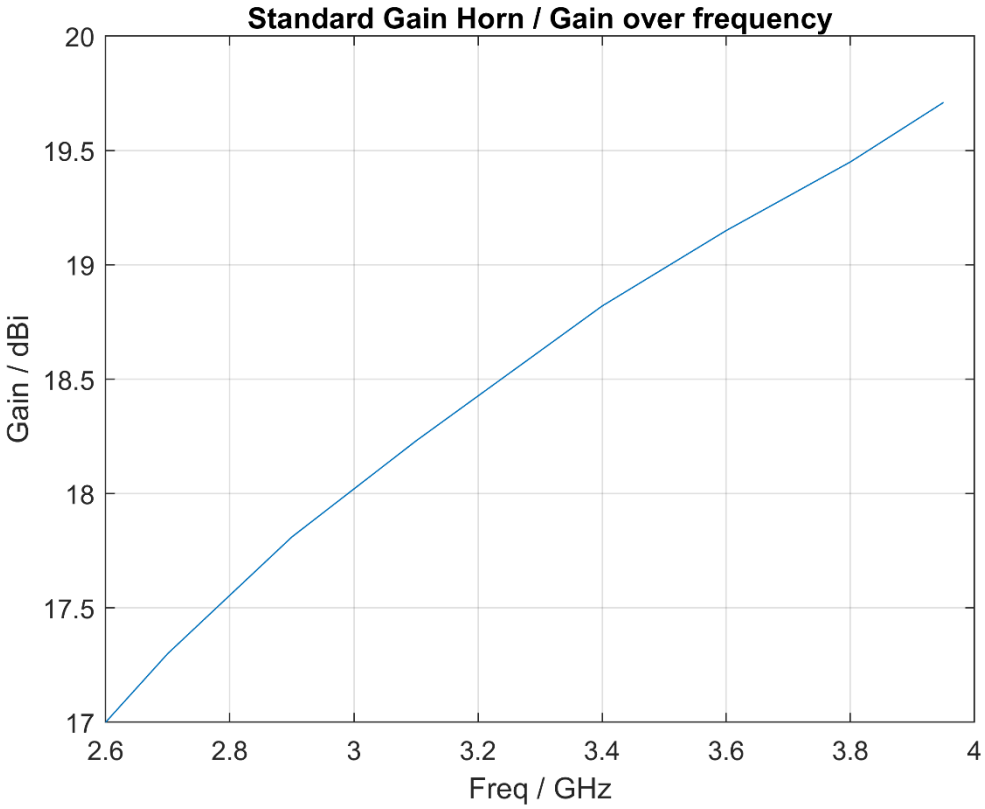

FIGURE 18 S-BAND GAIN HORN, GAIN OVER FREQUENCY

Calibration data. For reference only.

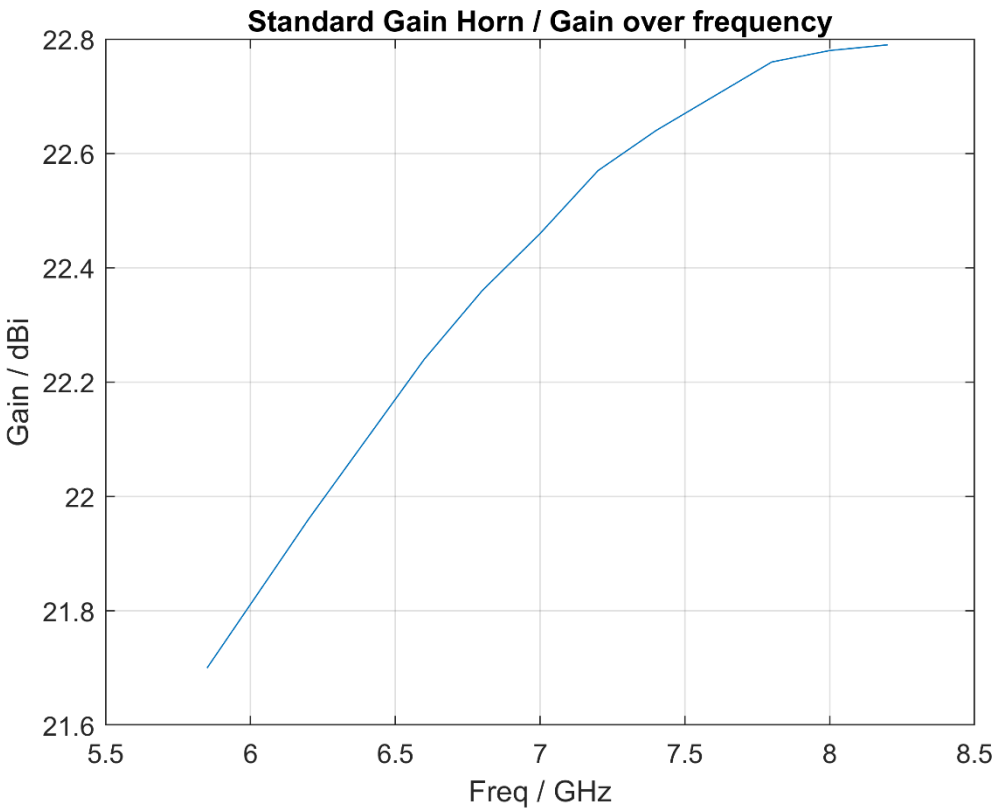

FIGURE 19 C-BAND GAIN HORN, GAIN OVER FREQUENCY

Calibration data. For reference only.

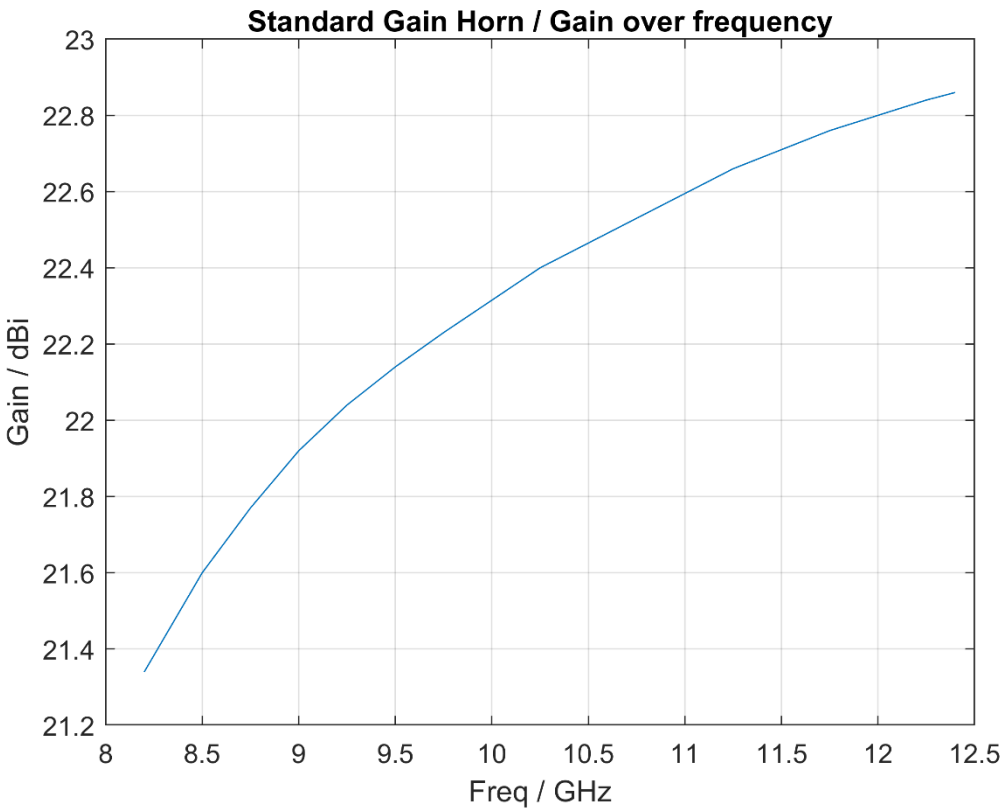

FIGURE 20 X-BAND GAIN HORN, GAIN OVER FREQUENCY

Calibration data. For reference only.