Technical Report:

Topographical Analysis of Proposed Aletta Wind Farm

Work done for: BioTherm Energy

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Document Approval

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Document History

Revision	Date of Issue	Comments
DRAFT	27 March 2015	Report (#BIO/AL/15/03/27/DRAFT)
REV0	08 April 2015	Report (#BIO/AL/15/03/27/REV0)
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Executive Summary

MESA Solutions was asked by BioTherm Energy to do a topographical analysis of the terrain profile between the Aletta wind farm and the SKA closest and core-site telescopes.

- An equivalent emission level that is 10 dB below the SKA threshold (SARAS) limit was defined. This level can be verified through measurements.
- The maximum allowed emission level is related to the well-known CISPR 11/22 Class B standard.
- The total path loss is a function of topography and frequency, as well as characteristics such as the transmitter and receiver heights.
- SPLAT! propagation results show that at lower frequencies emissions below CISPR are required in the case of the closest telescope. This is mainly due to the absence of any terrain loss over this short distance.
- Towards the core site the allowable measured levels increase slightly due to additional terrain loss.
- The possibility exists that the overall lower levels would have to be achieved to limit interference to the closest telescopes.

Contents

Nomenclature

AGA	Astronomy Geographic Advantage
DEM	Digital Elevation Model
FSPL	Free Space Path Loss
ITM	Irregular Terrain Model
ITWOM	Irregular Terrain With Obstruction Model
KAT	Karoo Array Telescope
SARAS	South African Radio Astronomy Services
SKA	Square Kilometre Array
SKA-SA	Square Kilometre Array South Africa
SPLAT	Signal Propagation, Loss And Terrain - Analysis Tool
TL	Terrain Loss
TPL	Total Path Loss

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1 Introduction

MESA Solutions was asked by BioTherm Energy to do a topographical analysis of the terrain profile between the Aletta Wind Farm plant and the Square Kilometre Array (SKA) closest and core-site telescopes. The wind farm is situated in the vicinity of the Karoo Central Astronomy Advantage Areas. These areas are protected against unwanted electromagnetic interference (EMI) under the Astronomy Geographic Advantage (AGA) Act [1] for the purpose of radio astronomy and related scientific endeavors. This currently includes the SKA. From the terrain evaluation we are able to determine what influences, if any, natural topographical features will have on the total expected propagation attenuation based on the location of the site. This determines the maximum allowable emission levels which the facility may generate in order to still comply with SKA threshold limits as specified by SARAS (South African Radio Astronomy Services) in [1]. The Aletta wind farm's proximity to the closest and core-site SKA telescopes are shown in Figs. 1 and 2, respectively. Also included in each figure is a basic elevation profile over the specified distance. Characteristics such as separation distance, transmitter height, and azimuth angle are given in Table 1.

It is important to note that the findings from this assessment is for the client's own edification, and will be taken into account by the SKA during its own propagation analysis. It is therefore not meant to supersede any investigation done by the SKA or relevant RFI working groups.

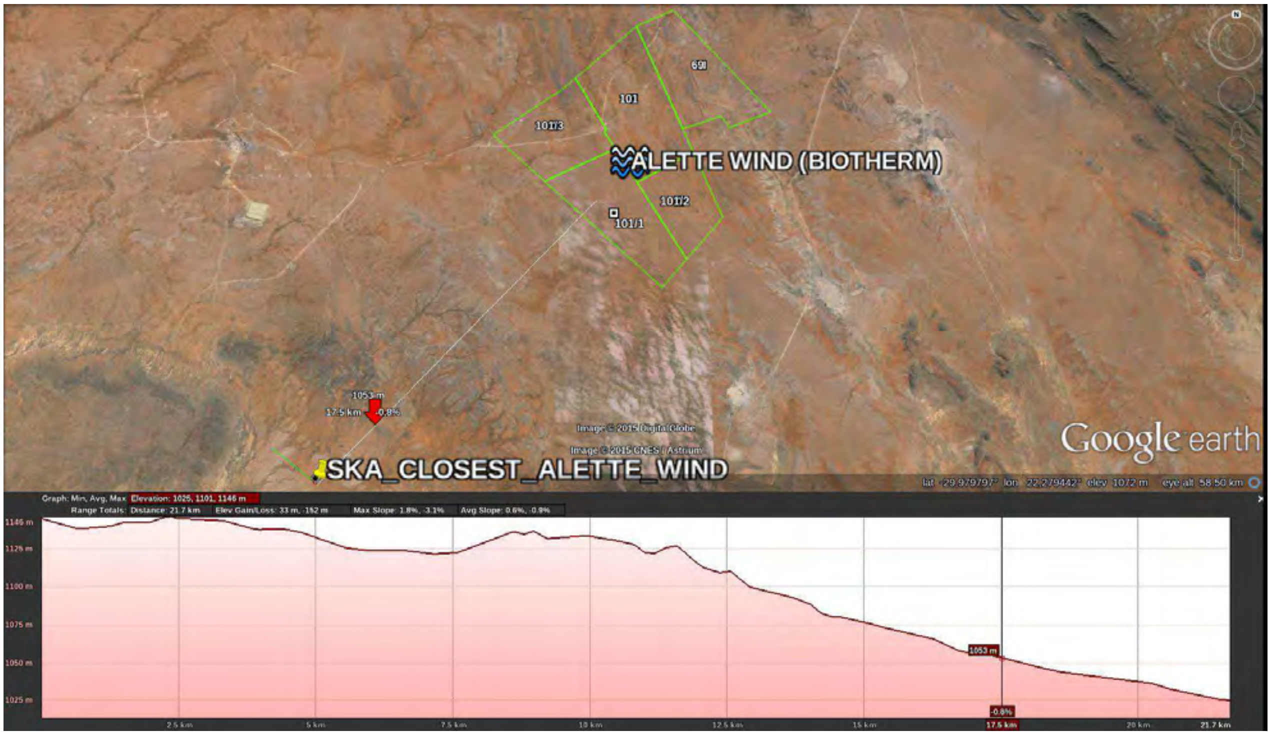

Figure 1: Google Earth location and elevation profile of Aletta Wind toward closest SKA telescope.

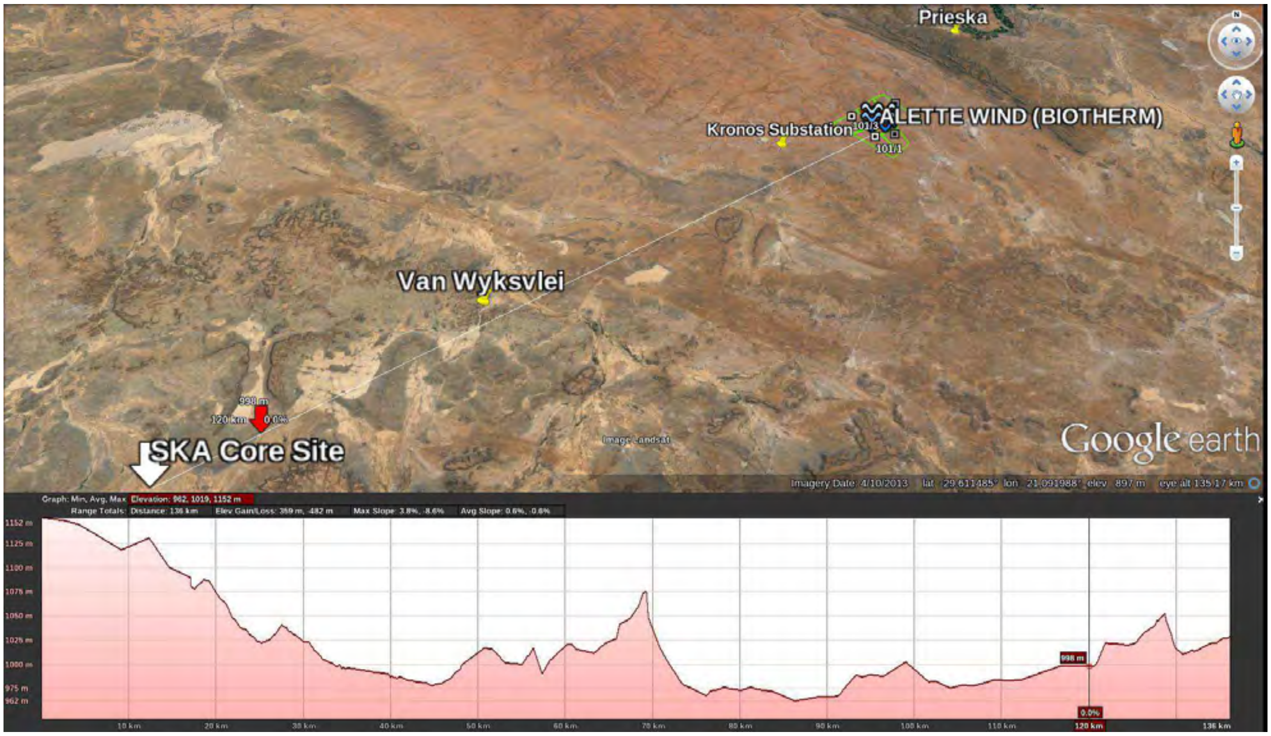

Figure 2: Google Earth location and elevation profile of Aletta Wind toward SKA core site.

Aletta Wind	**SKA Core Site**	**Closest Telescope**
Distance	135.62 km	23.92 km
Azimuth	235.66 ^{o}	223.15 ^{o}
Wind Tx Height	120 m	120 m
SKA Rx Height	15 m	15 m

Table 1: Specifications of Aletta wind farm relative to the SKA core and closest telescopes.

2 Topographical Analysis using SPLAT!

The default propagation analysis software used by MESA Solutions is called SPLAT!, which is a **S**ignal **P**ropagation, **L**oss **A**nd **T**errain analysis tool based on the *Longley-Rice Irregular Terrain Model (ITM)*, as well as the *Irregular Terrain With Obstructions Model (ITWOM 3.0)*. The software takes into account actual terrain elevation data to ultimately predict the total path loss (TPL) between a transmitter and a receiver. As part of the analysis, certain assumptions are made regarding the source characteristics. For this investigation the various parameters defining the SPLAT! propagation model are listed in Table 2. The digital elevation model (DEM) makes use of 3-arc-second (90 m) elevation resolution data.

For this investigation, the frequency range of interest are defined from 100 MHz to 3 GHz. While the upper frequency limit of the standard in [2] are specified to at least 10 GHz, the span is limited to what is practically measurable and representative of the majority of expected interference. In the analysis the allowable SKA radiation limit defined by SARAS in [1], including an additional 10 dB safety margin, are used as the reference level. This defines the maximum allowable level of radiated interference than can be tolerated at the telescope.

This maximum level, which is given as a power spectral density (PSD) in dBm/Hz, is compensated for by the TPL as predicted by SPLAT!, to provide an equivalent PSD associated with the closest and core-site telescopes. This PSD for each case is then converted to an equivalent electric field (E-field) as measured at either 10 m (frequency $<$ 1 GHz) or 3 m (frequency $>$ 1 GHz) away from the plant. The 3 and 10 m separation distances is in accordance with measurement specifications defined in the latest international special committee on radio interference's (CISPR) 11/22 Class B standard. This standard is used for reference purposes as it is internationally know and used for industry qualification. This calculation is done for a number of representative frequencies within the band of interest and defines an E-field upper limit which the plant is allowed to radiate without exceeding emission limits at the two telescope locations. Ultimately, conformance of the plant can then be determined by comparing representative measured results to the calculated levels provided.

SPLAT! Analysis Parameters

	Aletta Wind Farm
Frequency [MHz]	100 - 3000
Earth Dielectric Constant (Relative Permittivity [F/m])	4.000
Earth Conductivity [S/m]	0.001
Atmospheric Bending Constant	301
Radio Climate	4 (Desert)
Polarisation (Vertical=1; Horizontal=0)	1
Fraction of Time	0.05
Fraction of Situations	0.05

Table 2: SPLAT! parameters for predicted 100 MHz to 3 GHz emissions from Aletta wind farm to SKA core and closest telescope.

3 Total Path Loss

Shown in Table 3 below are the values for the free space path loss (FSPL), terrain loss (TL), and total path loss (TPL) at each of the frequencies chosen for the investigation. From the table it is clear that there is minimal contribution from the TL especially at the low frequencies. This is mainly due to the absence of any major natural obstructions between the wind farm and the SKA core site as evidence from Fig. 2. The 0 dB TL at 100 MHz is a purely mathematical limitation of the software indicating a negligible contribution at that frequency over this particular terrain.

	SKA Core Site			Closest Telescope		
Frequency	**SPLAT! FSPL**	**SPLAT! TL**	**SPLAT! TPL**	**SPLAT! FSPL**	**SPLAT! TL**	**SPLAT! TPL**
100 MHz	115.11 dB	0.0 dB	**115.11 dB**	100.04 dB	0.0 dB	**100.04 dB**
300 MHz	124.66 dB	0.0 dB	**124.66 dB**	109.58 dB	0.0 dB	**109.58 dB**
500 MHz	129.09 dB	0.0 dB	**129.09 dB**	114.02 dB	0.0 dB	**114.02 dB**
700 MHz	132.02 dB	2.93 dB	**134.94 dB**	116.94 dB	0.0 dB	**116.94 dB**
1000 MHz	135.11 dB	5.97 dB	**141.08 dB**	120.04 dB	0.0 dB	**120.04 dB**
1500 MHz	138.64 dB	9.39 dB	**148.02 dB**	123.56 dB	0.0 dB	**123.56 dB**
2000 MHz	141.13 dB	11.80 dB	**152.93 dB**	126.06 dB	0.0 dB	**126.06 dB**
2500 MHz	143.07 dB	13.67 dB	**156.74 dB**	128.00 dB	0.0 dB	**128.00 dB**
3000 MHz	144.66 dB	15.20 dB	**159.86 dB**	129.58 dB	0.0 dB	**129.58 dB**

Table 3: SPLAT! Free Space Path Loss (FSPL), Terrain Loss (TL) and Total Path Loss (TPL) for vertical polarisation Aletta Wind emissions.

4 Attenuation Coverage Maps

The coverage maps in this section gives an indication of the variation in TPL as a function of frequency. This has only been done for vertical polarisation with similar results assumed for horizontal polarisation.

4.1 Closest SKA Telescope

Shown in Figs. 3 to 10 are the attenuation maps in the direction of the closest SKA telescope.

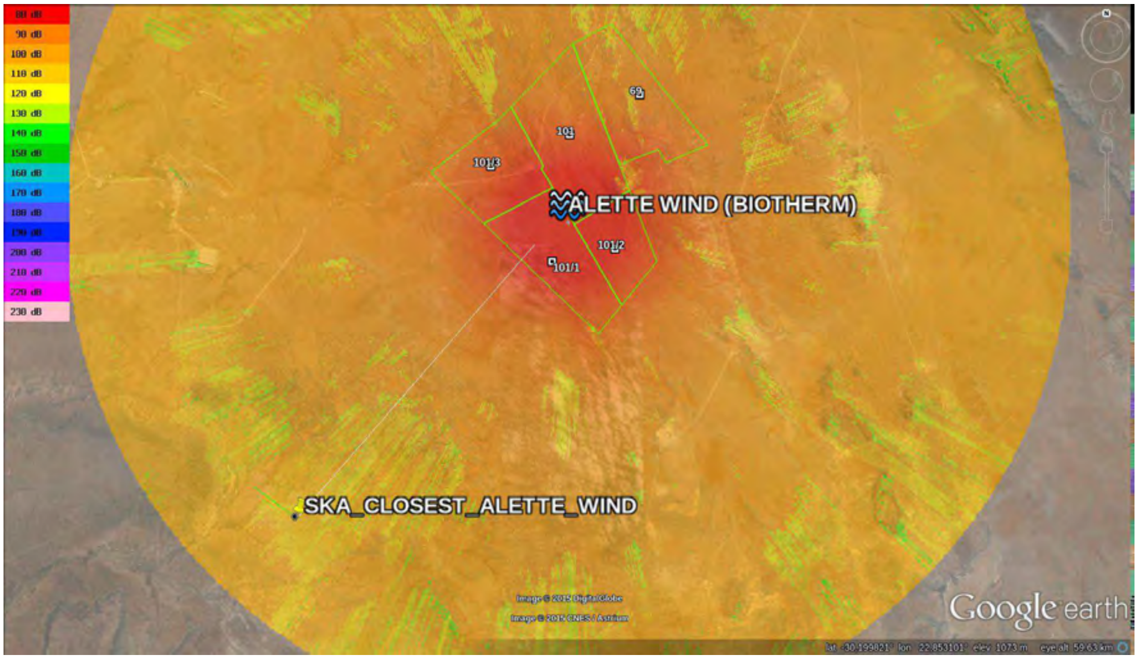

Figure 3: Attenuation map for f=100MHz from Aletta Wind to the closest SKA telescope.

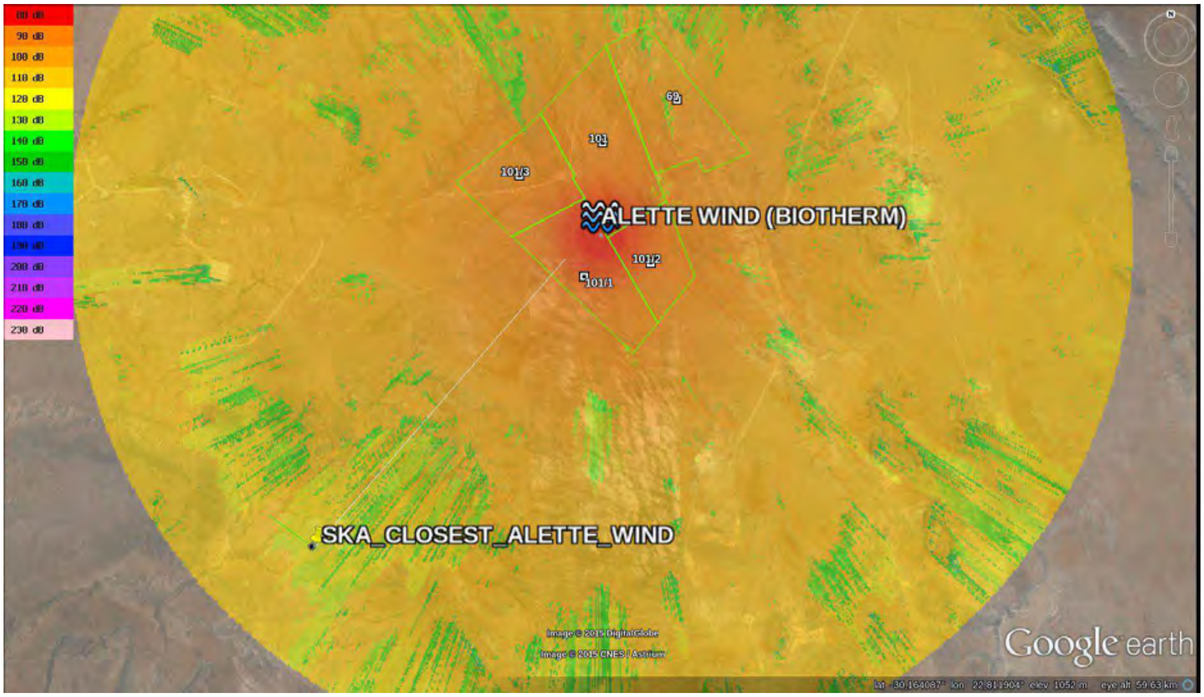

Figure 4: Attenuation map for f=300MHz from Aletta Wind to the closest SKA telescope.

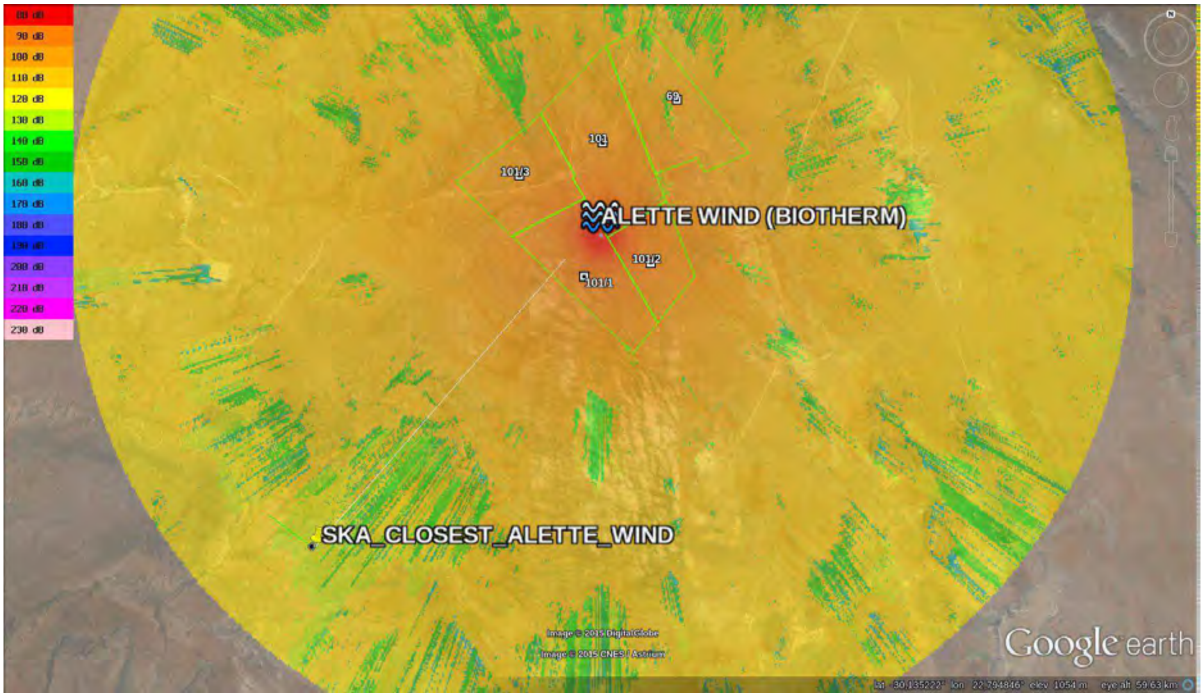

Figure 5: Attenuation map for f=500MHz from Aletta Wind to the closest SKA telescope.

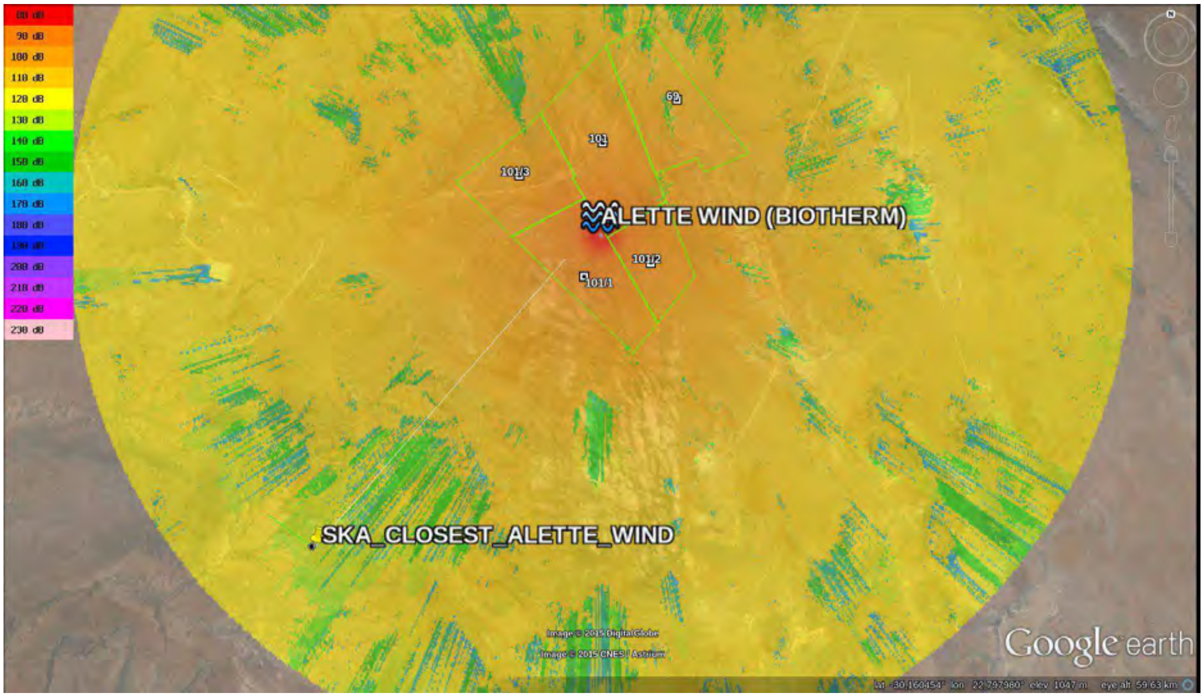

Figure 6: Attenuation map for f=700MHz from Aletta Wind to the closest SKA telescope.

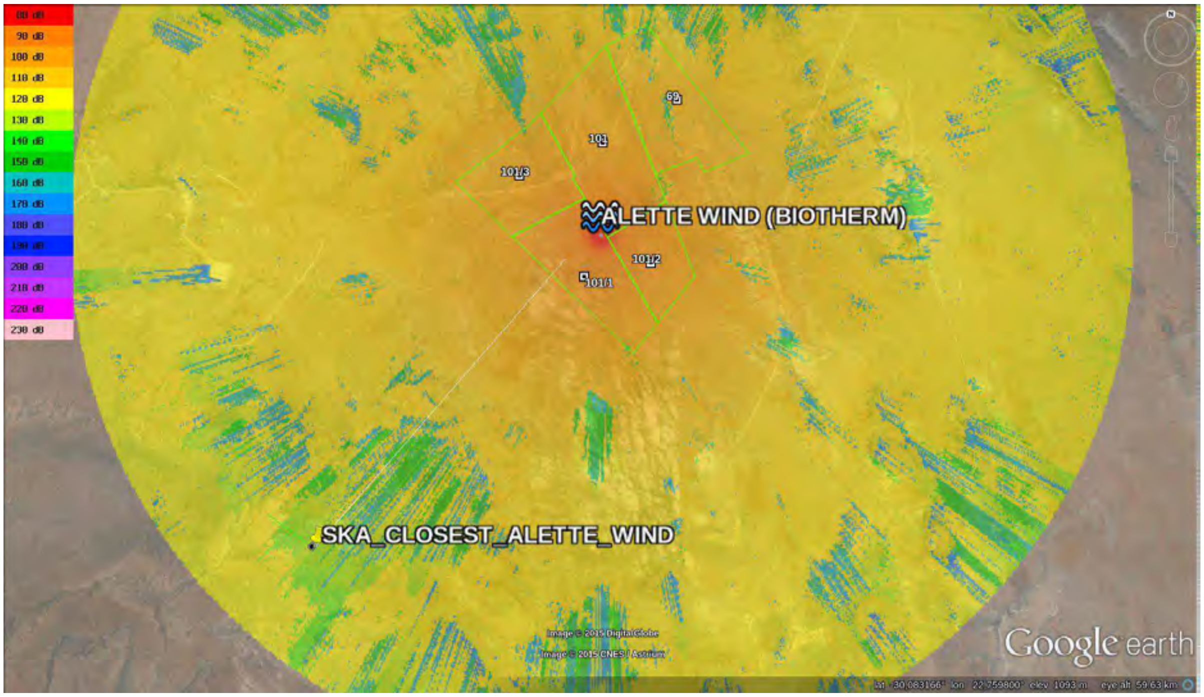

Figure 7: Attenuation map for f=1000MHz from Aletta Wind to the closest SKA telescope.

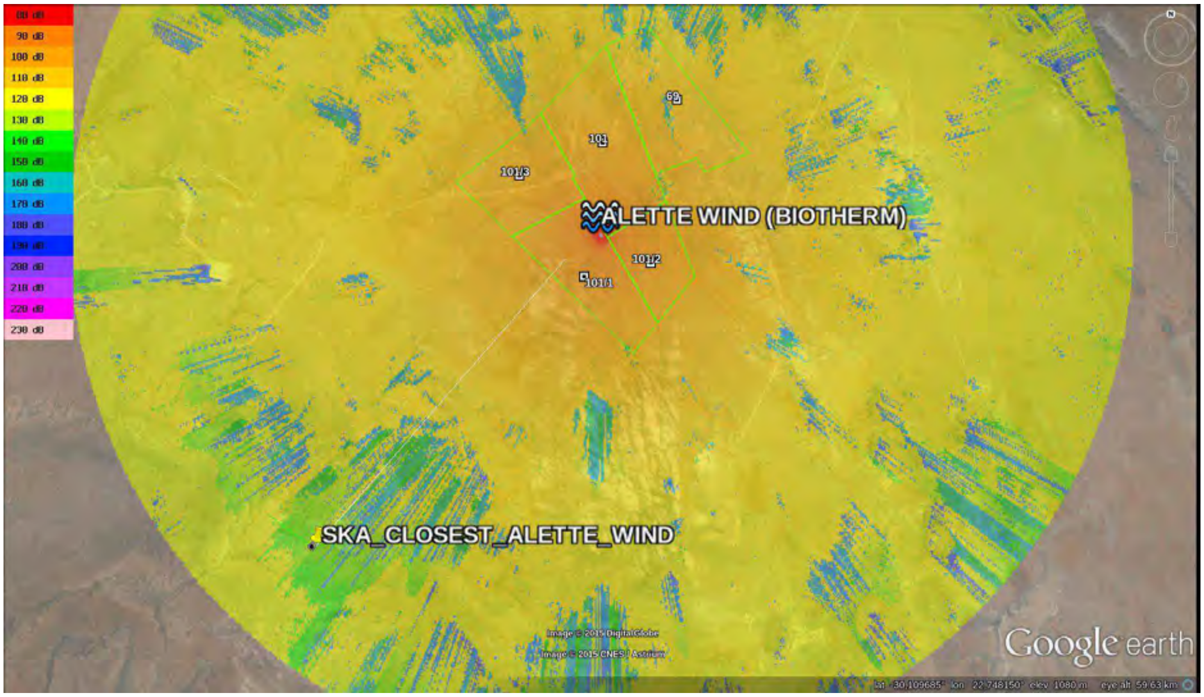

Figure 8: Attenuation map for f=1500MHz from Aletta Wind to the closest SKA telescope.

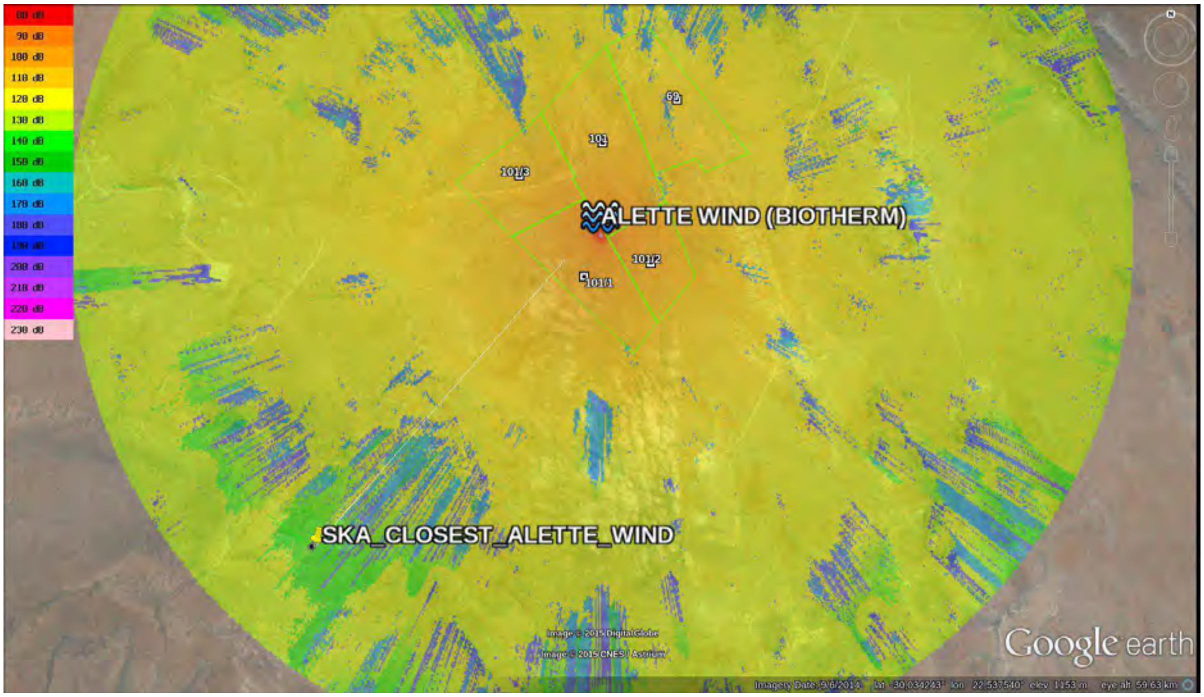

Figure 9: Attenuation map for f=2500MHz from Aletta Wind to the closest SKA telescope.

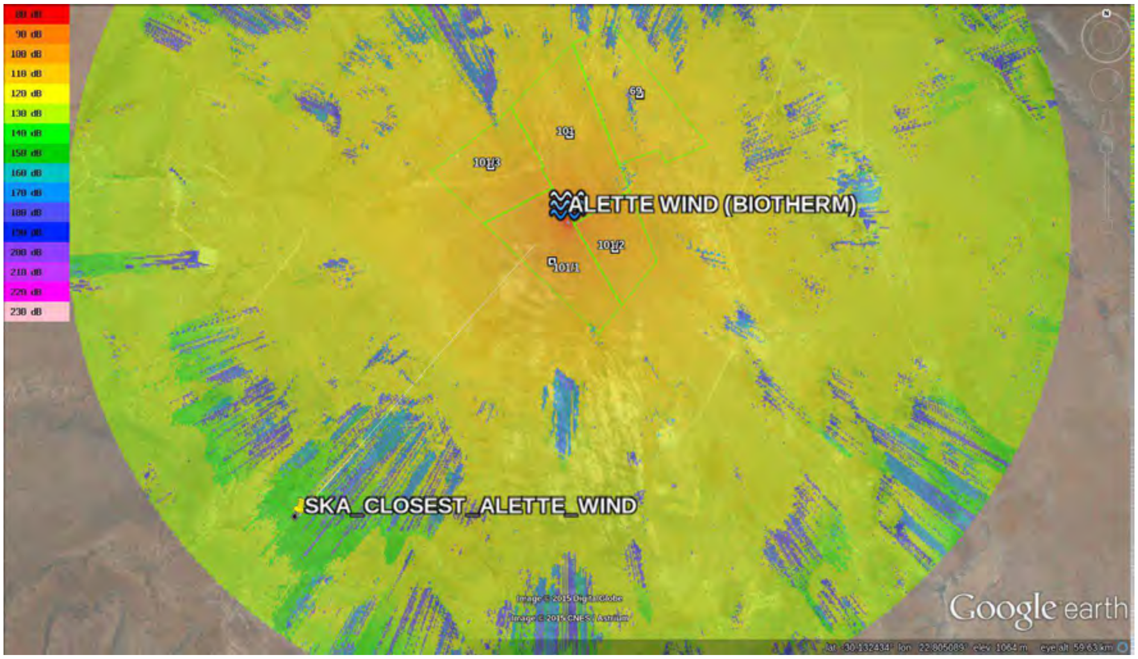

Figure 10: Attenuation map for f=3000MHz from Aletta Wind to the closest SKA telescope.

4.2 SKA Core Site

In Figs. 11 to 18 are the attenuation maps in the direction of the core site.

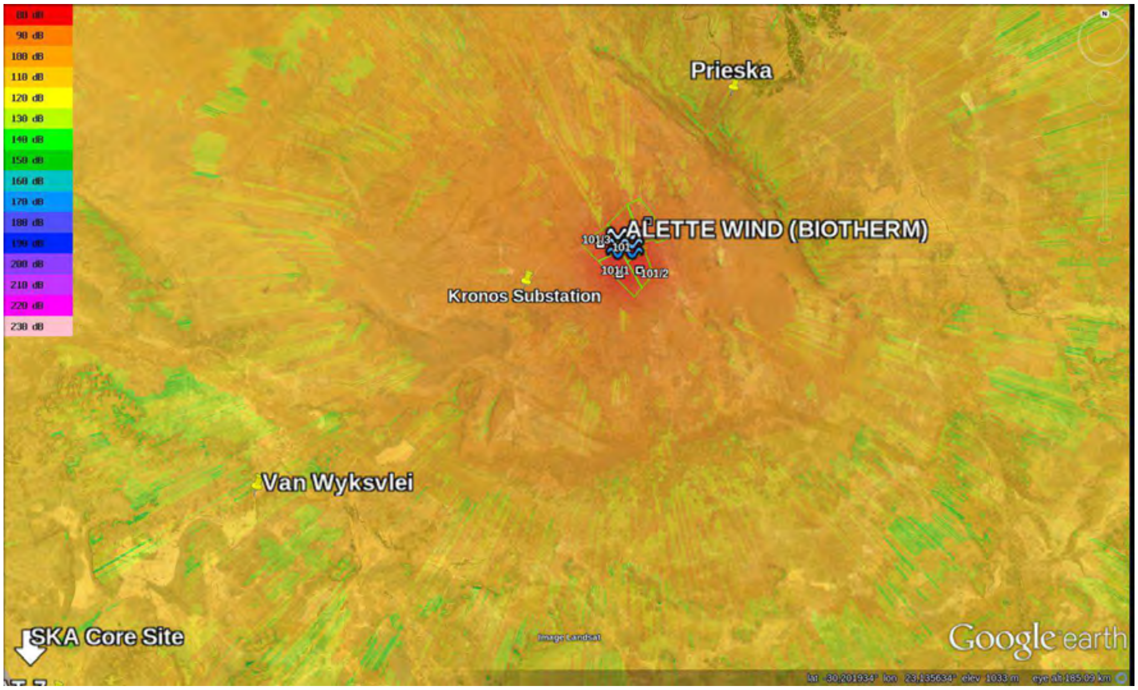

Figure 11: Attenuation map for f=100MHz from Aletta Wind to the SKA core.

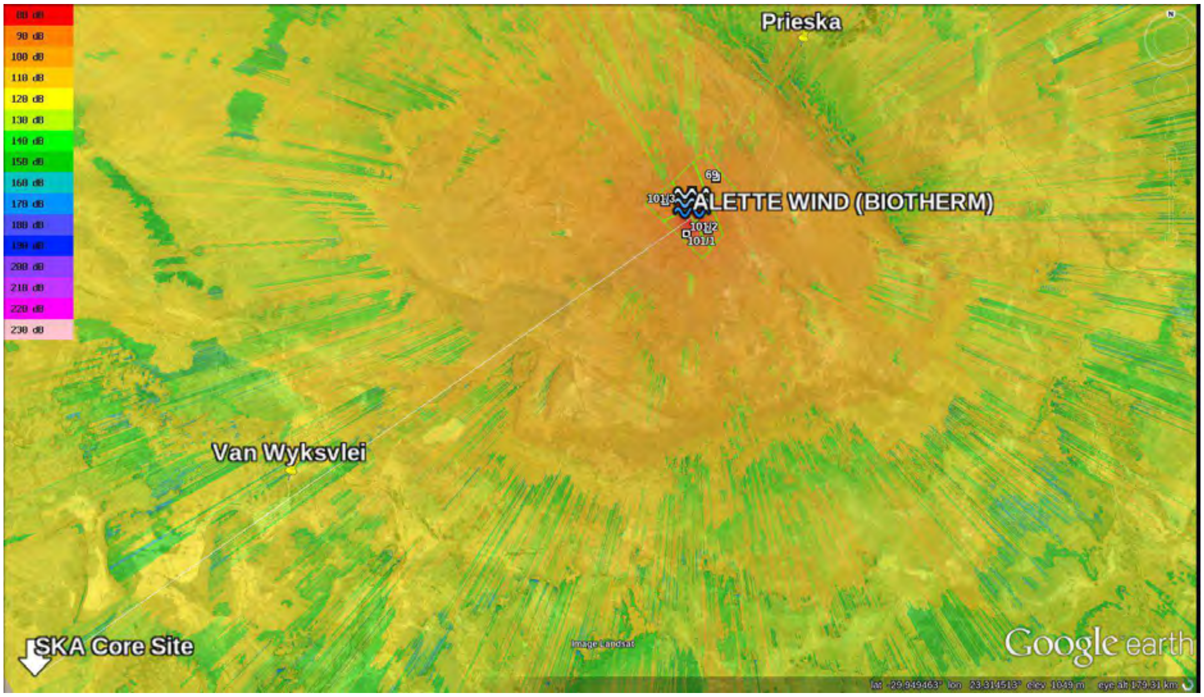

Figure 12: Attenuation map for f=300MHz from Aletta Wind to the SKA core.

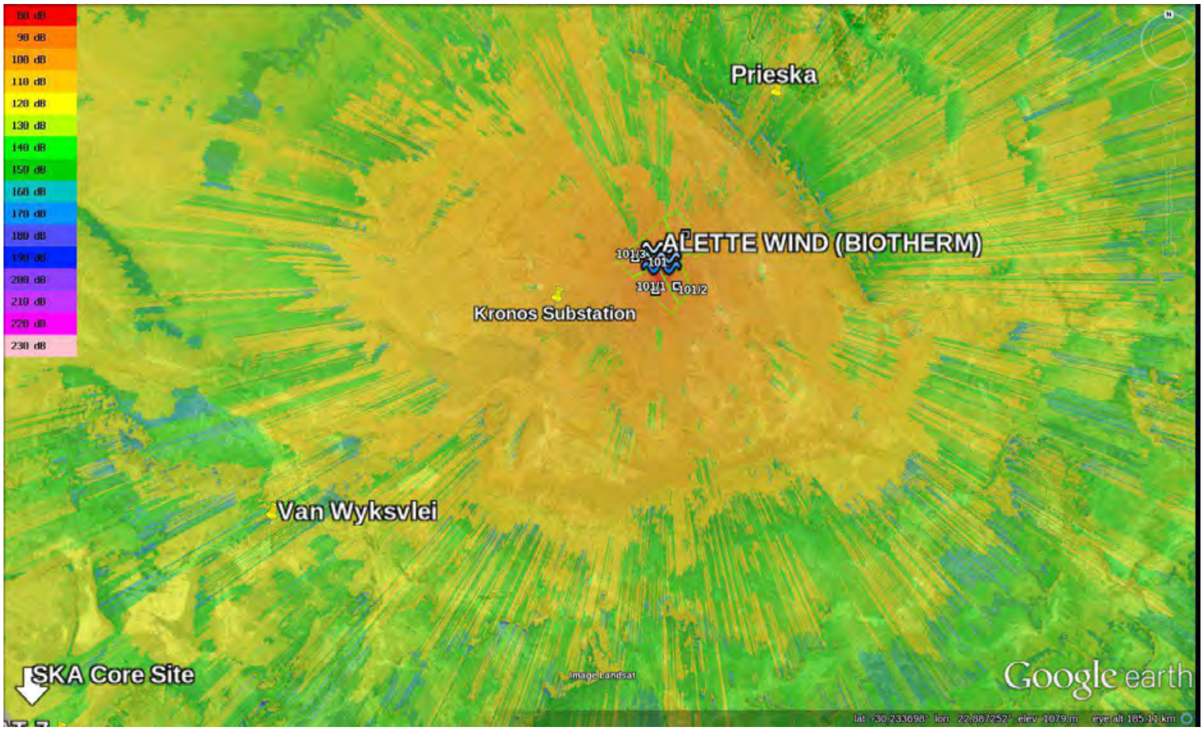

Figure 13: Attenuation map for f=500MHz from Aletta Wind to the SKA core.

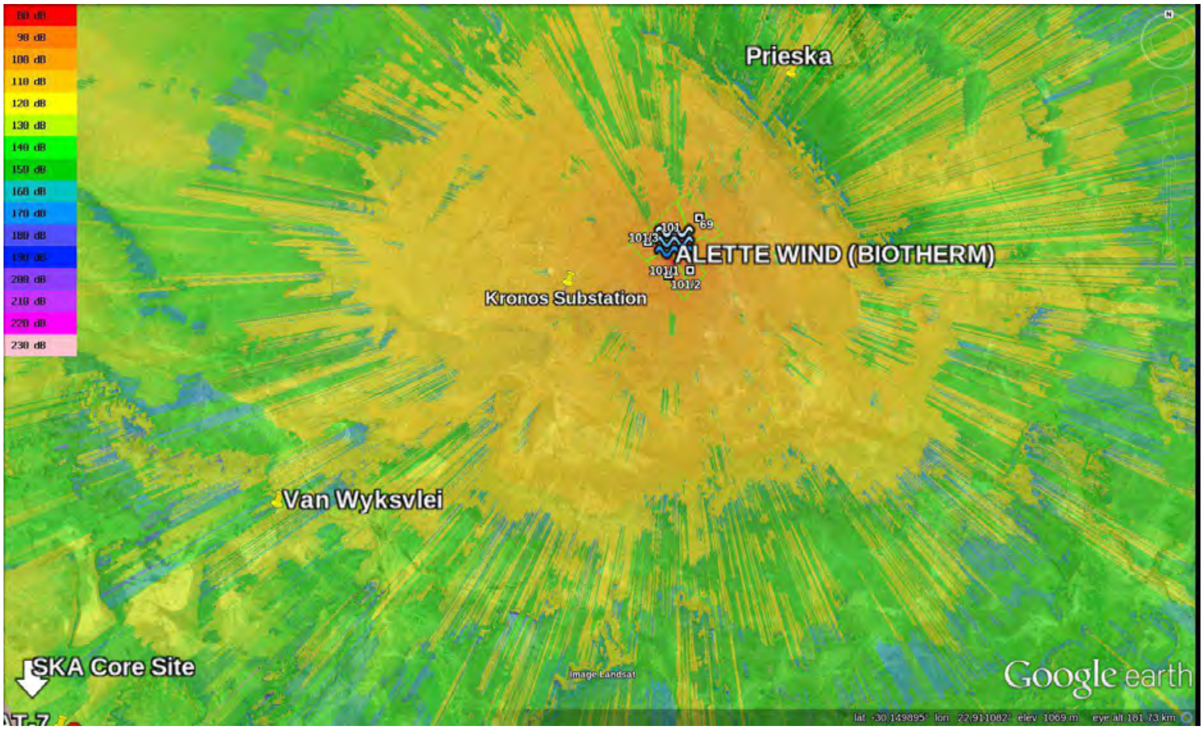

Figure 14: Attenuation map for f=700MHz from Aletta Wind to the SKA core.

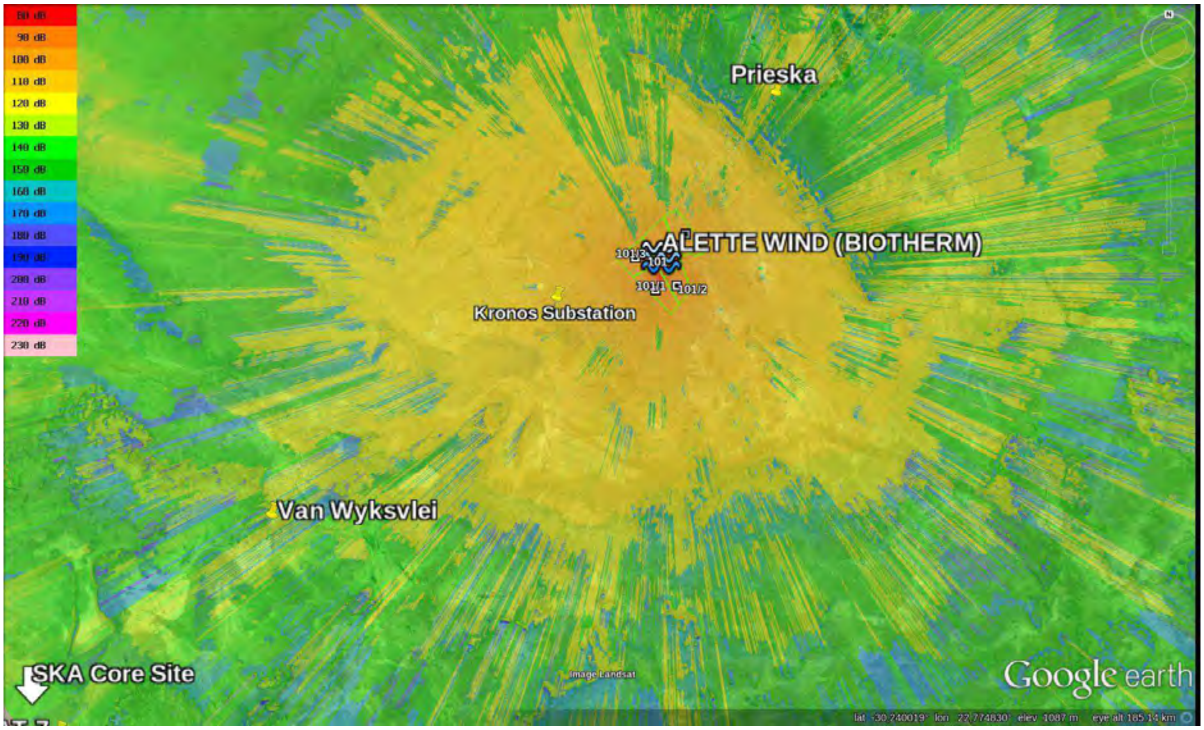

Figure 15: Attenuation map for f=1000MHz from Aletta Wind to the SKA core.

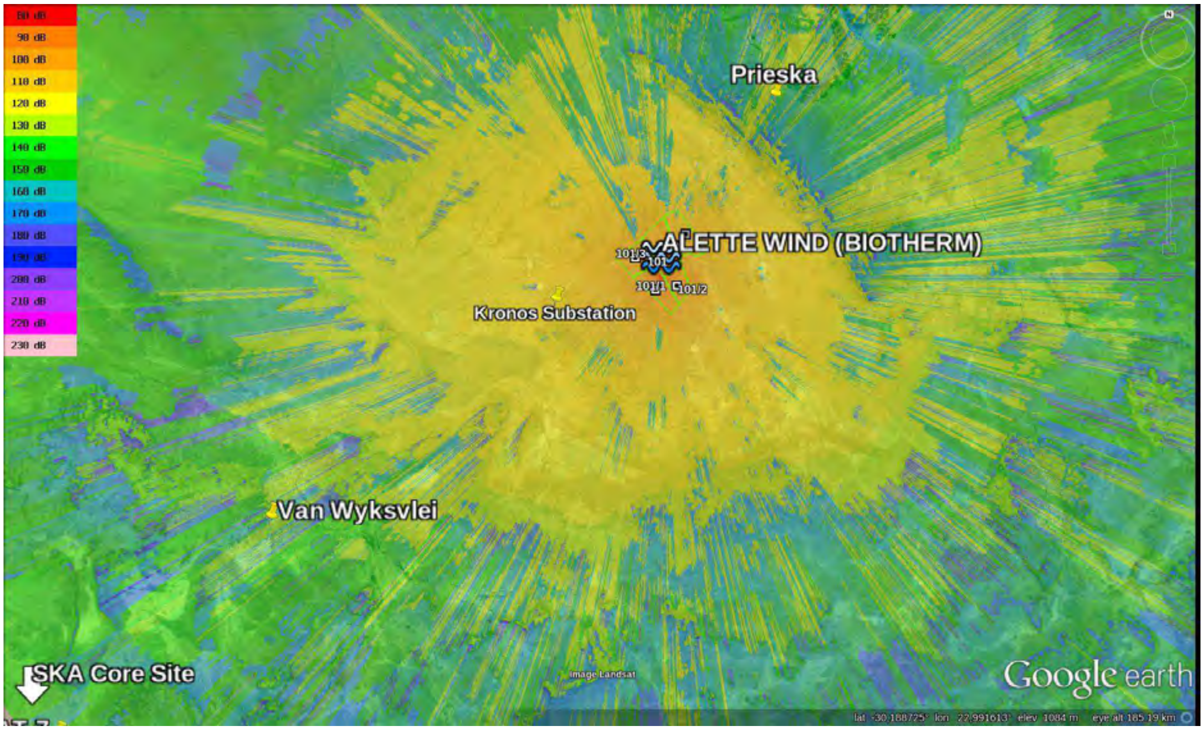

Figure 16: Attenuation map for f=1500MHz from Aletta Wind to the SKA core.

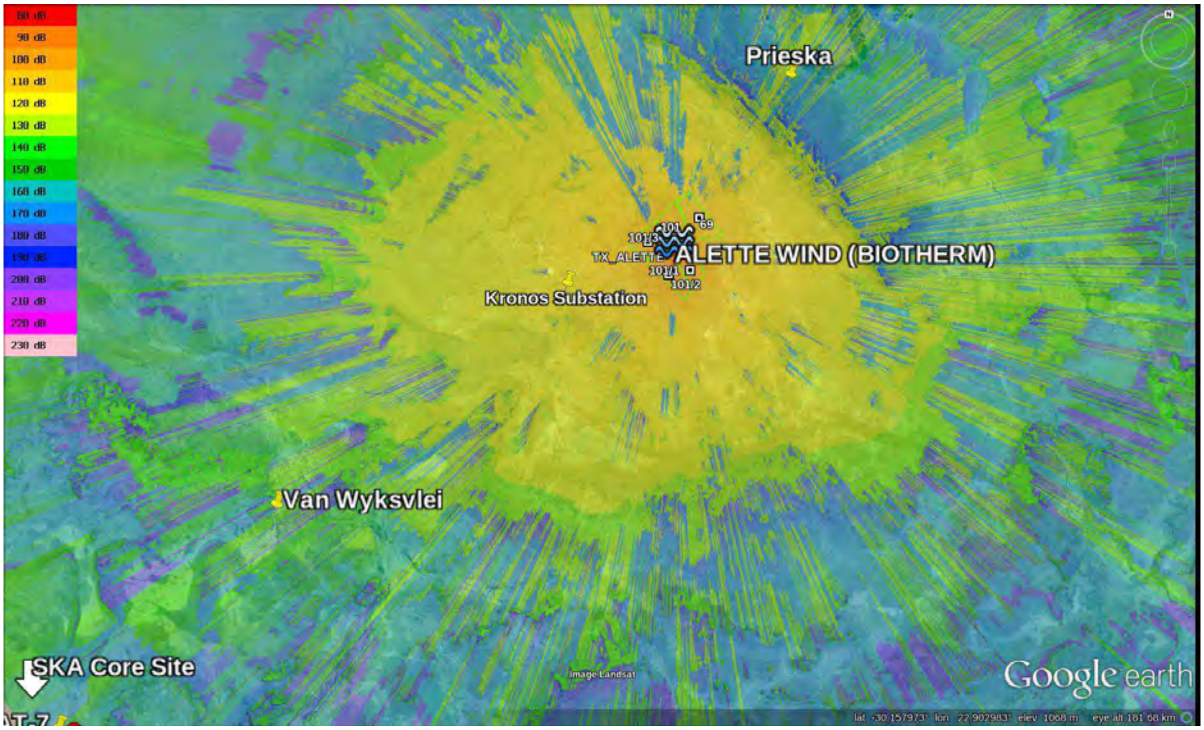

Figure 17: Attenuation map for f=2500MHz from Aletta Wind to the SKA core.

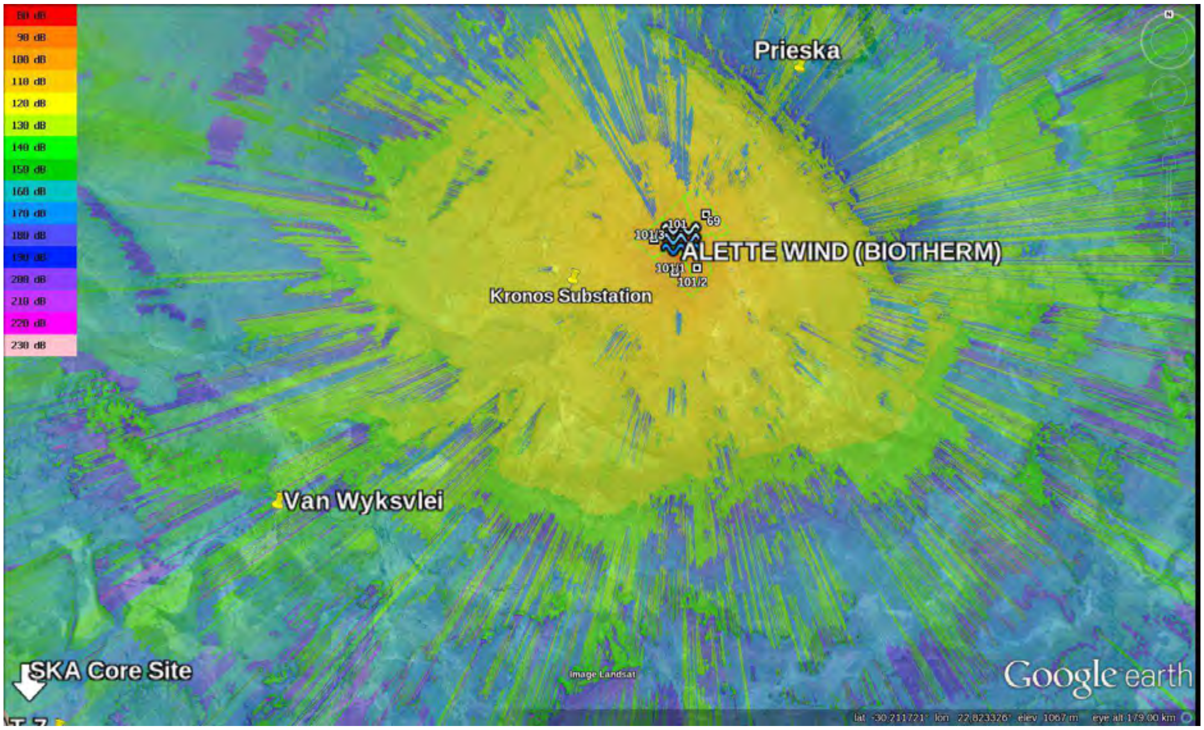

Figure 18: Attenuation map for f=3000MHz from Aletta Wind to the SKA core.

5 Fresnel Zones and Elevation Profiles

The Fresnel zones and elevation profiles, including the earth curvature, are shown in Figs. 19 to 26 for the closest SKA telescope and Figs. 27 to 34 for the core site. A more detailed terrain profile shows features not visible in a normal Google Map profile. This profile is then compensated for the earth curvature, clearly visible for the longer distance toward the core site. Important to note is the scale used in these figures. The elevation change is in meters but the separation distance varies in kilometers. The earth curvature representation is therefore somewhat enhanced.

5.1 Closest SKA Telescope

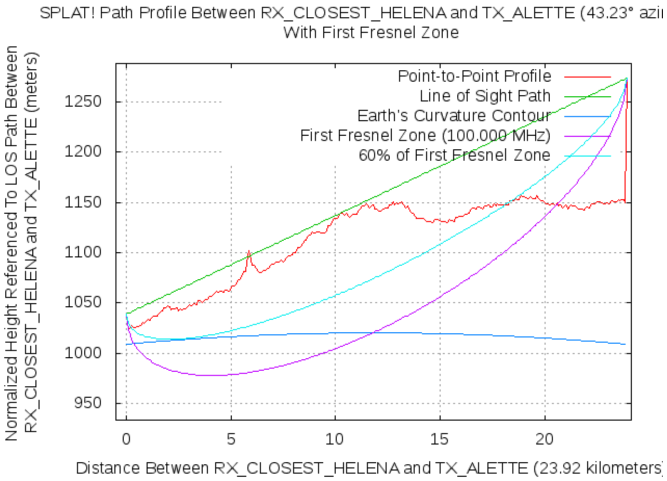

Figure 19: Elevation profile and first Freznel zones for f=100MHz from Aletta Wind to closest SKA telescope.

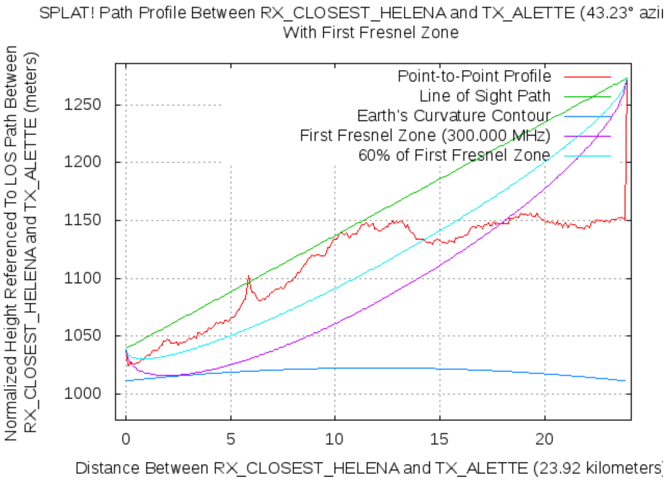

Figure 20: Elevation profile and first Freznel zones for f=300MHz from Aletta Wind to closest SKA telescope.

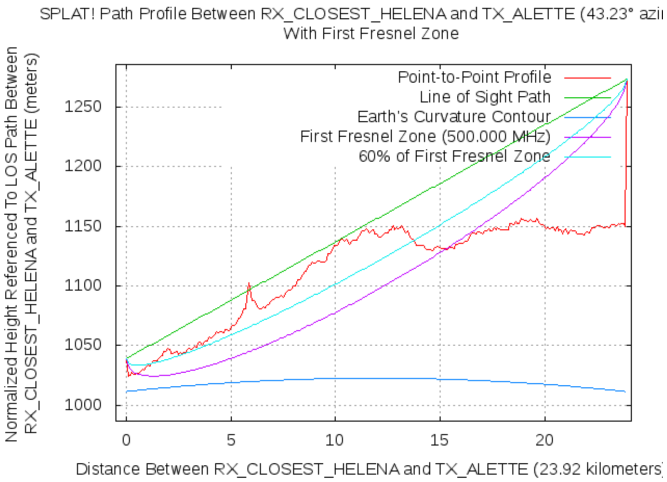

Figure 21: Elevation profile and first Freznel zones for f=500MHz from Aletta Wind to closest SKA telescope.

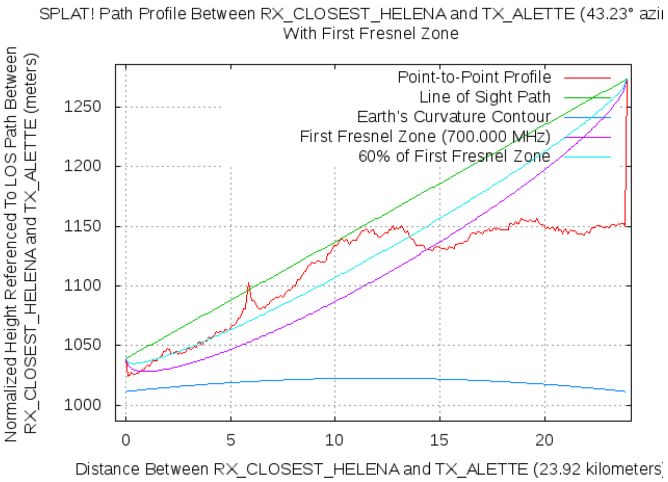

Figure 22: Elevation profile and first Freznel zones for f=700MHz from Aletta Wind to closest SKA telescope.

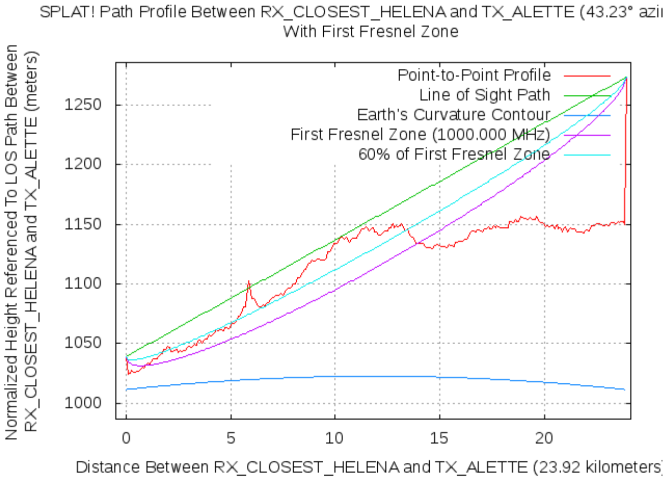

Figure 23: Elevation profile and first Freznel zones for f=1000MHz from Aletta Wind to closest SKA telescope.

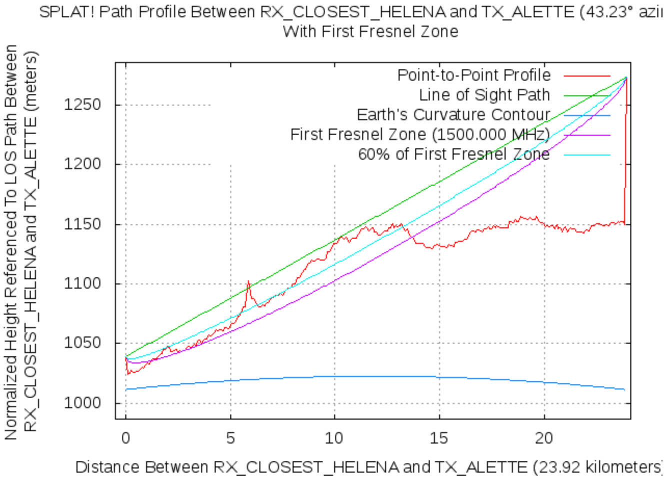

Figure 24: Elevation profile and first Freznel zones for f=1500MHz from Aletta Wind to closest SKA telescope.

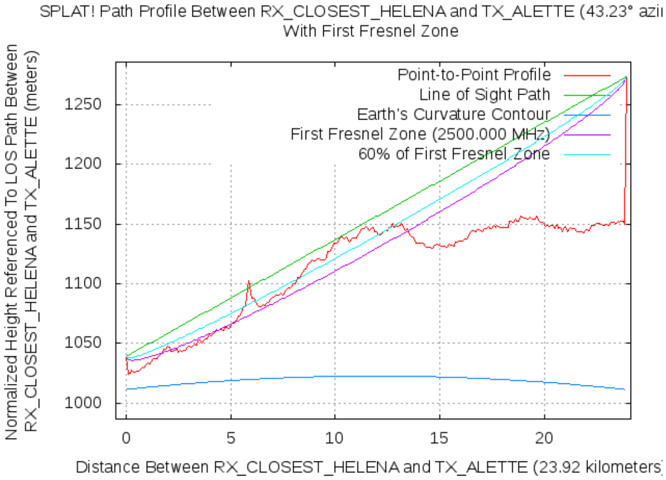

Figure 25: Elevation profile and first Freznel zones for f=2500MHz from Aletta Wind to closest SKA telescope.

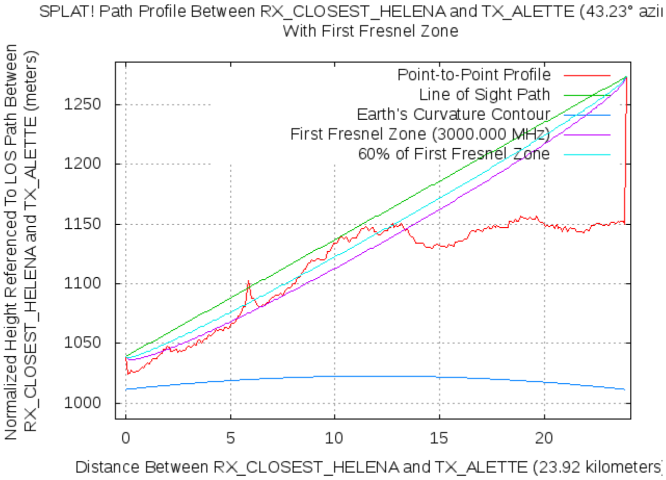

Figure 26: Elevation profile and first Freznel zones for f=3000MHz from Aletta Wind to closest SKA telescope.

5.2 SKA Core Site

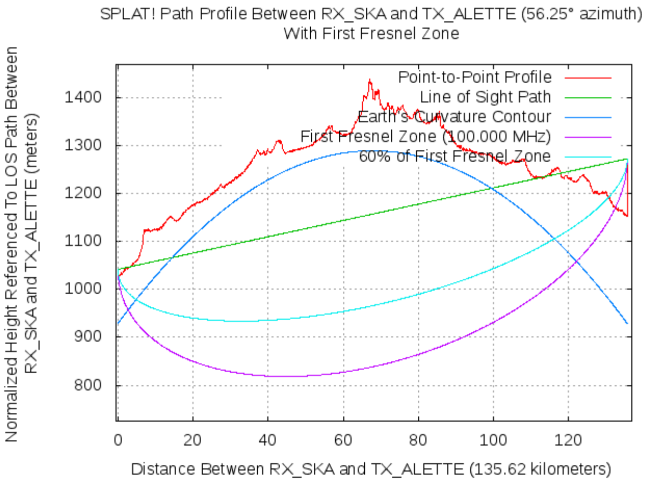

Figure 27: Elevation profile and first Freznel zones for f=100MHz from Aletta Wind to SKA core.

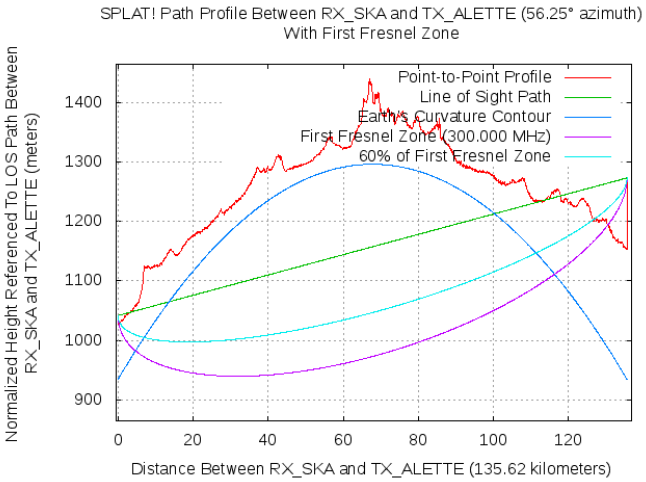

Figure 28: Elevation profile and first Freznel zones for f=300MHz from Aletta Wind to SKA core.

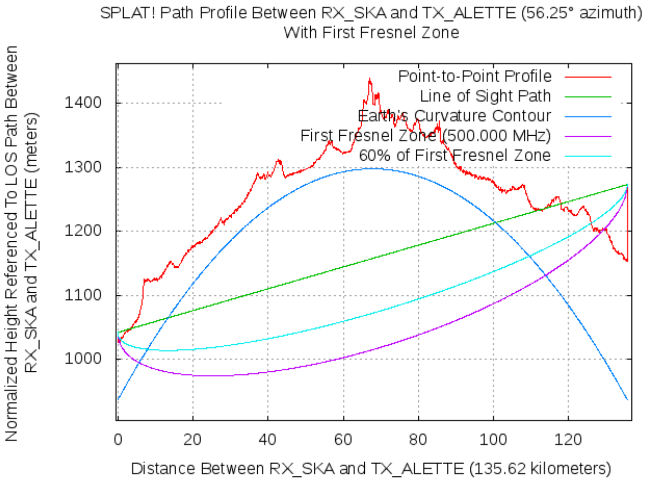

Figure 29: Elevation profile and first Freznel zones for f=500MHz from Aletta Wind to SKA core.

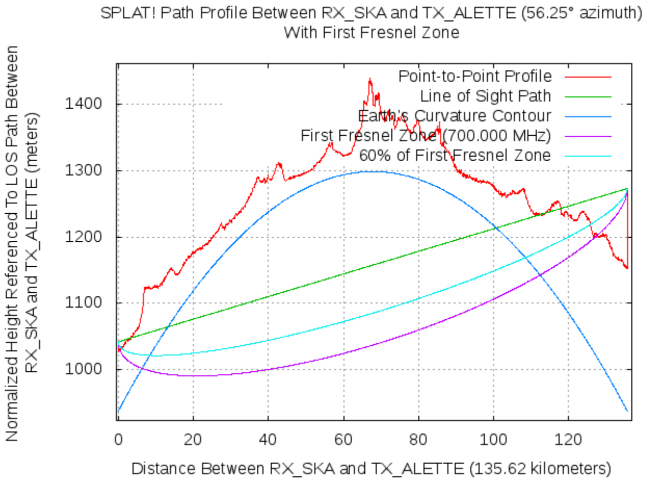

Figure 30: Elevation profile and first Freznel zones for f=700MHz from Aletta Wind to SKA core.

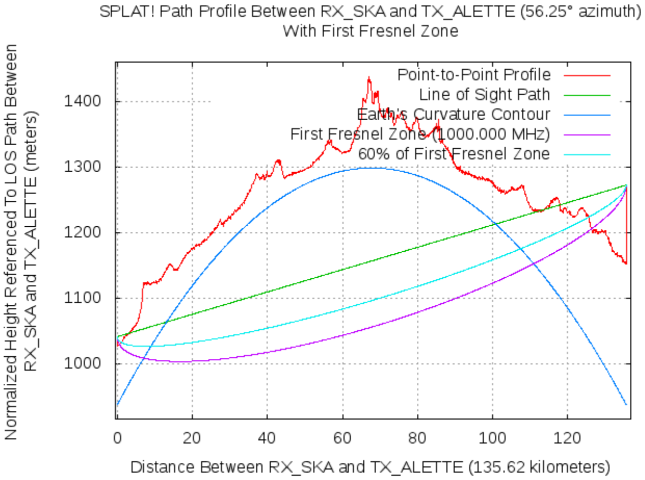

Figure 31: Elevation profile and first Freznel zones for f=1000MHz from Aletta Wind to SKA core.

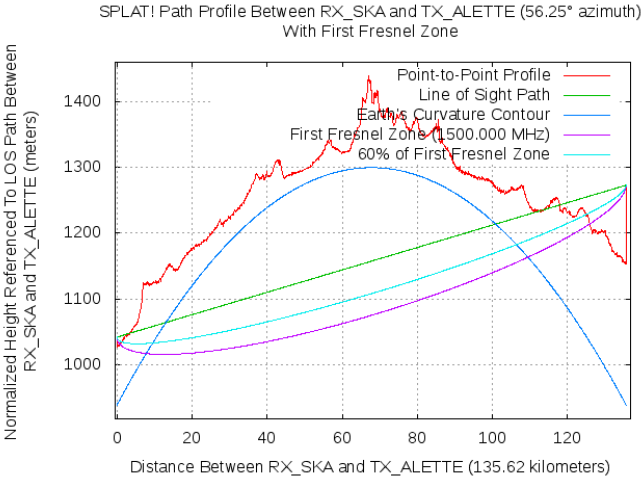

Figure 32: Elevation profile and first Freznel zones for f=1500MHz from Aletta Wind to SKA core.

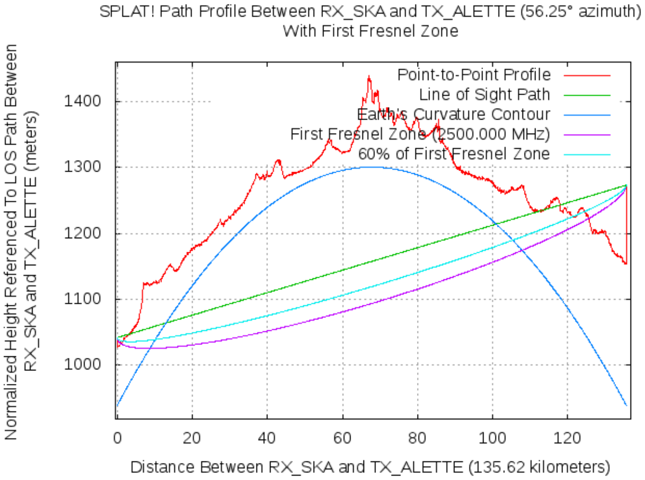

Figure 33: Elevation profile and first Freznel zones for f=2500MHz from Aletta Wind to SKA core.

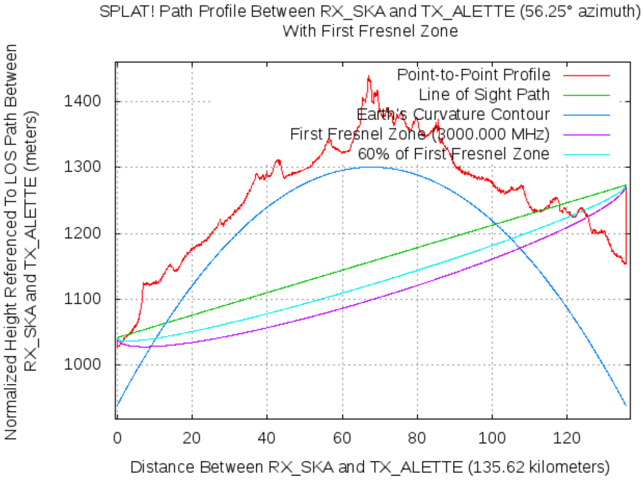

Figure 34: Elevation profile and first Freznel zones for f=3000MHz from Aletta Wind to SKA core.

6 SKA Threshold Limits (SARAS)

The results shown in this section are the comparison of the acceptable levels as measured at 3 and 10 m distances from the plant, which will produce radiated emission levels that are 10 dB below the SKA threshold limits as defined by SARAS in [1]. This takes into account the TPL calculated by SPLAT!.

6.1 Procedure

The required power spectral density (PSD) of the radiated emission levels experienced by the telescopes, as shown by the *black squares* in Figs. 35 and 37, is given by:

$$\mathrm{PSD}_{\mathrm{Required}}\ [\mathrm{dBm/Hz}] = \mathrm{PSD}_{\mathrm{SARAS\ Continuum}}\ [\mathrm{dBm/Hz}] - 10\ \mathrm{dB} \tag{1}$$

Considering the total path loss (TPL) calculated by SPLAT!, the required PSD at the source shown by the *red dots* in Figs. 35 and 37 is therefore given by:

$$\mathrm{PSD}_{\mathrm{Source}}\ [\mathrm{dBm/Hz}] = \mathrm{PSD}_{\mathrm{Required}}\ [\mathrm{dBm/Hz}] + \mathrm{TPL}\ [\mathrm{dB}] \tag{2}$$

The effective isotropic radiated power (EIRP) level at the source, as measured according to the CISPR 22 Class B standard with a RBW and distance of 120 kHz and 10 m (f $<$ 1 GHz), and 1 MHz and 3 m (f $>$ 1 GHz) respectively, is given by:

$$\mathrm{EIRP}\ [\mathrm{dBm}] = \mathrm{PSD}_{\mathrm{Source}}\ [\mathrm{dBm/Hz}] + 10\log_{10}(\mathrm{RBW})\ [\mathrm{Hz}] \tag{3}$$

The electric field (E_0) associated with the EIRP defined in Eq. 3, again as measured according to the CISPR 22 Class B standard, is given by:

$$E_0 = \mathrm{EIRP} - 20\log_{10} D + 104.8 \tag{4}$$

The allowable level of E-field to be measured, compared to the CISPR 22 Class B standard, is given by the *blue diamonds* in Figs. 36 and 38.

6.2 Closest SKA Telescope

The results in Fig. 35 are a comparison in terms of power spectral density, and in 36 in terms of E-field for the closest SKA telescope.

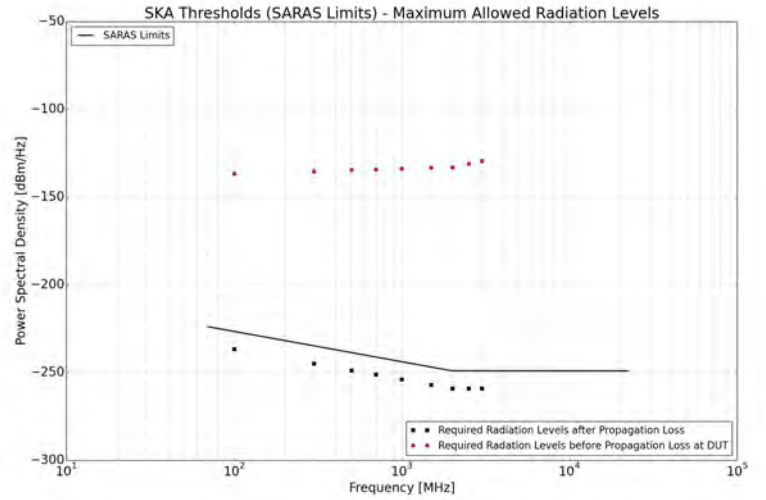

Figure 35: Aletta Wind maximum allowed PSD [dBm/Hz] radiation limit to ensure SKA threshold (SARAS) - 10 dB at the closest SKA telescope.

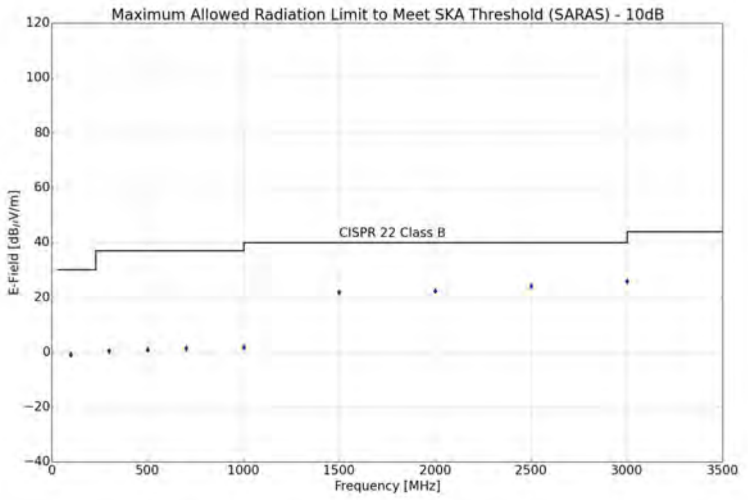

Figure 36: Aletta Wind maximum allowed E-Field [dBμV/m] to be measured according to CISPR 22 Class B at 10 m from DUT using RBW = 120 kHz for f < 1 GHz; and at 3 m from DUT using RBW = 1 MHz for f > 1 GHz to ensure SKA threshold (SARAS) - 10 dB at the closest SKA telescope.

6.3 SKA Core Site

The results in Fig. 37 are a comparison in terms of power spectral density, and in Fig. 38 in terms of E-field for the core-site telescope.

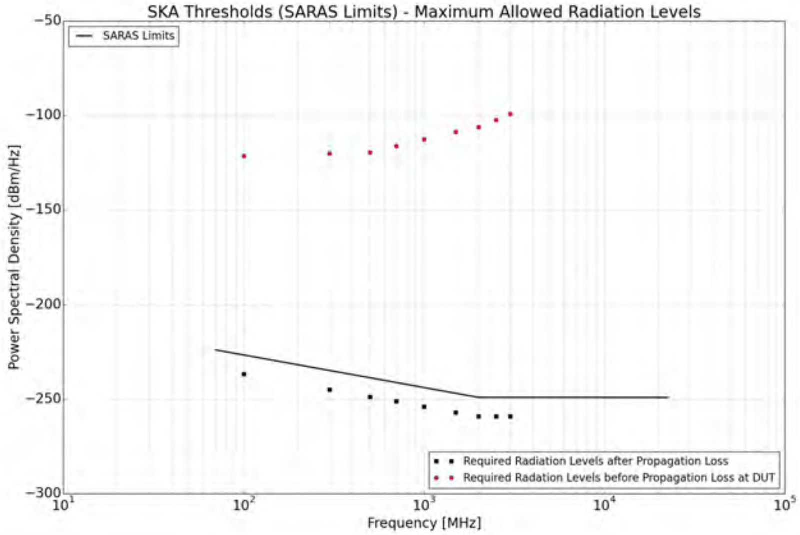

Figure 37: Aletta Wind maximum allowed PSD [dBm/Hz] radiation limit to ensure SKA threshold (SARAS) - 10 dB at the SKA core site.

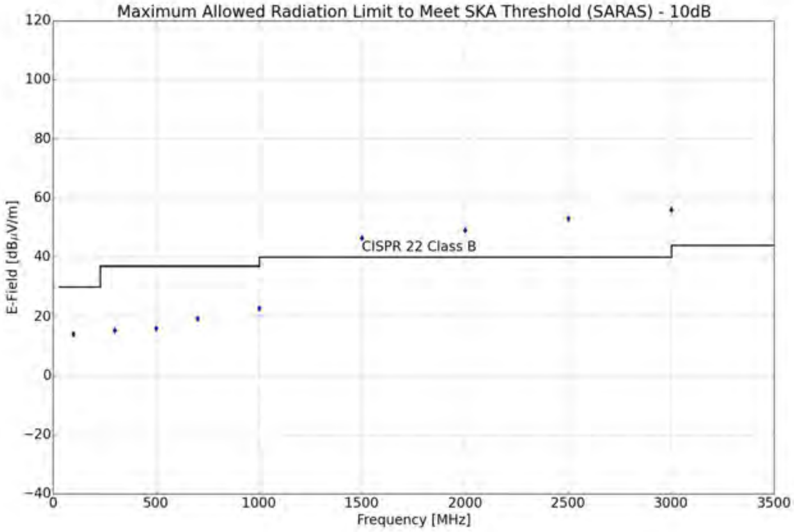

Figure 38: Aletta Wind maximum allowed E-Field [dBμV/m] to be measured according to CISPR 22 Class B at 10 m from DUT using RBW = 120 kHz for f $<$ 1 GHz; and at 3 m from DUT using RBW = 1 MHz for f $>$ 1 GHz to ensure SKA threshold (SARAS) - 10 dB at the SKA core site.

The proximity of the wind farm to the closest telescope means that there is only FSPL and essentially no TL as evident from Table 3. Additional TL in the propagation towards the core site, leads to the slightly higher allowable levels compared to CISPR as shown in Fig. 38. However, overall compliance would likely be determined by the lowest allowable emissions to help reduce the effect of interference on the outlying telescopes as much as possible.

7 Conclusion

MESA Solutions was asked by BioTherm Energy to do a topographical analysis of the terrain profile between the Aletta wind farm and the SKA closest and core-site telescopes. The purpose of the investigation is to define a level that can be verified through measurements which will result in an equivalent emission level that is 10 dB below the SKA threshold limit. This measurement level is influenced by the TPL between both telescope locations. However, the TPL is a function of topograhy and frequency as well as characteristics such as the transmitter and receiver heights. The measurement level is related to the well-known CISPR 11/22 Class B standard that is defined at a measurement distance of 10 m for frequencies below 1 GHz and at 3 m for frequencies above 1 GHz.

From the results in Section 6 it is clear that at lower frequencies, emissions below CISPR are required especially in the case of the closest telescope. This is mainly due to the absence of any TL over this short distance. Towards telescopes in the core site, the allowable measured levels increase slightly due to the additional TL. The possibility exists that the overall lower levels would have to be achieved to limit interference to the closest telescopes as much as possible.

MESA Solutions
Drs A. J. Otto and P. S. van der Merwe
March 2015

References

[1] *Astronomy Geographic Advantage Act, 2007*, No. 21 of 2007, Government Gazette, Vol. 516, No. 31157, Cape Town, Republic of South Africa, 17 June 2008.

[2] P. Dewdney and G. Han Tan, *SKA EMI/EMC Standards and Procedures*, Technical Report SKA-TEL-SKO-0000202, Revision 1, Square Kilometre Array (SKA) Organisation, Jodrell Bank Observatory, UK, 10 January 2015.

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PATH LOSS AND RISK ASSESSMENT REPORT FOR ALETTA WINDFARM

DOCUMENT NUMBER : **R 6114/16**

REVISION : **1.0**

DATE : **25 February 2016**

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ITC SERVICES Prepared By	C Fouché		25 February 2016
ITC SERVICES Reviewed By	H Joubert		

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ACRONYMS AND ABBREVIATIONS

AC	Alternating Current
AM	Amplitude Modulation
CAL	Calibration
CCW	Counter Clockwise
CM	Common Mode
E-Fields	Electric Fields
EM	Electro Magnetic
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
Eq	Equation
EUT	Equipment Under Test
Fr	Resonant frequency
H- Fields	Magnetic Fields
IEEE	Institute of Electrical and Electronic Engineers
MIL-STD	Military Standard
PSU	Power Supply Unit
R&S	Rohde and Schwarz
RF	Radio Frequency
SE	Shielding Effectiveness
SELDS	Shielded Enclosure Leak Detection System
SKA	Square Kilometer Array

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1. INTRODUCTION

An area, 15km east of Copperton in the Northen Cape Province, has been identified for the Aletta Windfarm Facility (Aletta) development by BioTherm Energy (Pty) Ltd (BioTherm).

The SKA is a stakeholder mentioned in the Environmental Authorisation of the proposed project. In order to determine whether the planned windfarm development could have any influence on the SKA, BioTherm requested a risk evaluation of the planned development to SKA activities.

The frequency band of concern for SKA mid-band is 200MHz to 20GHz.This assessment does not consider any potential telecommunication services or networks that are to be established as part of the operational plan.

This initial high level risk assessment would enable one to estimate the maximum permissible radiated emissions from the equipment installed within the Aletta and will be compared to known radiated emission data from the Acciona WTG.

1.1 REFERENCED AND APPLICABLE DOCUMENTS

[1] Regulations on Radio Astronomy Protection Levels in Astronomy Advantage Areas Decleared for the Purposes of Radio Astronomy No.R 90. Government Gazette 10 February 2012 (35007).
[2] K0000-2001V1-02 R: SKA Standard for calculating RFI Threshold Levels – RT Lord 8 December 2010.
[3] R 6387/15 Emission test report for the Gouda Windfarm: ITC Services 10 September 2015
[4] R 6487/15 Emission Test Report for the Cookhouse Substation: ITC Services 13 October 2015

2. METHODOLOGY

This phase of assessment consists of a paper exercise to determine technology risks (power conversion, wireless control systems, telemetry etc) of the renewable energy system. A total of 80 Acciona AW125/3000 turbines at 100m hub height are preliminary earmarked for installation at Aletta. These were characterized for the Preferred Bidder Garob Windfarm Facility development during August 2015. A second phase of assessment may become necessary, consisting of in-field measurements, to confirm results or provide further input. The proposed site of the renewable energy installation is also plotted with reference to the MeerKAT, SKA Phase 1 and SKA Phase 2 telescope locations.

SARAS receiver protection levels against expected received amplitudes from the renewable power technology are determined and plotted. The [1]EN 55022 Class B emission standards are also provided as reference.

Permissible emission levels, assuming attenuation between the proposed site and nearest four SKA stations as determined by the Irregular Terrain Model (Longley Rice model for frequencies between 20MHz and 20GHz), are presented in Graph 4. The mean values of the ITU-R P.1546-4 Land Path propagation model statistical simulation based on the Monte-Carlo method correlated well the ITM values. The reduction in power density of an electromagnetic wave as it propagates is a function of free-space loss (natural expansion of the wave front in free space i.e distance between source and receiver), diffraction loss (part of the wave front is obstructed by an obstacle, in this case terrain such as a hill), vegetation and foliage (environment) and the propagation medium (dry/ moist air in this case) to name a few.

Graph 5 shows permissible emission levels based on the worst case (minimum) path loss as calculated with Monte Carlo based ITU 1546-4 path loss software and can be compared to known emissions from comparable installations to support the evaluation of mitigation requirements.

The following inputs are required for this Analysis Phase:

- SARAS protection levels
- SKA dish(es) location most likely to be affected
- Identification of potential interference sources
- Block diagram and description of potential interference source building blocks
- EMC test reports if available
- Potential source measurements, should EMC Test Reports not be available or not be representative of the installation.

---

[1] Superseded by EN 50561-1:2013 and EN 55032: 2012

3. TECHNOLOGY DESCRIPTION

The Acciona wind turbine system has the following building blocks elements:

- Rotor (Blades, hub and pitch system)
- Nacelle housing the generator, gearbox, yaw system and monitoring/control system (top controller)
- Tower (concrete) housing in its base monitoring/control system (ground controller), power converter and transformer

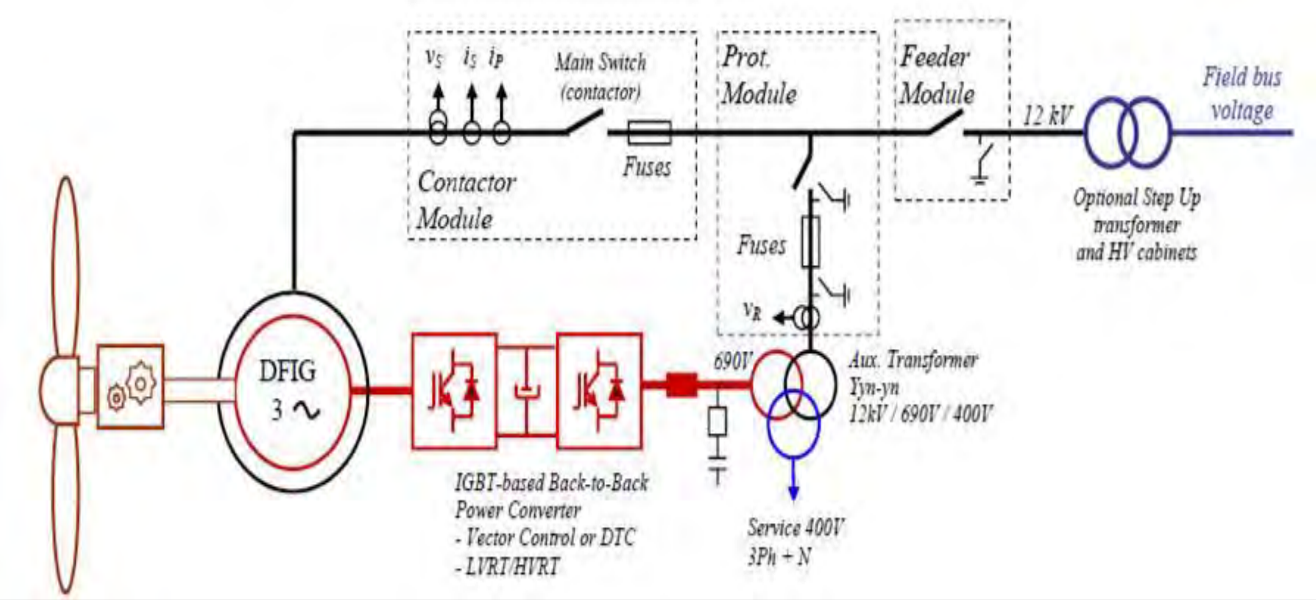


Figure 1: Wind turbine block diagram

4. RISK IDENTIFICATION

4.1 TECHNOLOGY RISKS

The following building blocks are viewed as potential interference sources:

- Control/ monitoring systems – specially nacelle mounted systems
- Power conversion equipment (rectifier/ invertor systems)
- Control and operations centre (computer equipment)

4.1.1 Control/ monitoring systems

- Environmental sensors
- Warning lights
- Cabinets housing PLC equipment
- Variable speed drives (yaw and pitch control system)

4.1.2 Control and operations centre

Equipment installed in the control and operations centre should comply with EN55022. The control and operations building shielding effectiveness should be at least 10dB, unless a 10dB safety margin is added to the EN55022 limit.

4.1.3 Power Convertor

- Thyristor/ IGBT switching rectification and invertor circuits
- UPS for control circuits

4.1.4 Cumulative emissions

A large number of non-correlated noise sources (inverters, telemetry, controls etc.) could increase the noise floor at a receiving site distant from the noise sources. This was however included in the measurement data of

R 6387/15. Adding more plants will result in a theoretical increase of 10 log N dB where N equals the number of plants.

4.2 SITE LOCATION

4.2.1 Area Map

Picture 1: Area map showing location relative to SKA

Four WTG locations (WTG 3, WTG 5, WTG 42 and WTG 79) are shown at the site perimeters.

4.2.2 Local Map

Picture 2: Local map showing nearest four SKA Locations

4.2.3 Elevation Maps

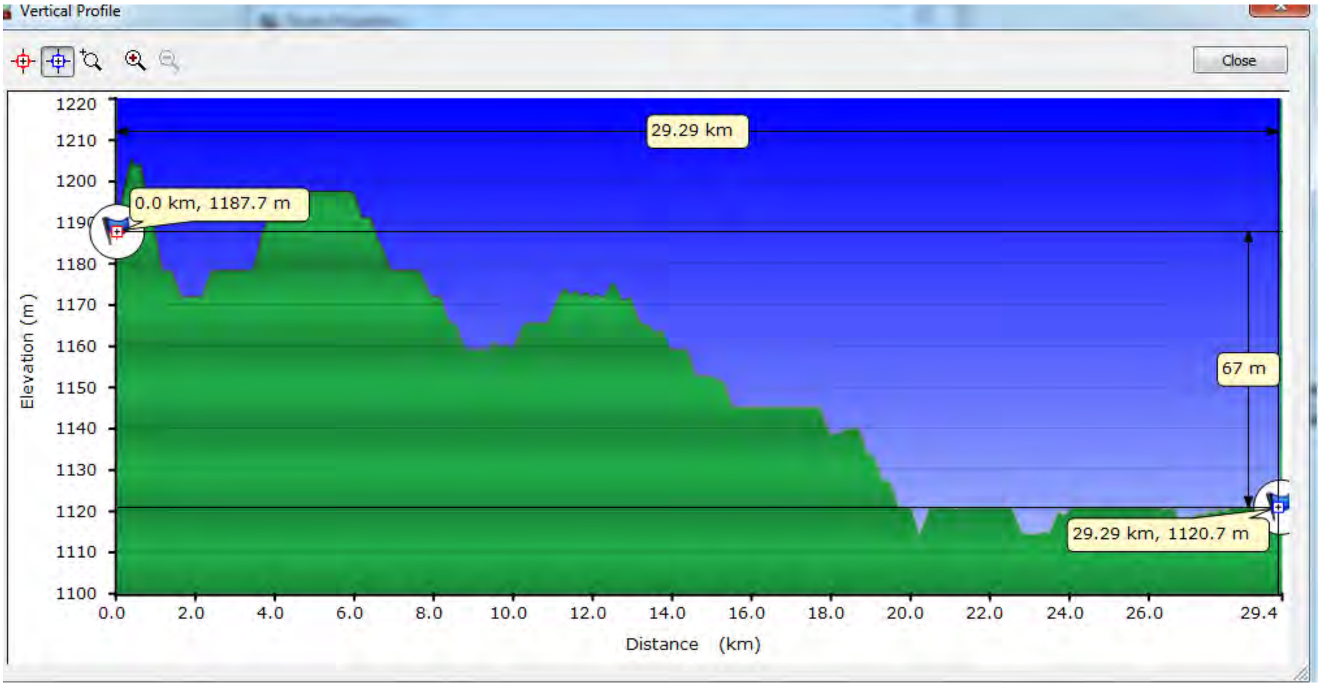


Figure 2: WTG 3 to SKA ID 1895

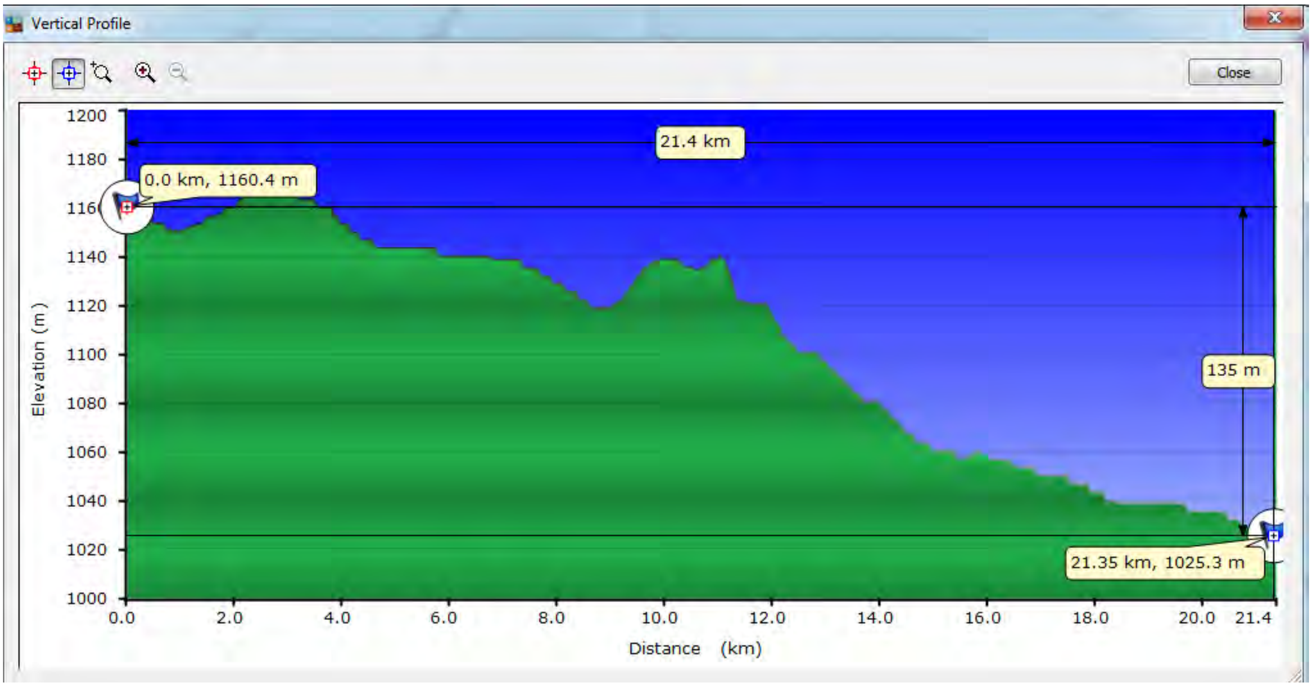


Figure 3: WTG 5 to SKA ID 1890

4.3 INPUT DATA

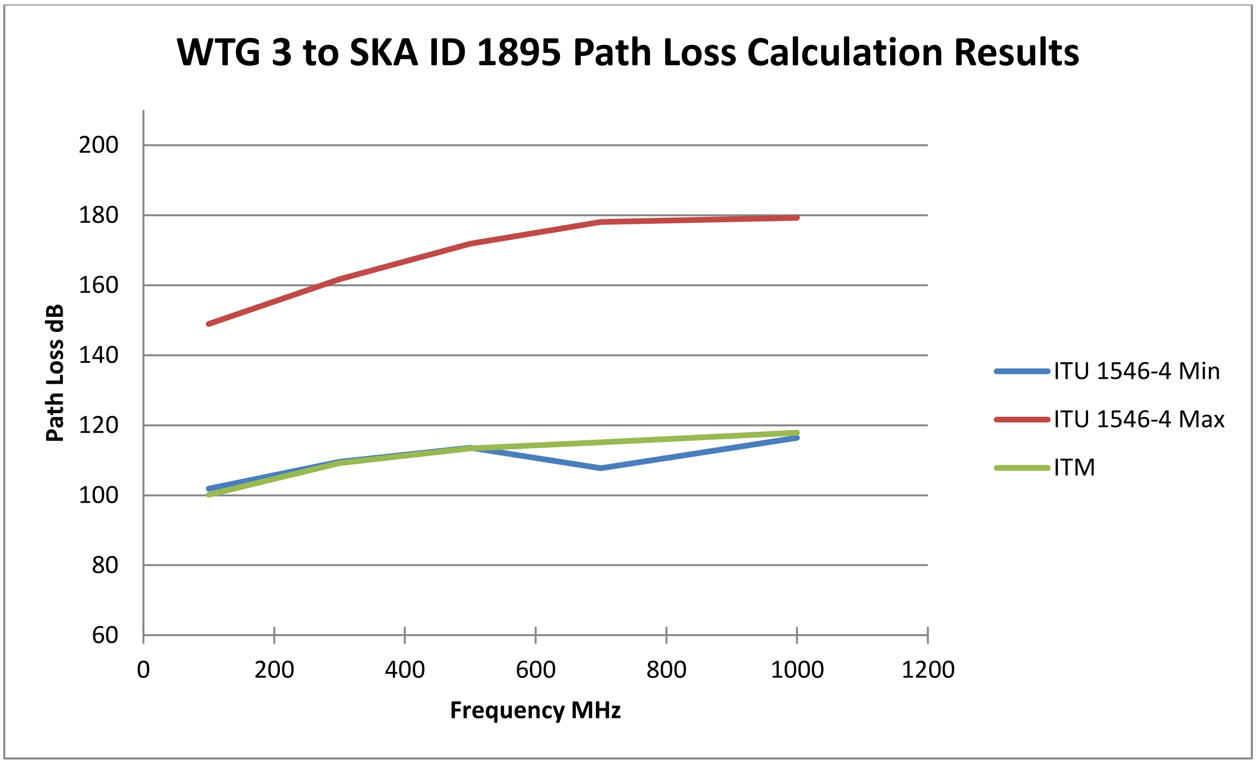
Parameter	Description	Quantity	Comment
Source/ Victim separation distance	WTG 3 to SKA ID 1895	29.4km	Figure 2 refers
Source/ Victim separation distance	WTG 5 to SKA ID 1890	21.4km	Figure 3 refers
Frequency	Frequencies assessed	100MHz, 300MHz, 500MHz, 1000MHz	Frequencies above 1GHz were not included in the

			calculations
TX Power	EN 55022 @ 10m	30 dBµV/m for >230MHz 37 dBµV/m for <230MHz	Based in the allowable emission limit for Class B equipment with a CE mark
SARAS	Protection level	dBm/Hz = -17.2708 log 10 (f) - 192.0714 for f<2GHz	Government Gazette 10 February 2012
Locations	WTG 3	29°53'28.0"S 22°31'46.9"E @1200m	Waypoint received from BioTherm Energy
Locations	WTG 5	30°01'26.8"S 22°32'52.4"E @1159.9m	Waypoint received from BioTherm Energy
Location	SKA ID 1890	29°56'35.70"S 22°22'18.01"E @1096m	Waypoint received from SKA SA (Pty) Ltd
Location	SKA ID 1895	29°42'18.75"S 22°18'48.41"E @1122m	Waypoint received from SKA SA (Pty) Ltd
Location	SKA ID 2348	30° 14' 23.9S" 22° 54' 44.8"E @1080m	Waypoint received from SKA SA (Pty) Ltd
Location	SKA S2 17	30° 15' 45.4"S 22° 13' 18.5"S @1052m	Waypoint received from SKA SA (Pty) Ltd
TX height	WTG 3 & WTG 5	100m	Nacelle height
RX height	All SKA receivers	15m	Height used for SKA receive horn

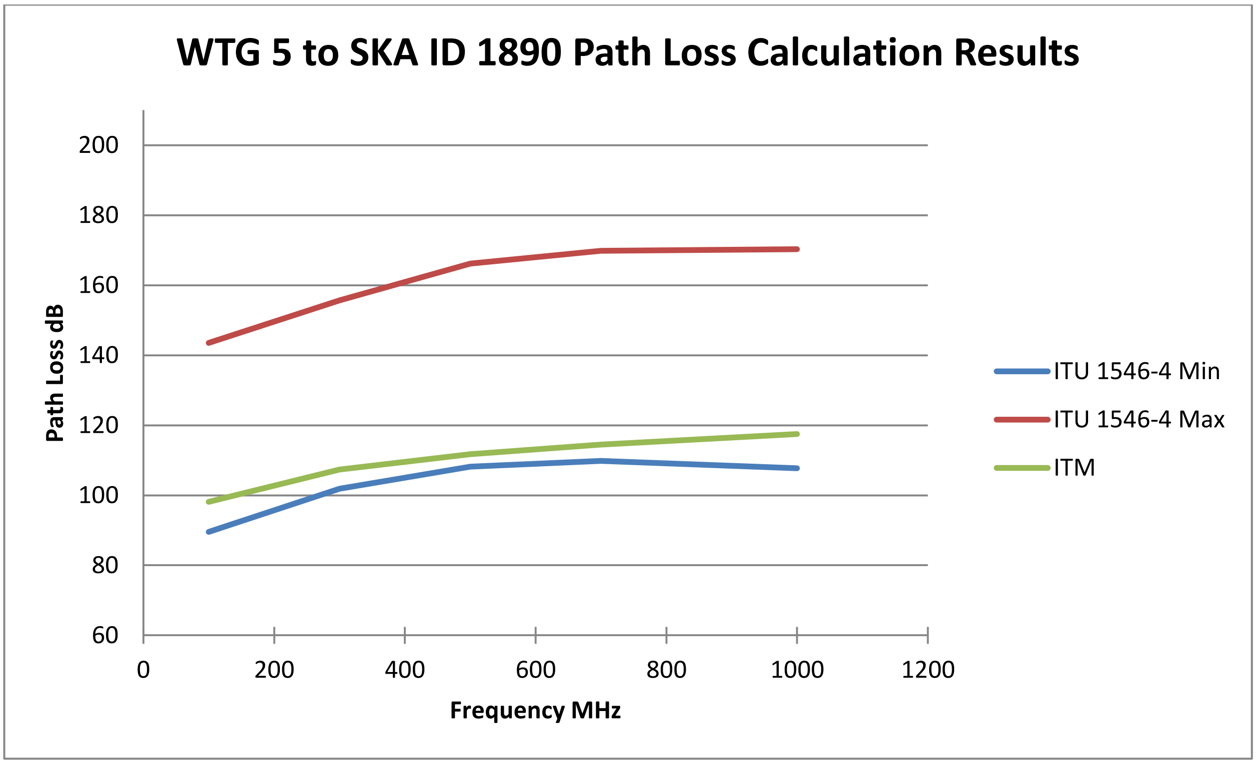
Table 1: Parameters used for calculations

4.4 PATH LOSS CALCULATIONS

The path loss was calculated using the parameters as specified in Table 1.



Graph 1: WTG 3 to SKA ID 1895 Path Loss Calculation result



Graph 2: WTG 5 to SKA ID 1890 Path Loss Calculation result

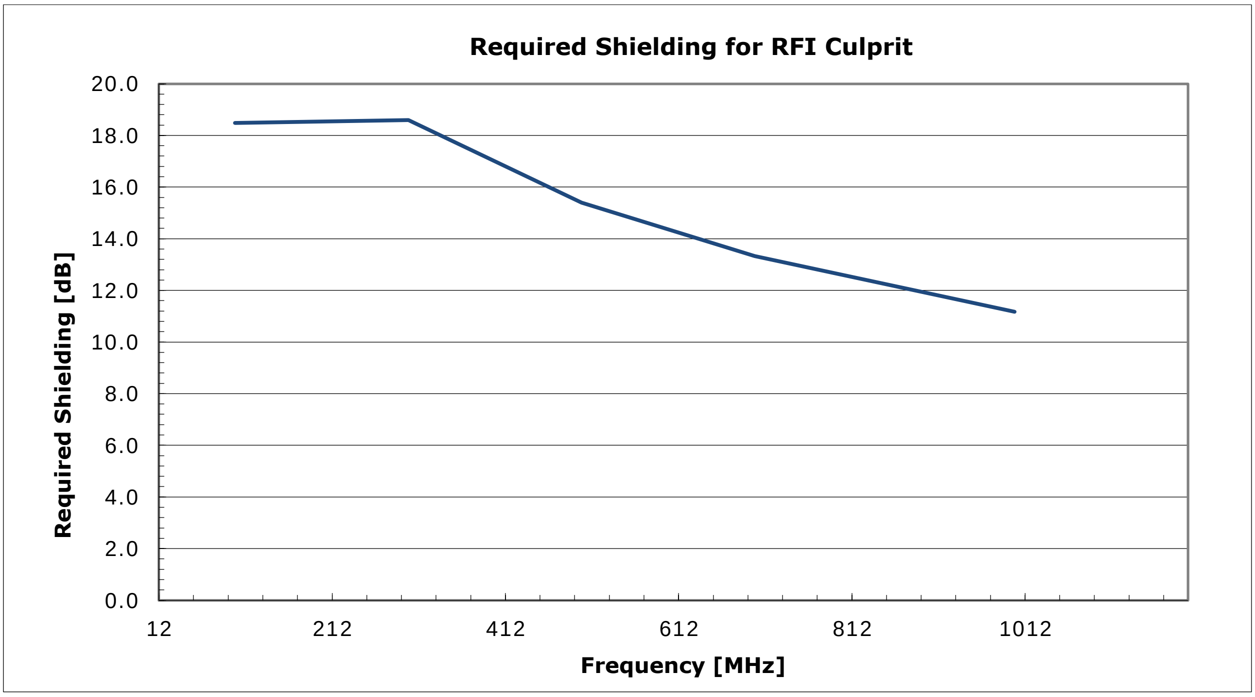
The bottom trace in Graph 1 and Graph 2 is the minimum attenuation of the electromagnetic emission due to the distance between WTG 3 and the SKA 1895 and WTG5 and the SKA 1890 antenna location as calculated with Monte Carlo based ITU 1546-4 path loss software.
In each calculation the ITM results is within the statistical minimum – maximum result of the ITU 1546-4 prediction model.
The minimum path loss calculated is expected between WTG 5 and SKA ID 1890 for the ITU 1546-4 due to the 21.43km separation distance.

A factor of 10 $\log_{10}$ N where N = the number of turbines to account for cumulative emissions is normally account for. For this project, the cumulative effect is already accounted for in the Gouda measurement and no additional cumulative effect factor is used.

5. ATTENUATION REQUIRED

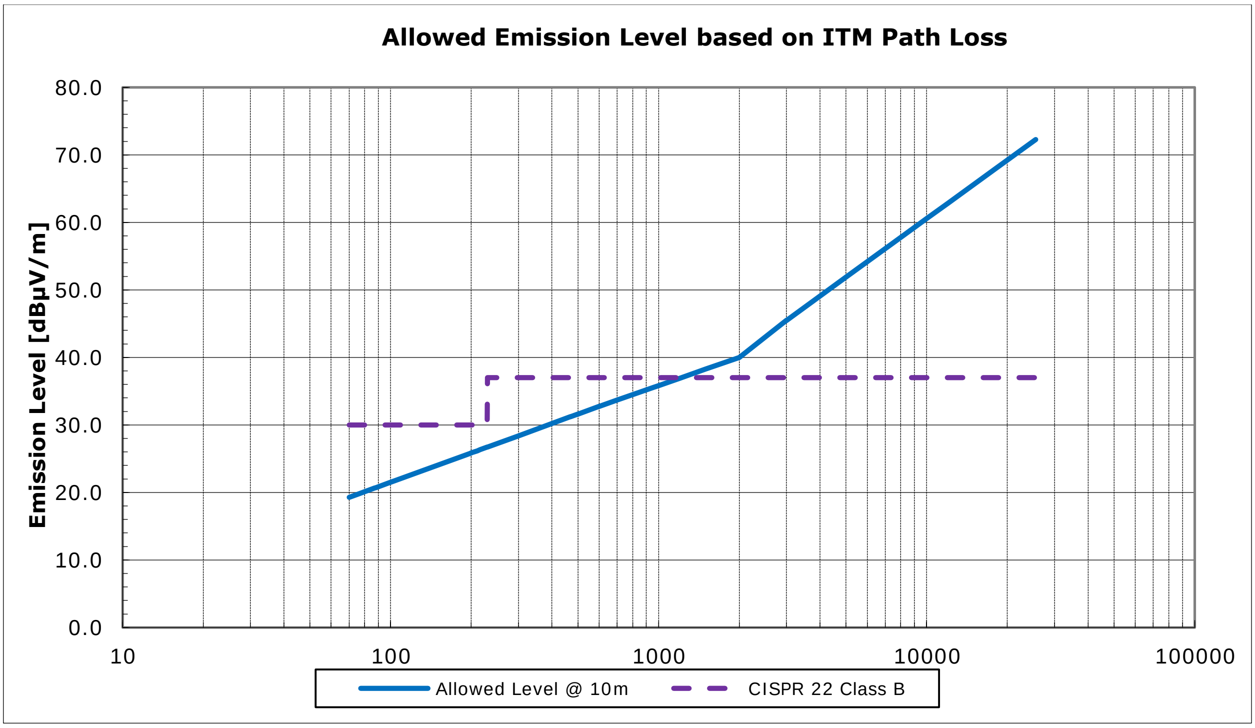
As the minimum path loss was calculated between WTG 5 and SKA ID 1890 with the ITU 1546-4 method, it was used for the calculations that follow.

Based on compliance of all equipment to EN55022 Class B additional attenuation of < 20dB will be required as shown in **Graph 3**. A 10 dB safety margin was added to the EN55022 Class B levels and the ITM path loss values were used for this calculation.



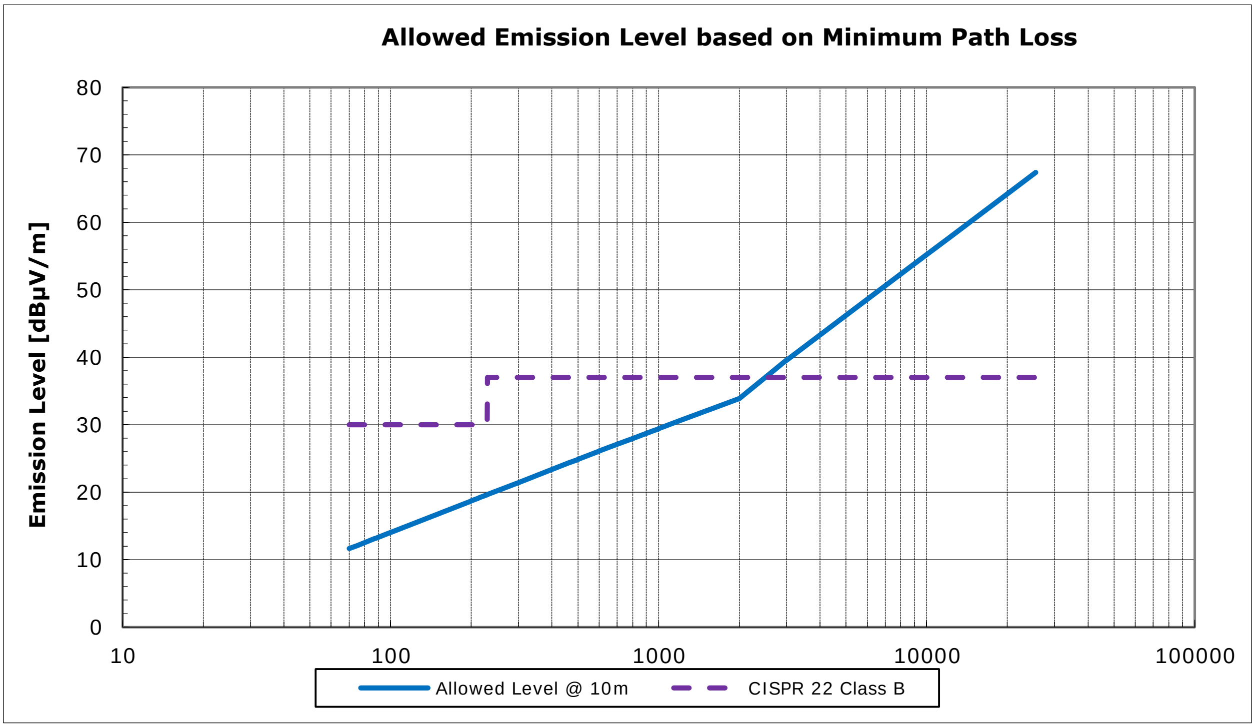
Graph 3: Required attenuation (ITM path loss values)

The maximum amplitude of radiated emissions referred to the CISPR test method (120kHz resolution bandwidth and 10m distance) based on the ITM path loss values is shown in Graph 4



Graph 4: Allowed levels based on ITM path loss values

The maximum amplitude of radiated emissions referred to the CISPR test method (120kHz resolution bandwidth and 10m distance) based on the statistical minimum path loss value of ITU-R P.1546-4 Land Path propagation model is shown in Graph 5.



Graph 5: Allowed level based on statistical minimum path loss values

6. MITIGATION

Measurements at the Gouda Windfarm were compromised by unexpected substation emissions and the high-site emissions, located <5km from the windfarm. The results do however show that required levels of 10 to 20 dB below the CISPR 22 Class B limit should be achievable.

7. CONCLUSION

Based on the current SKA location information, a first order impact analysis shows a possible interference scenario between the Aletta Windfarm and the nearest SKA installation at 21.43km separation distance . In order to negate the risk to an acceptable level, all equipment to be installed on site must comply with levels of 10 to 20dB below the EN 55022 Class B limit as the primary mitigation measure. Where equipment exceeds this threshold, additional shielding and filtering should be implemented to reduce the electromagnetic emissions from the windfarm. Shielding and filtering solutions are available to ensure installed plant equipment emissions remain within SKA risk tolerances

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PATH LOSS AND RISK ASSESSMENT REPORT FOR NEW ALETTA WINDFARM LAYOUT INCLUDING EMISSION CONTROL PLAN FOR THE AW125 TH100A WTG

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4	0.5	25	0.5	46	0.5	67	0.5	
5	0.5	26	0.5	47	0.5	68	0.5	
6	0.5	27	0.5	48	0.5	69	0.5	
7	0.5	28	0.5	49	0.5	70	0.5	
8	0.5	29	0.5	50	0.5	71	0.5	
9	0.5	30	0.5	51	0.5	72	0.5	
10	0.5	31	0.5	52	0.5	73	0.5	
11	0.5	32	0.5	53	0.5	74	0.5	
12	0.5	33	0.5	54	0.5			
13	0.5	34	0.5	55	0.5			
14	0.5	35	0.5	56	0.5			
15	0.5	36	0.5	57	0.5			

ACRONYMS AND ABBREVIATIONS

AC	Alternating Current
AM	Amplitude Modulation
CAL	Calibration
CCW	Counter Clockwise
CM	Common Mode
E-Fields	Electric Fields
EM	Electro Magnetic
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
Eq	Equation
EUT	Equipment Under Test
Fr	Resonant frequency
H- Fields	Magnetic Fields
IEEE	Institute of Electrical and Electronic Engineers
MIL-STD	Military Standard
PSU	Power Supply Unit
R&S	Rohde and Schwarz
RF	Radio Frequency
SE	Shielding Effectiveness
SELDS	Shielded Enclosure Leak Detection System
SKA	Square Kilometer Array

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1. INTRODUCTION

An area, 20km east of Copperton in the Northern Cape Province, has been identified for the Aletta Windfarm Facility (Aletta) development by BioTherm Energy (Pty) Ltd (BioTherm). This is the second update of the initial site layout. The initial site layout had 125 turbines with a 20.9dB cumulative effect. As part of the mitigation strategy, it was reduced to 80 turbines ((19dB cumulative effect) and the new layout has 60 turbines (17.8dB cumulative effect). There has also been a slight change in location to obtain better total path loss values. With the initial layout the nearest turbine was located 20km from the nearest SKA Station, this has now been increased to 25km with the layout update.

The SKA is a stakeholder listed in the Interested and Affected parties of the EIA phaseof the proposed project. In order to determine whether the planned windfarm development could have any influence on the SKA, BioTherm requested a risk evaluation of the planned development to SKA activities.

The frequency band of concern for SKA mid-band is 200MHz to 20GHz.This assessment does not consider any potential telecommunication services or networks that are to be established as part of the operational plan.

This risk assessment would enable one to estimate the maximum permissible radiated emissions from the equipment installed within the Aletta and will be compared to known radiated emission data from the Acciona WTG.

2. SCOPE

This assessment and Electromagnetic Control Plan with its associated procedures addresses mitigation actions required to reduce the radiated emissions of the AW 125 TH 100A wind turbine generator (WTG) to levels acceptable for installation within the declared Karoo Central Astronomy Advantage Area. The AW 125 TH 100A is the model within the AW 3000 platform that will be evaluated for this project. This Plan will be updated based on additional measurement results and design information as it becomes available.

2.1 INTENT

With reference to the letter from the South African SKA Project Office dated 14th April 2016 [3], the intent of this plan is to ensure that this facility poses a low risk of detrimental impact on the SKA by describing specific mitigation measurements to be implemented in order to achieve 40 dB of attenuation, as agreed with SKA South Africa. This plan provides general Electromagnetic Compatibility guidelines as well as specific guidelines to assist and maintain electromagnetic compatibility between the windfarm and Square Kilometer Array (SKA) facility.

This plan concerns itself with the goal of eliminating, to the greatest extent possible, causes of electromagnetic interference (EMI), which can adversely affect the performance of the SKA Radio telescope.

3. REFERENCES

3.1 REFERENCED DOCUMENTS

[1]	No.R 90. Government Gazette 10 February 2012 (35007).	Regulations on Radio Astronomy Protection Levels in Astronomy Advantage Areas Declared for the Purposes of Radio Astronomy
[2]	NIE 49577REM.001	Measurements according to client protocol “ Emission Test Procedure for the AW TH100A WTG”
[3]	DG200233 Rev G	AW3000 Earthing and Lightning protection Systems; Acciona Windpower
[4]	INP125 Rev A	Windfarm Communications – Garob / Copperton: Acciona Windpower
[5]	R6114	Aletta Path Loss and RA 25 Feb 2016V1.0: ITC Services 25 February 2016

3.2 GENERAL REFERENCE MATERIAL

a. EMC Analysis Methods and Computational Models, Frederick M. Tesche, Michel V. Ianoz, Torbjörn Karlson, Wiley Interscience, 1997

b. Noise reduction techniques in electronic systems, Second edition, Henry W. Ott, Wiley Interscience Publications, 1998

c. Electromagnetic Compatibility - Principles and Applications, Second Edition, David A. Weston, Marcel Dekker Inc, 2000

4. TESTING AND QUALIFICATION

It is not intended that EMC/EMI testing will be done for every subsystem. It is rather anticipated that most EMC/EMI tests will be performed on integrated system level. Where possible, units such as shielded cabinets will be tested before installation on site. The final system test will be done on site.

In order to evaluate the impact of the completed windfarm on the ambient emissions, reference measurements are to be done before construction and after construction. A separate test plan will be developed for that.

4.1 PROCEDURES FOR IDENTIFYING AND RESOLVING EMI PROBLEMS

In the event of an EMI problem being identified, the following methodology will be followed:

a. Is the emission repeatable and consistent?

b. Can EMI source(s), coupling path(s) and victim(s) be identified?

c. What are possible corrective actions?

d. Which of the proposed EMI fixes are most desirable in terms of safety, reliability, effectiveness, cost and simplicity?

e. What effect will the proposed fixes have on the program schedule and other functional disciplines?

4.2 CONFLICT RESOLUTION

In the case of solving an EMI problem, a balanced approach will be required in the following general order of precedence:

a. Personnel safety

b. Functionality

c. Reliability

d. Simplicity

e. Cost/Schedule

f. Maintainability

5. SYSTEM ARCHITECTURE

5.1 BASIC INFORMATION

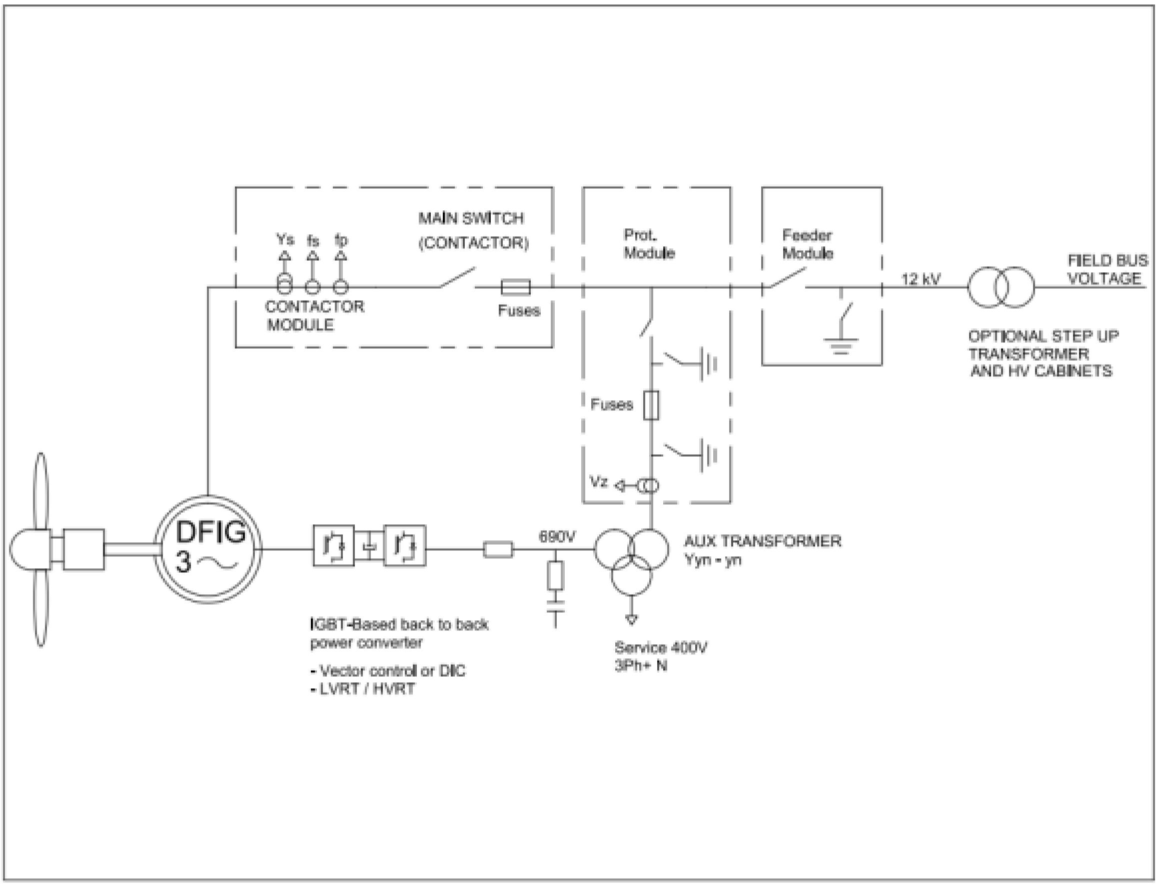


Figure 1: High level block diagram

5.2 TURBINE STRUCTURE & LAYOUT

The turbine configuration evaluated as part of this control plan consists of a base, a 100m concrete tower and a nacelle on top as shown in Figure 2. For the South African projects, the transformer will be installed in the tower base and not external to the base as shown.

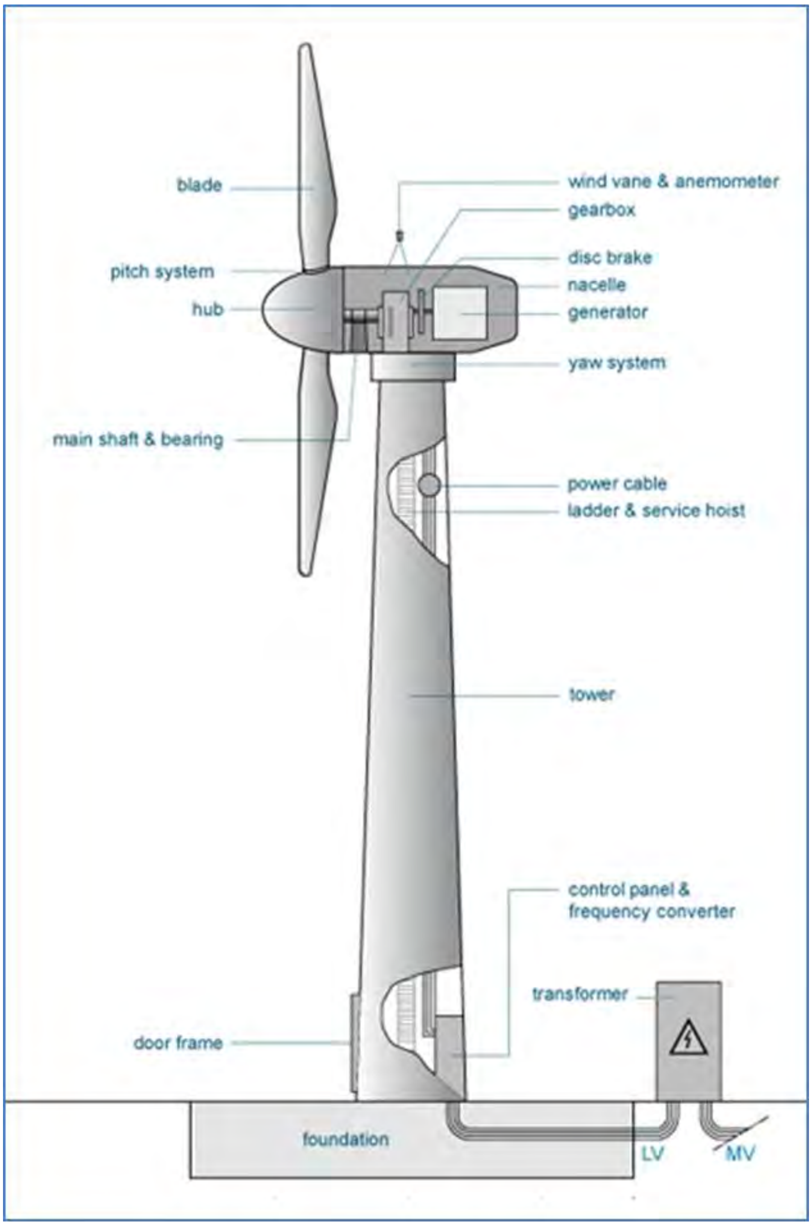


Figure 2: Turbine components

5.3 TURBINE BASE

The following components are installed in the base:

- power controller cabinet
- switch cabinet
- ground converter cabinet
- power converter intercooler
- auxiliary transformer (12kV)
- power transformer (34kVA)

The base component layout is shown in Figure 3.

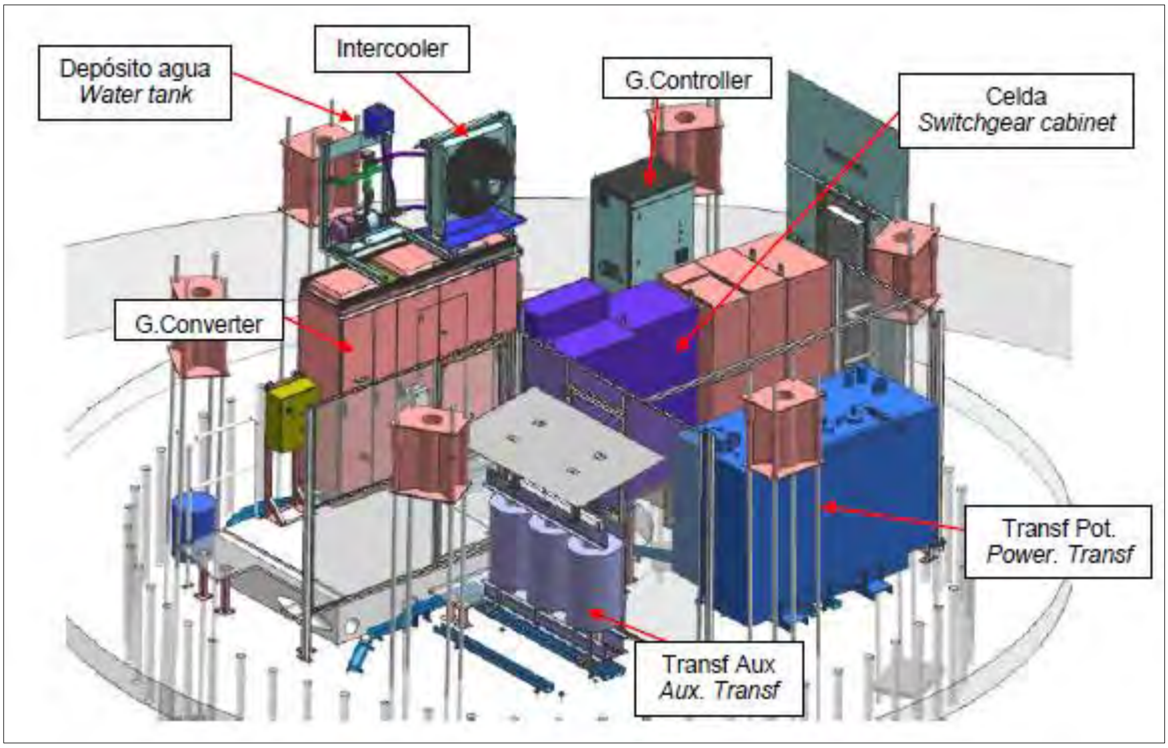


Figure 3: Base component layout

5.4 NACELLE

The nacelle is manufactured from fiber glass panels and is transparent to radio frequency signals.

The following components are installed in the nacelle

- gearbox
- generator
- ring gear
- control electronics

The gearbox and generator are connected with the drive shaft. Additional earth reference cables (bonding straps) also connect them together.
The entire nacelle rotates on a ring gear which is positioned at the top of the turbine pedestal.
Communications within the nacelle between different sub-systems will be via a shielded cable.
The nacelle component layout is shown in Figure 4

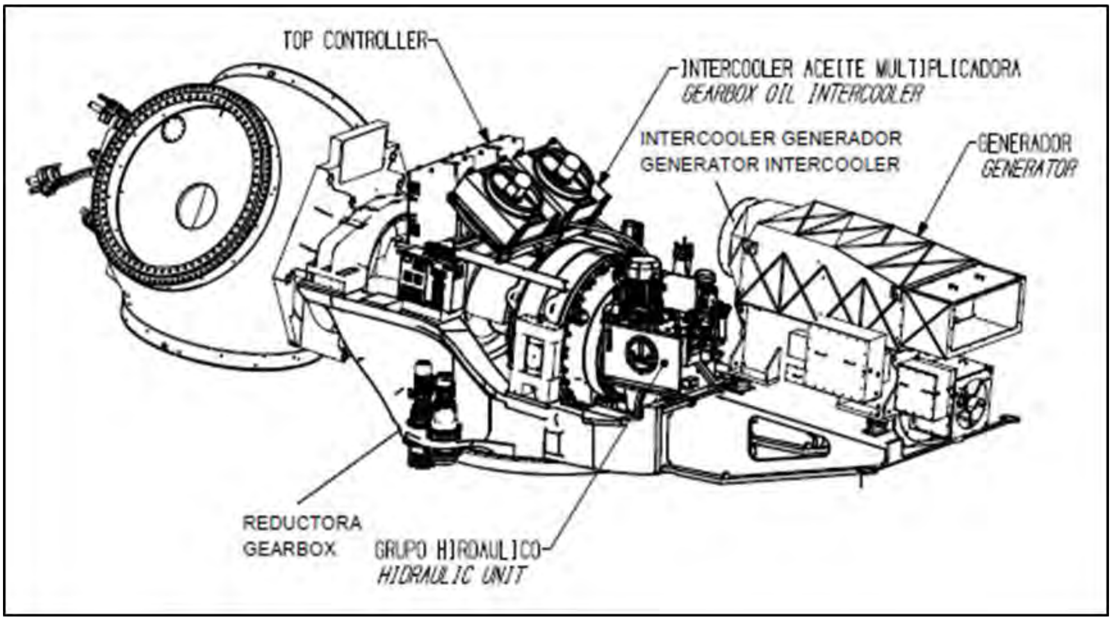


Figure 4: Nacelle layout

5.5 TOWER

The Ground Converter is connected to the Nacelle by nine power cables (rotor cables) and one control cable (generator encoder). There is also a safety system cable connection to the bottom controller.

- Power cables: Three cables per phase, each cable is 1x 300mm^2 Aluminum conductor, 400A max current at 690V. The external diameter 32mm max.
- Control cables: Connected from the bottom controller to the generator encoder, 4x2x0.5mm^2 shielded cable. The external diameter 12mm max.
- Safety system cable: Connected from the ground controller to Top with a14x0.5mm^2 shielded copper conductor. The external diameter is 14mm max.
- Earth cables: From the nacelle to the base is a 95mm^2 aluminum earth conductor that also serves as the lightning down conductor. Keystones (tower sections) are equipotentially connected to this earth cable by 25mm^2 aluminum conductors. At the base, all the earth cables are connected to the strips coming out from the foundation using four 95mm^2 aluminum cables.

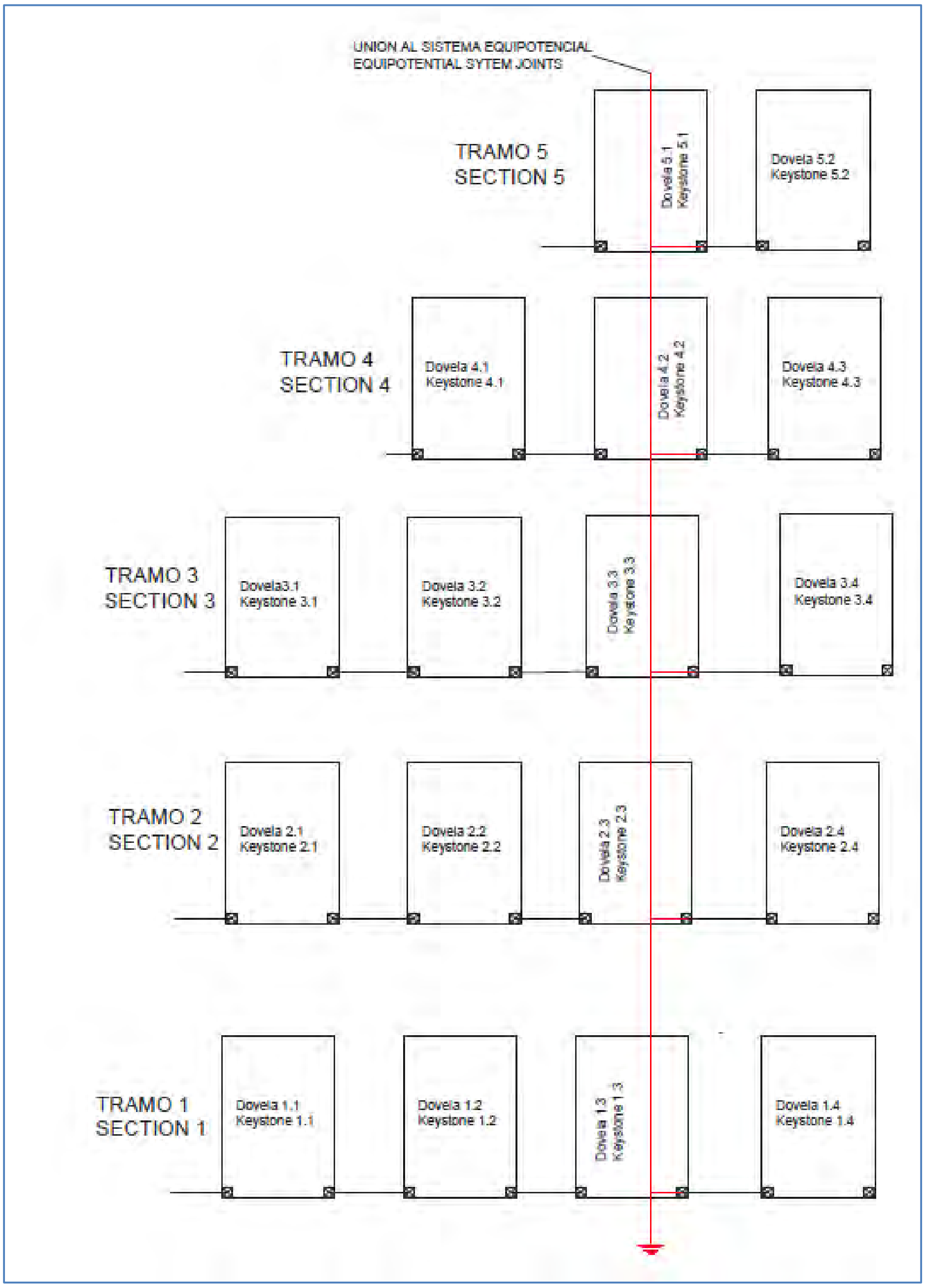


Figure 5: Tower earth cable and connections

5.6 SITE WIDE COMMUNICATIONS

The communication among the wind turbines, the met masts and windturbines and the substation will always be through an Ethernet optical fiber network as described in INP125-A.

6. EMC REQUIREMENTS

The current requirement is a 30dB reduction in radiated emissions to ensure the cumulative emission level of a wind farm is within the requirements of SKA.

7. POTENTIAL NOISE SOURCES

7.1 NACELLE

The top controller cabinet consists of two sections: Power Section as shown in Figure 6 and Control section as shown in Figure 7.

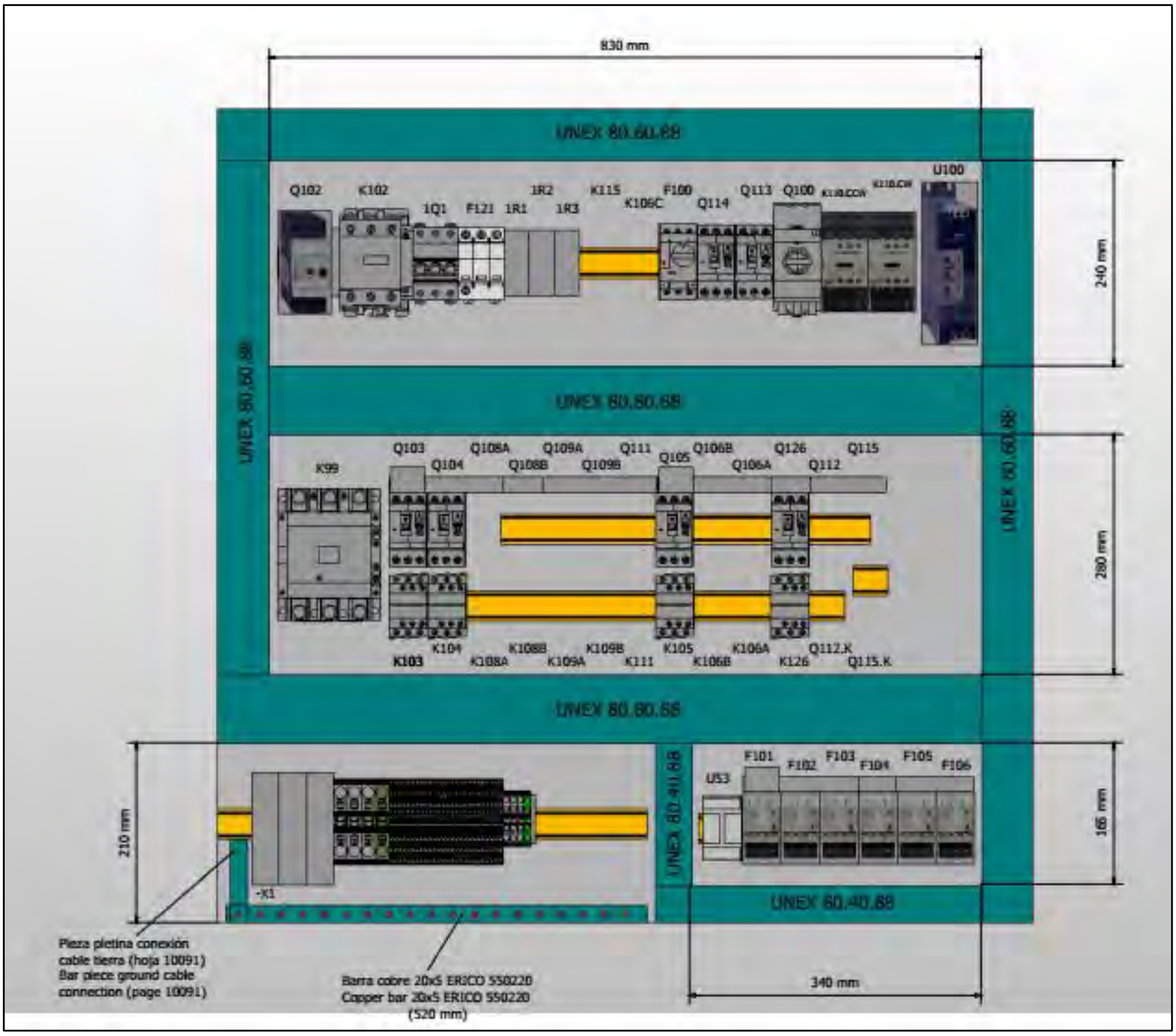


Figure 6: Power section of the top controller cabinet

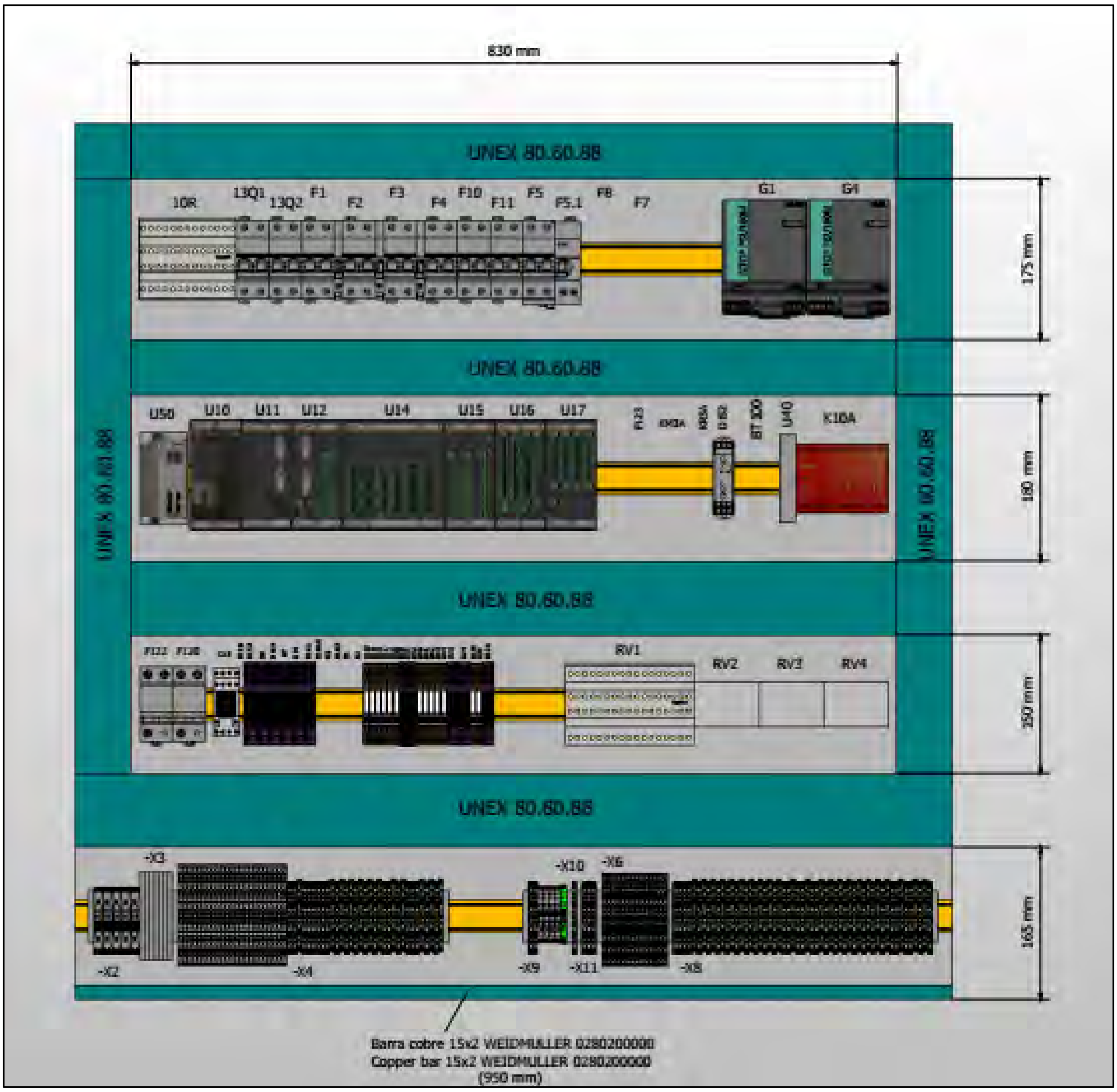


Figure 7: Control section of the top controller cabinet

Sensors and motors in the nacelle are connected to the Top Controller Cabinet. All the contactors, plc's etc. are housed inside the Top Controller Cabinet.

Although the components that generate the interference are located inside the cabinet, it would be the interconnecting cables between the cabinet and the equipment that would form the radiating element.

7.2 TOWER

The tower does not have any equipment installed; however the cabling between the nacelle and base running inside the tower is considered a radiating source.

7.3 BASE

7.3.1 Ground controller cabinet

The ground controller cabinet (Figure 8) differs from the nacelle mounted top cabinet in it being a top-bottom configuration rather than a side-by-side configuration.

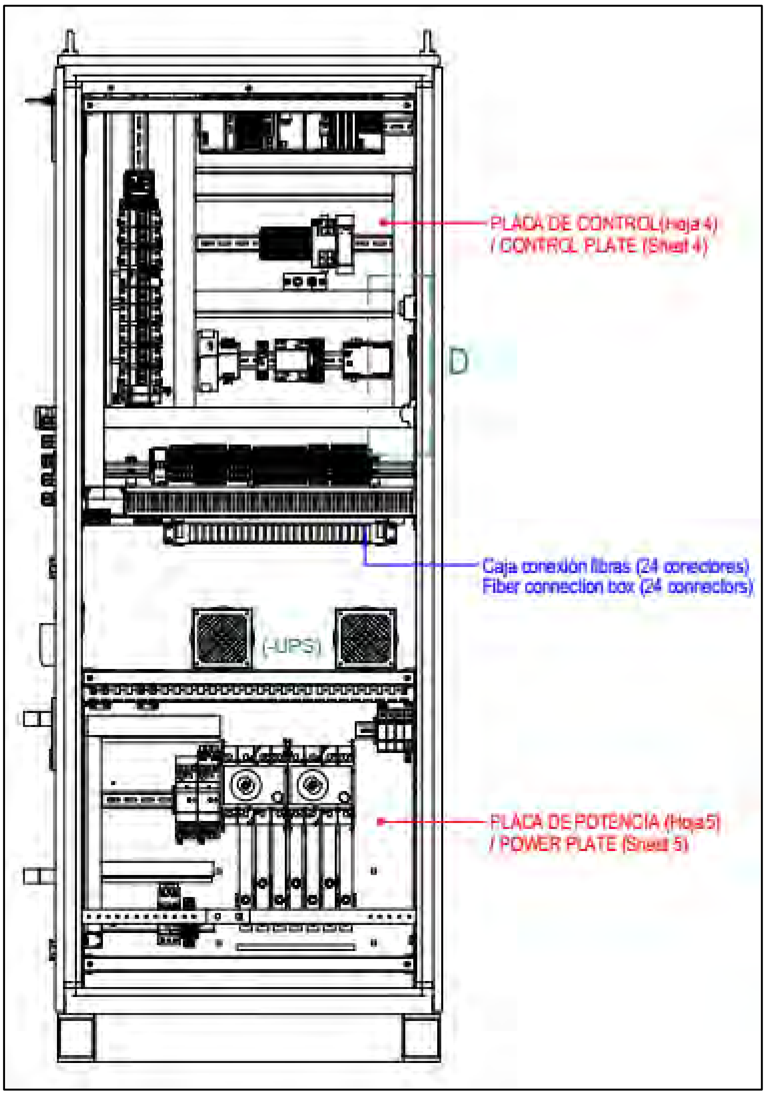


Figure 8: Bottom control cabinet

As with the top controller, interference generated inside the controller cabinet will be radiated by the interconnecting cables.

7.3.2 Ground converter

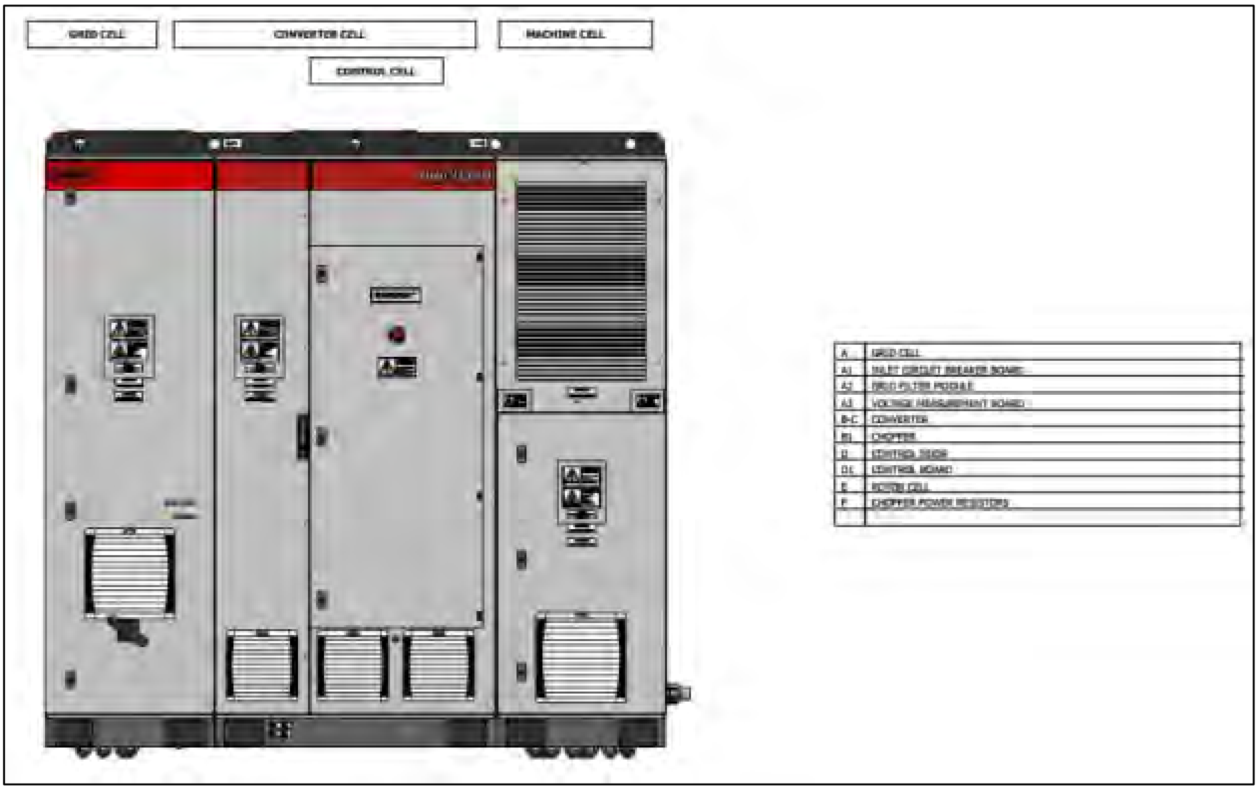


Figure 9: Ground converter cabinet

The ground converter is the most likely main interfering source as high dV/dT and dI/dT signals are generated.

Other base installed equipment such as the elevator and elevator controls, auxiliary transformer, switching cabinets etc is seen as low risk equipment as it is either temporarily used (elevator) or in a static switched position.

8. DESIGN FEATURES

The emphasis is not on redesigning a special turbine configuration, but rather to improve and control the installation.

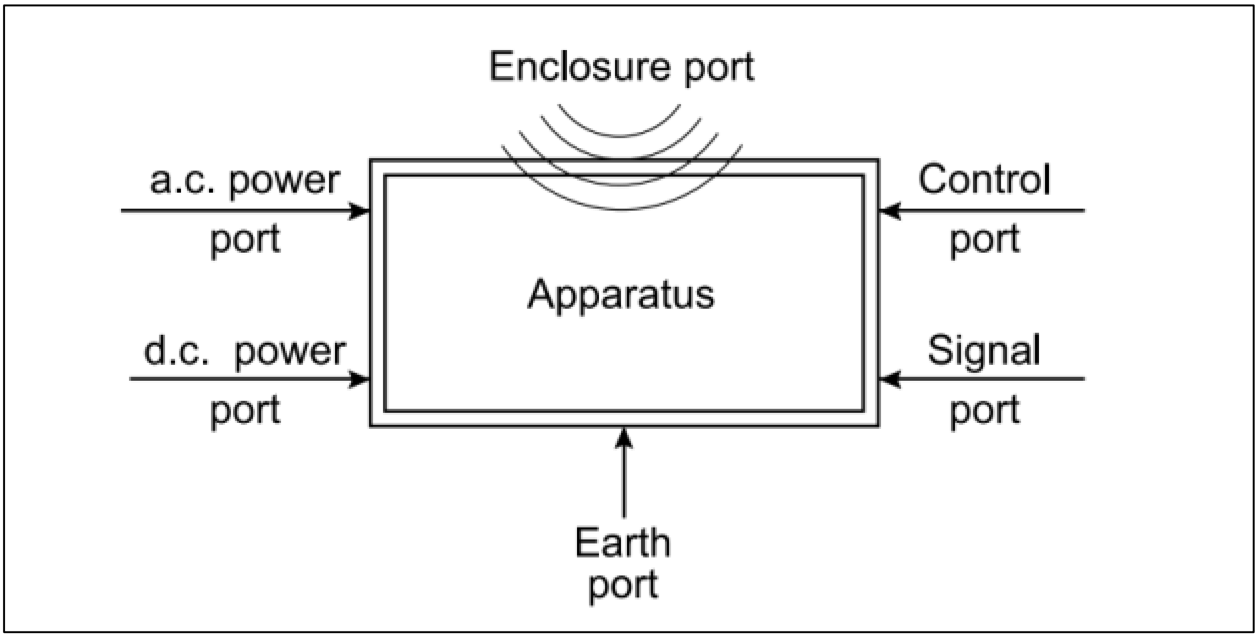


Figure 10: Port definition

Figure 10 shows how ports can be defined for leaking electromagnetic interference based on a six port scenario. Mitigation measures for the critical components will be evaluated on the general six port model.

8.1 ELECTRICAL DESIGN

The approach to EMC during installation will be to control radiated emissions by reducing noise source levels where practical and to reduce propagation efficiency. It is however not envisaged that there will be control over low level circuit design as the components used are commercial off the shelf units.

Rotor currents are sinusoidal. The frequency of the fundamental is variable and depends on the turbine rotation speed. For 50Hz turbines, the revolution range will be between 700rpm to 1200rpm (rated speed can be 1100rpm or 1200rpm, depending on the turbine type)

At 700rpm, the rotor current amplitude is low and fundamental frequency is about 15Hz.

At 1000rpm (synchronism), rotor current amplitude is near to zero and fundamental frequency is also zero.

At 1100rpm/1200rpm rotor currents are close to maximum levels and fundamental frequency is 5Hz to 10Hz.

The rotor currents will have harmonic content at the rotor side converter with a fundamental frequency, of 2kHz for the GHAC0039 model and 2.75kHz for PT0085 model.

8.1.1 Nacelle equipment

- All analog signals (sensors, emergency and DC power), CAN bus and digital signals are routed via shielded looms.
- 50Hz sinewave signals are routed via unshielded cables.
- Soft start is implemented for Yaw motors
- All the contactors have a snubber circuit for switching transients. The hydraulic pump motor is the biggest in the nacelle

8.1.2 Base equipment

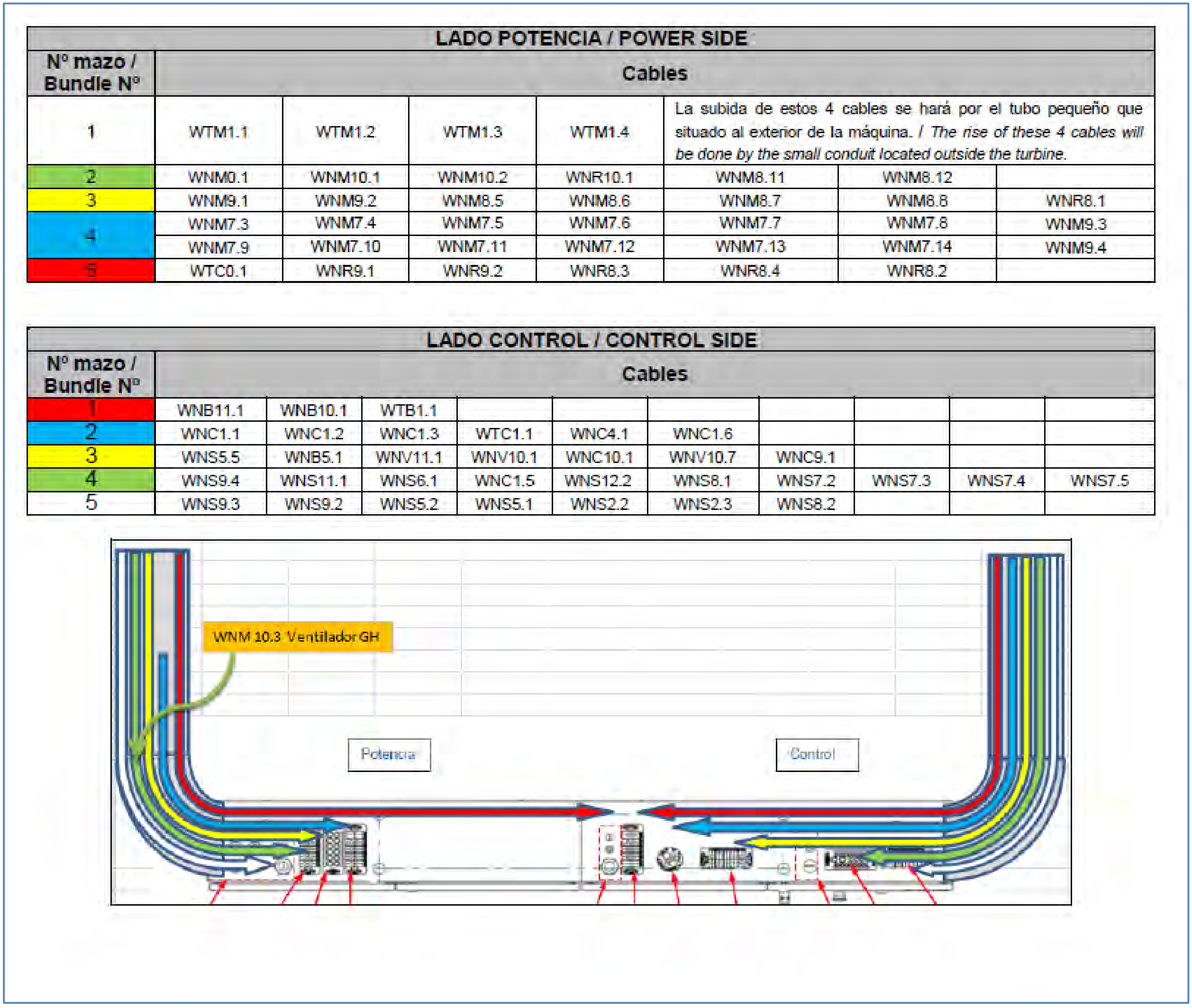
- The Controller and Converter are fitted with filters.

8.2 WIRING DESIGN

As the site wiring is most likely responsible for emitting interference signals careful consideration should be given to the types of wire and installation methodology.

8.2.1 Nacelle cable groups

The cable grouping of the nacelle is shown below in Figure 11.



LADO POTENCIA / POWER SIDE							
Nº mazo / Bundle Nº	**Cables**						
1	WTM1.1	WTM1.2	WTM1.3	WTM1.4	La subida de estos 4 cables se hará por el tubo pequeño que situado al exterior de la máquina. / *The rise of these 4 cables will be done by the small conduit located outside the turbine.*		
2	WNM0.1	WNM10.1	WNM10.2	WNR10.1	WNM8.11	WNM8.12	
3	WNM9.1	WNM9.2	WNM8.5	WNM8.6	WNM8.7	WNM8.8	WNR8.1
4	WNM7.3	WNM7.4	WNM7.5	WNM7.6	WNM7.7	WNM7.8	WNM9.3
	WNM7.9	WNM7.10	WNM7.11	WNM7.12	WNM7.13	WNM7.14	WNM9.4
5	WTC0.1	WNR9.1	WNR9.2	WNR8.3	WNR8.4	WNR8.2	

LADO CONTROL / CONTROL SIDE										
Nº mazo / Bundle Nº	**Cables**									
1	WNB11.1	WNB10.1	WTB1.1							
2	WNC1.1	WNC1.2	WNC1.3	WTC1.1	WNC4.1	WNC1.6				
3	WNS5.5	WNB5.1	WNV11.1	WNV10.1	WNC10.1	WNV10.7	WNC9.1			
4	WNS9.4	WNS11.1	WNS6.1	WNC1.5	WNS12.2	WNS8.1	WNS7.2	WNS7.3	WNS7.4	WNS7.5
5	WNS9.3	WNS9.2	WNS5.2	WNS5.1	WNS2.2	WNS2.3	WNS8.2			

Figure 11: Nacelle cable grouping

8.2.2 Tower Cable grouping

The cables between the base and nacelle are grouped as shown in Figure 12.

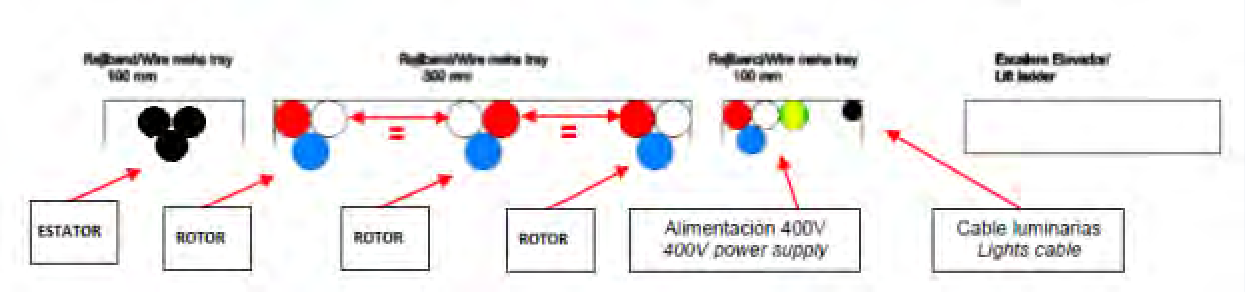


Figure 12: Tower cable grouping

8.2.3 Base cable grouping

The cables in the base are as shown in Figure 13.

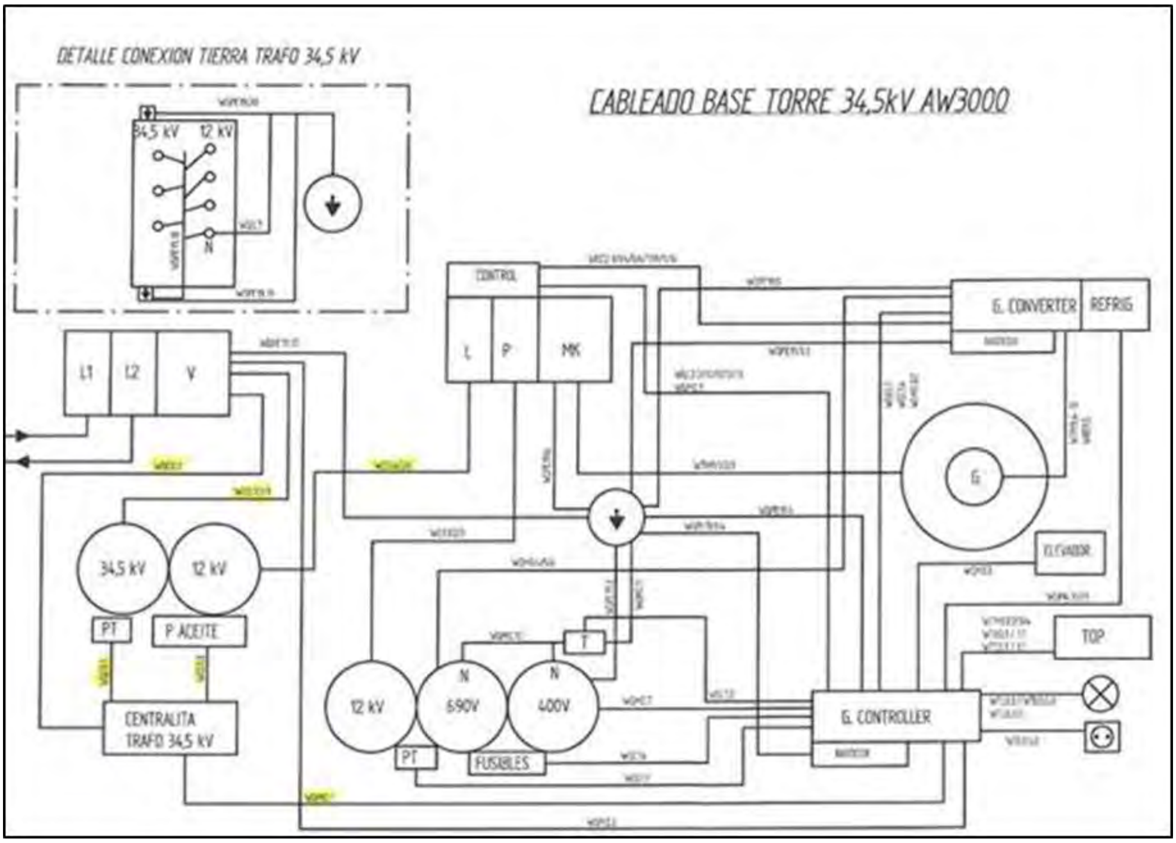


Figure 13: Tower base cabling

8.2.4 General cable practices

a. All internal screens should be terminated at both the source end and load end to minimize antenna effects.

b. Internal screens should be terminated to the external cable bundle screen by means of a knitted wire and clamp configuration or any similar technique that will ensure a maximum contact resistance of 25mΩ.

c. Pigtail connections shall not be allowed.

d. All external screens shall be terminated 360° with regard to connector back shells.

e. It is recommended that all cables shall be installed as close to a ground plane (grounded cable tray) as possible.

f. When conductors of more than one category are routed through a single connector, the conductors shall be separated and routed by category as soon as possible after exiting the connector.

g. Wires of different categories will be segregated to maximum extent possible within the constraints imposed upon packaging and interface cable design.

8.3 ELECTRICAL GROUNDING

Equipotential bonding of the nacelle equipment and hub is achieved by means of the nacelle main frame, hub, low speed shaft bearings and also through the gearbox case .Dedicated bonding conductors are used to bond the various components to the nacelle main frame.
The nacelle is bonded to the base and the foundation earth system by a conductor of 95mm^2 minimum.

A single line earth diagram with lightning protection zoning is shown in Figure 14 and the foundation equipotential diagram is shown in Figure 15.

Although the grounding system is currently designed for lightning protection and safety, more parallel connections between the nacelle and base might be required for radio frequency bonding.

8.4 BONDING

The purpose of electrical bonding is to provide structural homogeneity with respect to the flow of RF currents for proper operation of filters, fault current paths and prevents or safely discharges static charges. Electrical bonding prevents the development of electrical potentials between shield terminations, connectors and metallic enclosures to prevent personnel shock.

8.4.1 Bonding Classes

Electrical bonds are classified according to the purpose of the bond. There may be more than one purpose for bonding a specific interface, and the bond shall meet the requirements of each applicable class. The applicable classes for this project are:

a. Class H (Shock Hazard)

b. Class R (Radio Frequency)

c. Class L (Lightning)

	Power Return	**Shock Hazard**	**Radio Frequency**	**Lightning**	**Electrostatic Charge**
BOND CLASS	**CLASS "C"**	**CLASS "H"**	**CLASS "R"**	**CLASS "L"**	**CLASS "S"**
PURPOSE OF BOND	Reduces power and voltage losses. Applies to equipment & structure, which are required to return intentional current through structure.	Protects against fire or shock to personnel. Applies to equipment & structure that may be required to carry fault current in case of a short to case or structure.	Applies to equipment that could generate, retransmit, or be susceptible to RF. Covers wide frequency range.	Applies to equipment or structure that would carry current resulting from a lightning strike.	Protects against electrostatic discharge. Applies to any item subject to electrostatic charging.
BOND REQT	Requires low impedance & low voltage across joints to assure adequate power to the user. Jumpers and Straps acceptable.	Requires low impedance & low voltage across joints to prevent shock hazard or fire due to short. Jumpers and straps acceptable.	Requires low RF impedance at high frequency. Direct contact preferred. No jumpers. Short, wide strap may be used as last resort.	Requires low impedance at moderate frequency. Bonding components must withstand high current. Straps and jumpers must withstand high magnetic forces.	Allows moderate impedance. Jumpers and straps acceptable.

	Power Return	**Shock Hazard**	**Radio Frequency**	**Lightning**	**Electrostatic Charge**
BOND CLASS	**CLASS "C"**	**CLASS "H"**	**CLASS "R"**	**CLASS "L"**	**CLASS "S"**
DC BOND RESISTANCE REQT.	Bonding resistance requirement depends on current.	Bonding resistance requirement, 0.1 ohm or less. Special requirements when near flammable vapours.	Bonding resistance requirement, 5.0 milliohms or less. Low inductance required.	Bonding resistance Requirement depends on current. Low inductance required.	Typical bonding resistance requirement, 1.0 ohm or less.
FREQ. REQT.	Low	Low	High	High	Low
CURRENT REQT.	High	High	Low	High	Low
Low frequency bonds allow use of straps and jumpers. High frequency bonds require low inductance paths. Short straps sometimes acceptable. High current bonds require large cross sectional areas. Low current bonds allow use of small contact areas.					

Table 1 Summary of Electrical Bonding Classes

The following design criteria will be followed:

a. Bonding will be designed into the system. Specific attention will be directed to the interconnections between conductors and between structural members.

b. Metal surfaces allocated for bonding, will be controlled for flatness surface finish and cleanliness.

c. Insofar possible, bonds will be made between similar metals. When different metals are to be bonded, the materials will be selected for maximum galvanic compatibility.

d. Protection of the bond from moisture and other corrosive elements will be recommended

e. Bonds should be installed in accessible locations for inspections, tests and maintenance.

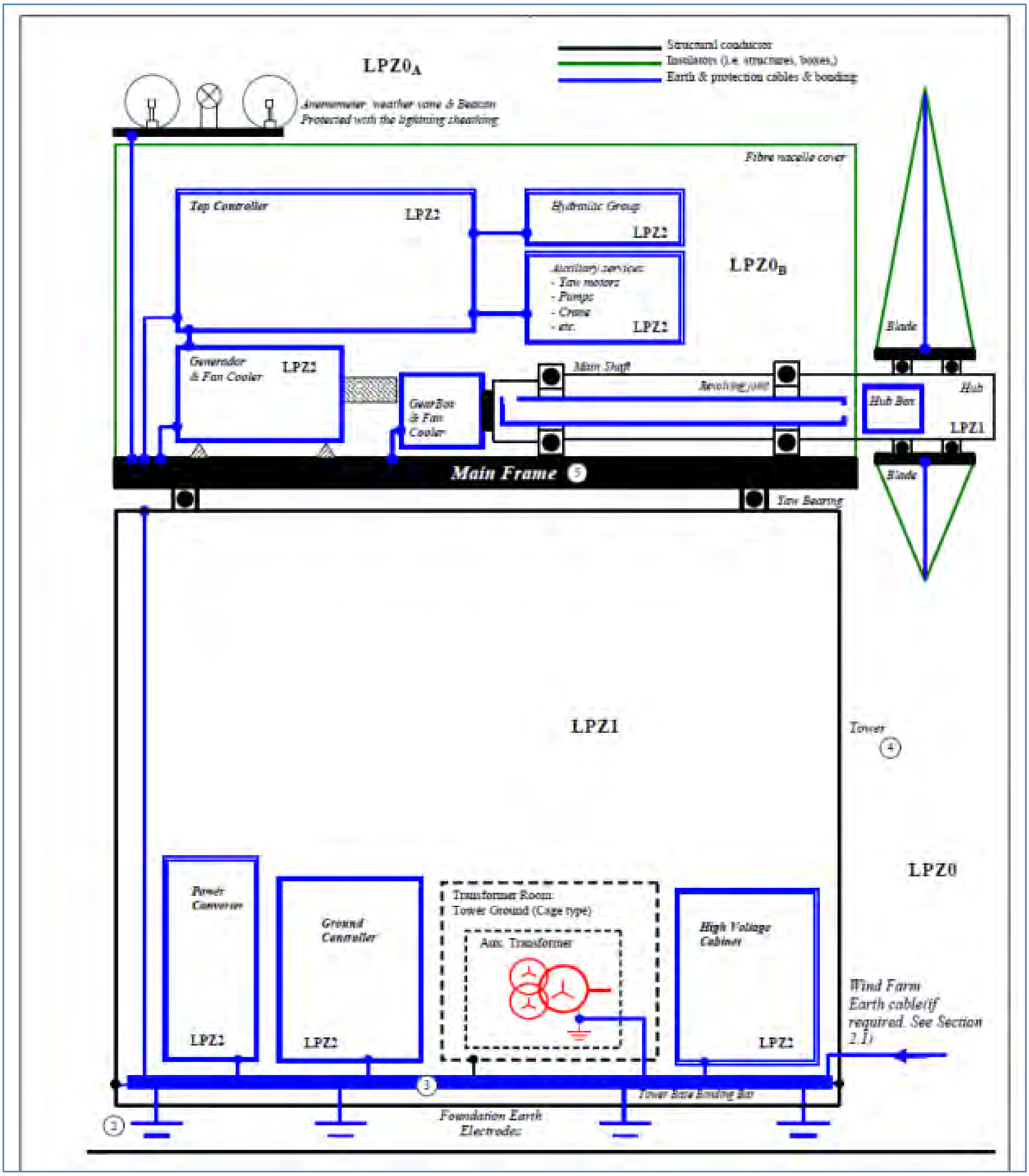


Figure 14: Equipotential system and lightning protection zones

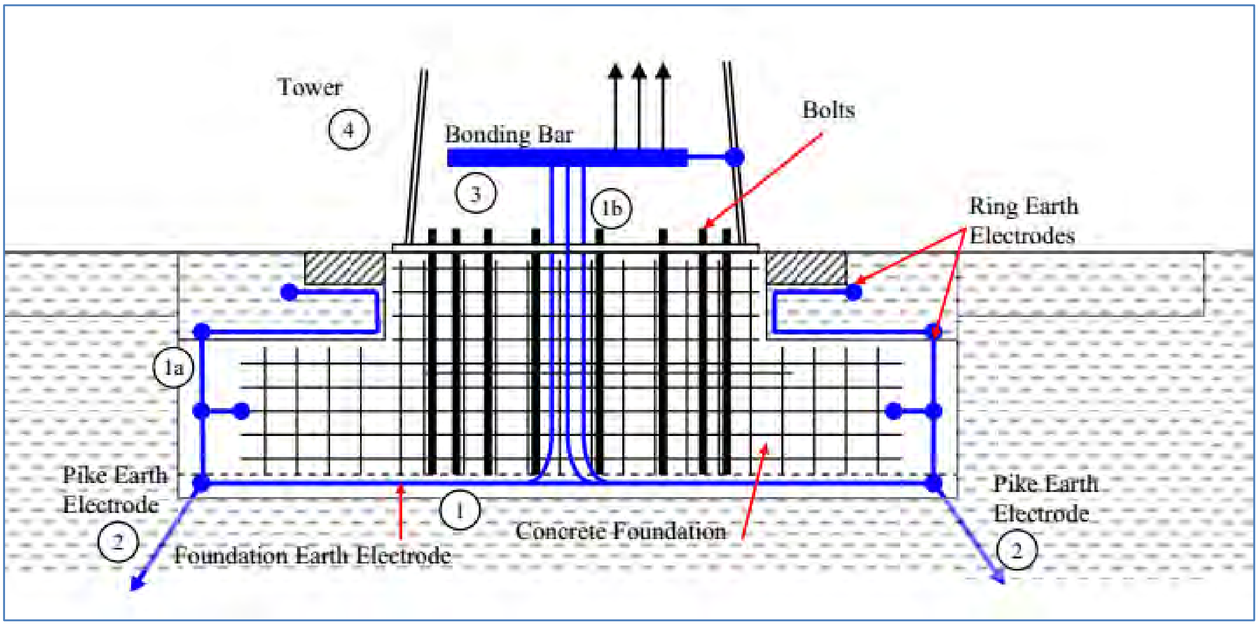


Figure 15: Foundation earth equipotential diagram

9. MECHANICAL DESIGN

9.1 ENCLOSURE MATERIALS

CONVERTER ENCLOSURE		
Item	**Description**	**Value**
1	Enclosure Height	2189,5 mm
2	Enclosure Width	2293 mm
3	Enclosure Depth	670 mm
4	Material Thickness	2mm
5	Type of enclosure, e.g.	
	Metal framed plastic enclosure	
	Metallised plastic enclosure	
	Sheet-metal enclosure	X
	Milled enclosure	
6	Enclosure surface impedance in ohms/square	The impedance does not exceed 100m Ohms for the power and auxiliary circuits.
7	Enclosure individual aperture dimensions. There might be more than one aperture per enclosure. (fuse holder, connector etc)	Apart from main connections , air inlets and fans
8	Enclosure lid overlap depth	40 mm
9	Centre to centre fastener spacing of lid	600 mm in lids,350 mm in doors
10	Specification of EMI gaskets used	No EMI gasket

Table 2: Converter enclosure mechanical details

TOP ENCLOSURE		
Item	**Description**	**Value**
1	Enclosure Height	1040mm
2	Enclosure Width	2138mm
3	Enclosure Depth	298mm
4	Material Thickness	2mm
5	Type of enclosure, e.g.	
	Metal framed plastic enclosure	
	Metallised plastic enclosure	
	Sheet-metal enclosure	x
	Milled enclosure	
6	Enclosure surface impedance in ohms/square	The impedance does not

TOP ENCLOSURE		
Item	**Description**	**Value**
		exceed 100m Ohms for the power and auxiliary circuits.
7	Enclosure individual aperture dimensions. There might be more than one aperture per enclosure. (fuse holder, connector etc)	Only main connections.
8	Enclosure lid overlap depth	20 mm
9	Centre to centre fastener spacing of lid	400 mm in lids and doors
10	Specification of EMI gaskets used	No EMI gasket

Table 3: Top enclosure mechanical detail

9.2 SHIELDING

The enclosures will perform a critical function with regard to shielding from EMI, both for radiation and susceptibility. The design goal for the different enclosure's shielding effectiveness for electric field radiation should be a minimum of 30dB from 30MHz to 3GHz. The shielding effectiveness of the enclosures should be maximized using the following principles.

a. Mechanical discontinuities will be kept to a minimum.

b. All necessary mechanical discontinuities will be electrically continuous using conductive gaskets. The gasket material should at least have an electric field attenuation of 30dB minimum between 30MHz and 10GHz.

c. The wave-guide below cut-off (WGBCO) principle will be applied for all drain holes.

d. The wave-guide below cut-off (WGBCO) principle will be applied for applicable apertures such as cooling vents etc where needed.

e. Provisions will be made to control surface flatness to ensure constant and uniformly distributed contact pressure across metal-to-metal bonded joints.

10. EMC ANALYSIS

As a working system is available for measurements, actual values are to be used during further analyses rather than a theoretic analysis.

10.1 SITE LOCATION

10.1.1 Area Map

Picture 1: Area map showing Aletta locations relative to SKA

Three WTG locations (WTG 1, WTG 25 and WTG 31) and four SKA installations were used for the evaluation.

10.1.2 Local Map

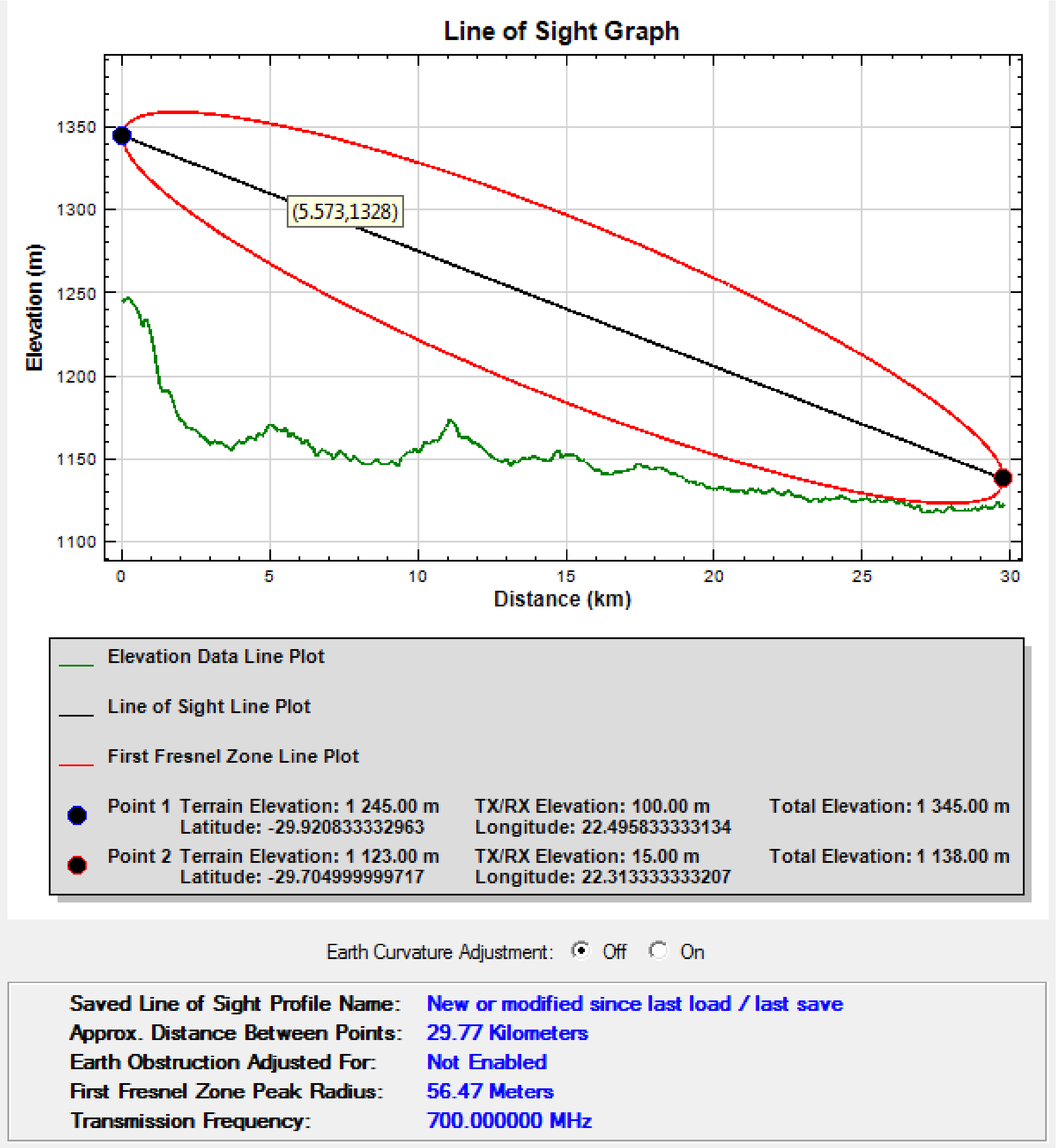
Picture 2: Local map showing nearest four SKA Locations

10.1.3 Distance Table

	Aletta WTG 1	**Aletta WTG 25**	**Aletta WTG 31**
SKA 004 (Phase 1)	46.52km	50.22km	44.63km
SKA ID 1895 (Phase 2)	29.77km	29.39km	42.46km
SKA ID 1890 (Phase 2)	26.78km	30.65km	24.99km
SKA ID 2348 (Phase 2)	53.42km	53.38km	40.88km
MeerKAT (Core)	119.82km	121.6km	119.96km

Table 4: New Aletta layout distance from SKA infrastructure

10.1.4 Elevation Maps

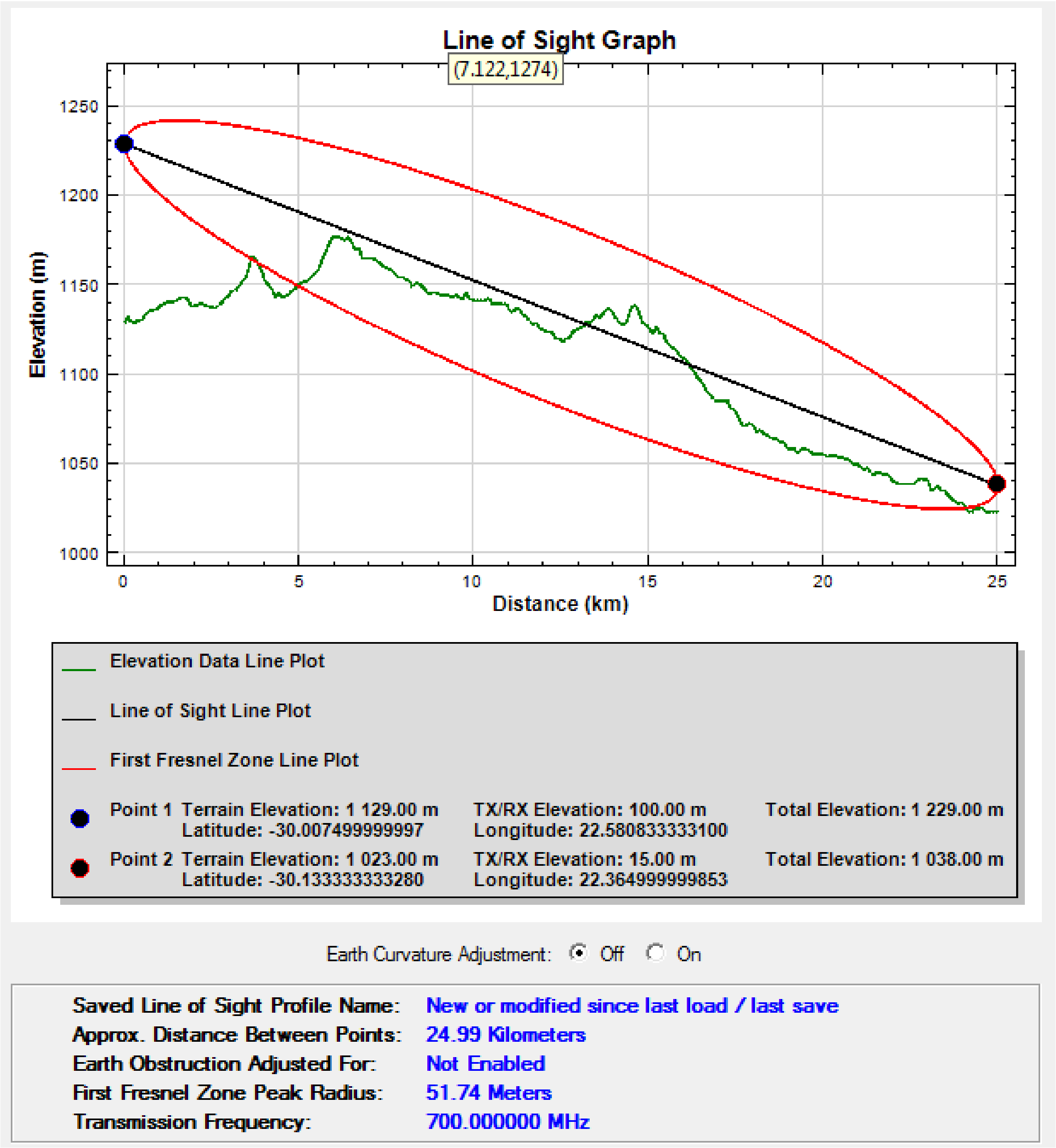


Point 1	Terrain Elevation: 1 245.00 m Latitude: -29.920833332963	TX/RX Elevation: 100.00 m Longitude: 22.495833333134	Total Elevation: 1 345.00 m
Point 2	Terrain Elevation: 1 123.00 m Latitude: -29.704999999717	TX/RX Elevation: 15.00 m Longitude: 22.313333333207	Total Elevation: 1 138.00 m

Earth Curvature Adjustment: ● Off ○ On

Saved Line of Sight Profile Name:	New or modified since last load / last save
Approx. Distance Between Points:	29.77 Kilometers
Earth Obstruction Adjusted For:	Not Enabled
First Fresnel Zone Peak Radius:	56.47 Meters
Transmission Frequency:	700.000000 MHz

Figure 16: WTG 1 to SKA ID 1895



Elevation Data Line Plot

Line of Sight Line Plot

First Fresnel Zone Line Plot

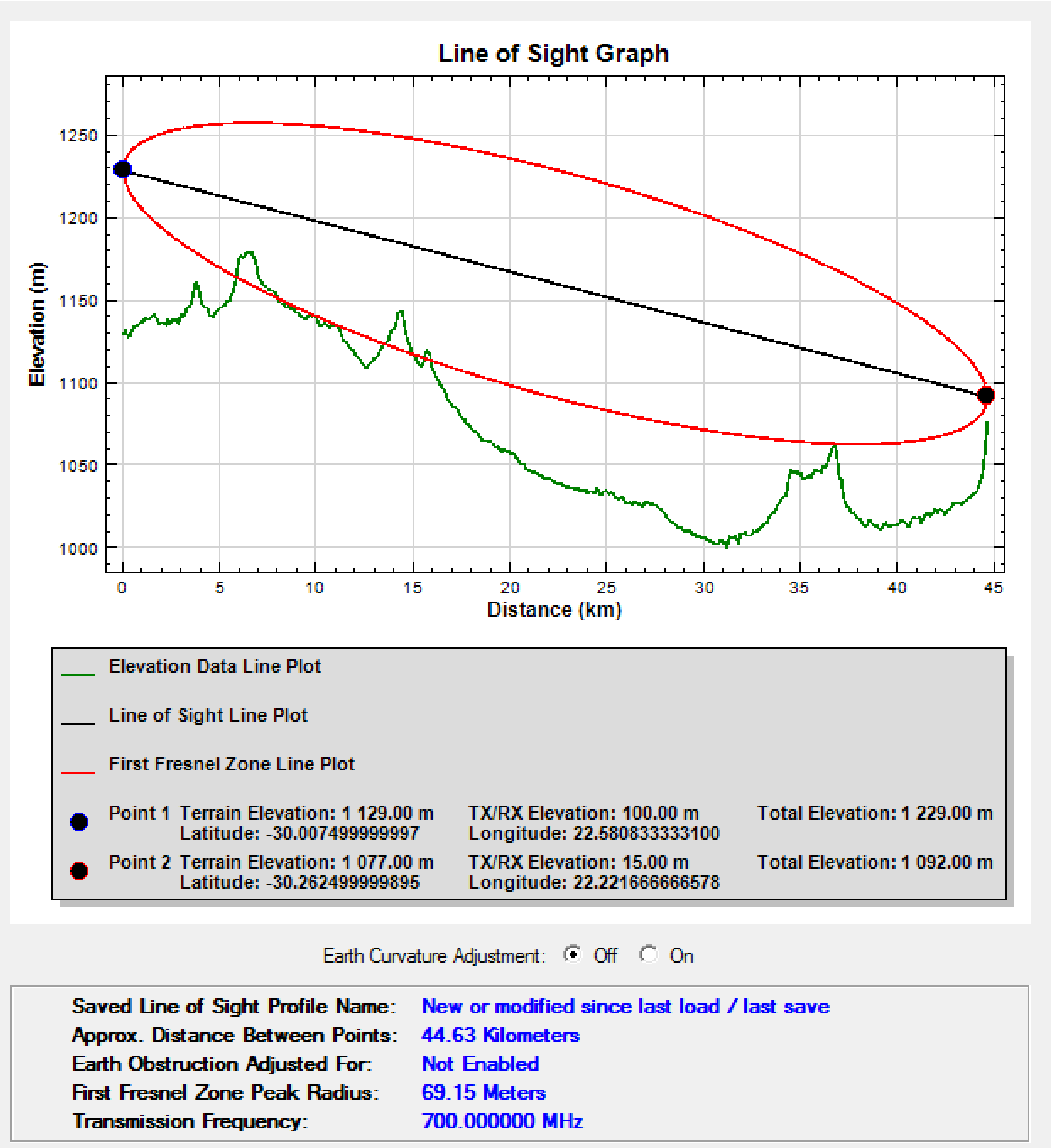
● Point 1 Terrain Elevation: 1 129.00 m TX/RX Elevation: 100.00 m Total Elevation: 1 229.00 m
Latitude: -30.007499999997 Longitude: 22.580833333100

● Point 2 Terrain Elevation: 1 023.00 m TX/RX Elevation: 15.00 m Total Elevation: 1 038.00 m
Latitude: -30.133333333280 Longitude: 22.364999999853

Earth Curvature Adjustment: ● Off ○ On

Saved Line of Sight Profile Name:	New or modified since last load / last save
Approx. Distance Between Points:	24.99 Kilometers
Earth Obstruction Adjusted For:	Not Enabled
First Fresnel Zone Peak Radius:	51.74 Meters
Transmission Frequency:	700.000000 MHz

Figure 17: WTG 31 to SKA ID 1890



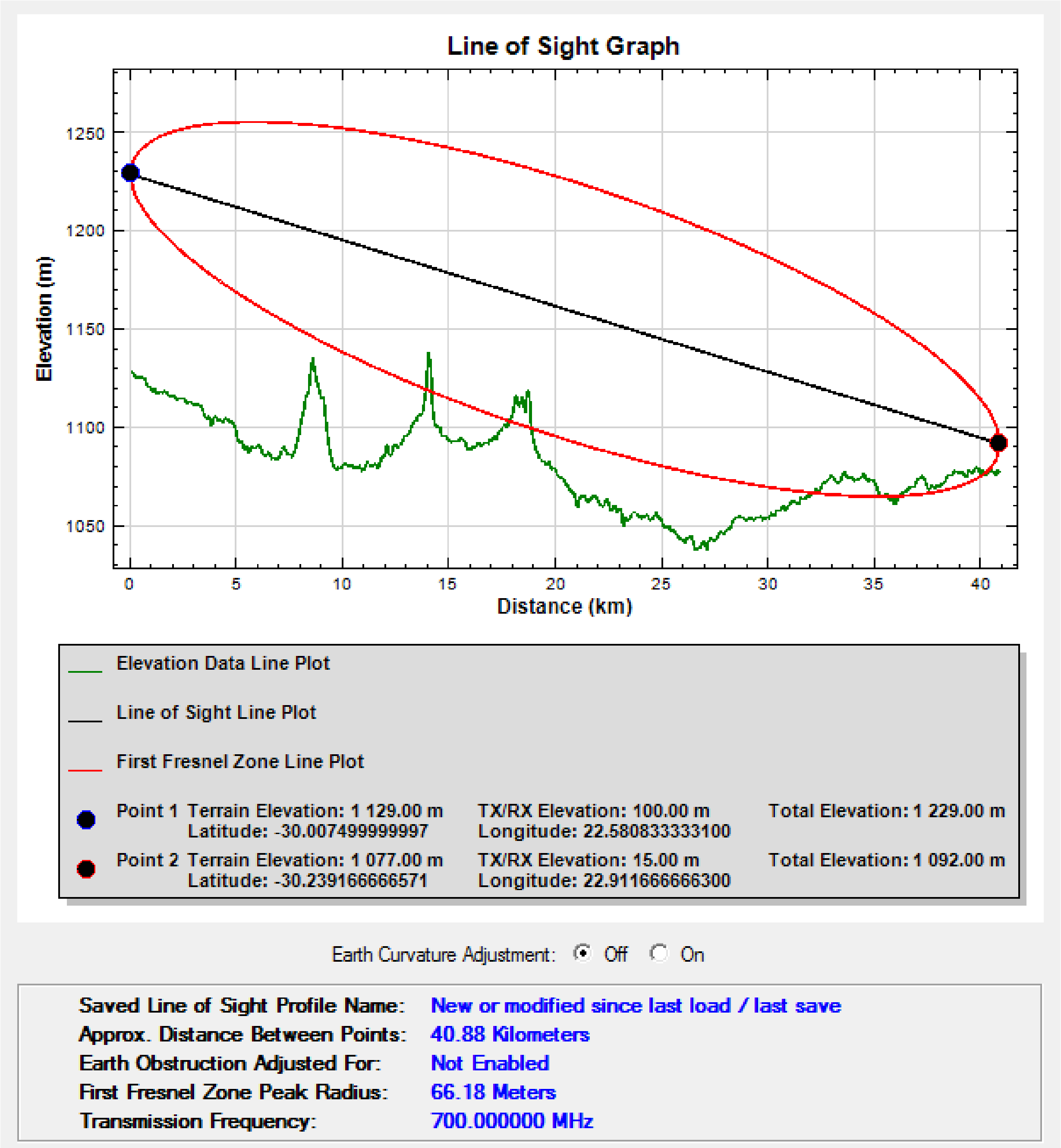
Point 1 Terrain Elevation: 1 129.00 m TX/RX Elevation: 100.00 m Total Elevation: 1 229.00 m
Latitude: -30.007499999997 Longitude: 22.580833333100

Point 2 Terrain Elevation: 1 077.00 m TX/RX Elevation: 15.00 m Total Elevation: 1 092.00 m
Latitude: -30.262499999895 Longitude: 22.221666666578

Earth Curvature Adjustment: ● Off ○ On

Saved Line of Sight Profile Name: New or modified since last load / last save
Approx. Distance Between Points: 44.63 Kilometers
Earth Obstruction Adjusted For: Not Enabled
First Fresnel Zone Peak Radius: 69.15 Meters
Transmission Frequency: 700.000000 MHz

Figure 18: WTG 31 to SKA 004



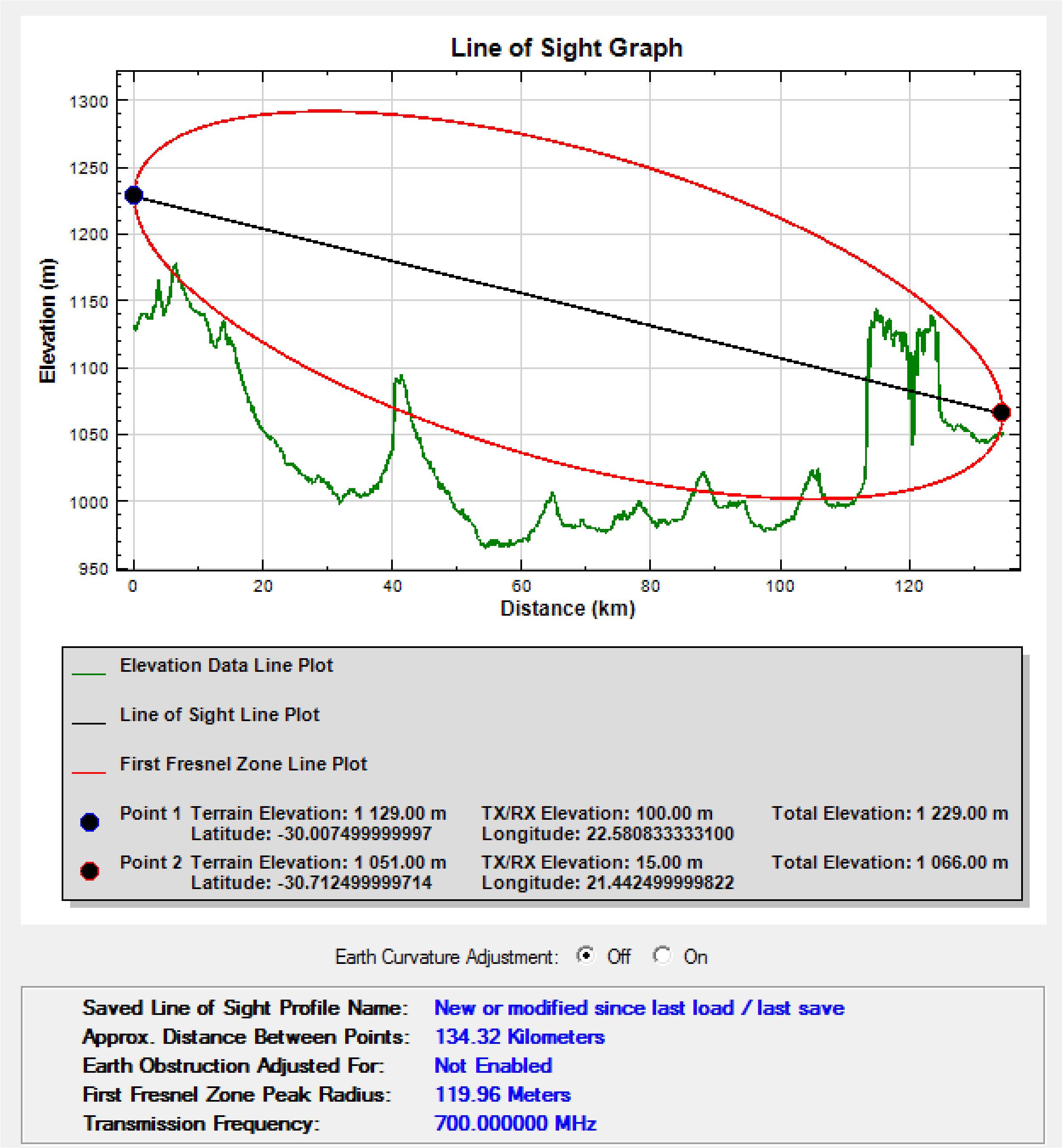
● Point 1 Terrain Elevation: 1 129.00 m TX/RX Elevation: 100.00 m Total Elevation: 1 229.00 m
Latitude: -30.007499999997 Longitude: 22.580833333100

● Point 2 Terrain Elevation: 1 077.00 m TX/RX Elevation: 15.00 m Total Elevation: 1 092.00 m
Latitude: -30.239166666571 Longitude: 22.911666666300

Earth Curvature Adjustment: ● Off ○ On

Saved Line of Sight Profile Name: New or modified since last load / last save
Approx. Distance Between Points: 40.88 Kilometers
Earth Obstruction Adjusted For: Not Enabled
First Fresnel Zone Peak Radius: 66.18 Meters
Transmission Frequency: 700.000000 MHz

Figure 19: WTG 31 to SKA 2348



Elevation Data Line Plot

Line of Sight Line Plot

First Fresnel Zone Line Plot

● Point 1 Terrain Elevation: 1 129.00 m TX/RX Elevation: 100.00 m Total Elevation: 1 229.00 m
Latitude: -30.007499999997 Longitude: 22.580833333100

● Point 2 Terrain Elevation: 1 051.00 m TX/RX Elevation: 15.00 m Total Elevation: 1 066.00 m
Latitude: -30.712499999714 Longitude: 21.442499999822

Earth Curvature Adjustment: ● Off ○ On

Saved Line of Sight Profile Name: New or modified since last load / last save
Approx. Distance Between Points: 134.32 Kilometers
Earth Obstruction Adjusted For: Not Enabled
First Fresnel Zone Peak Radius: 119.96 Meters
Transmission Frequency: 700.000000 MHz

Figure 20: WTG 31 to the MeerKAT Core

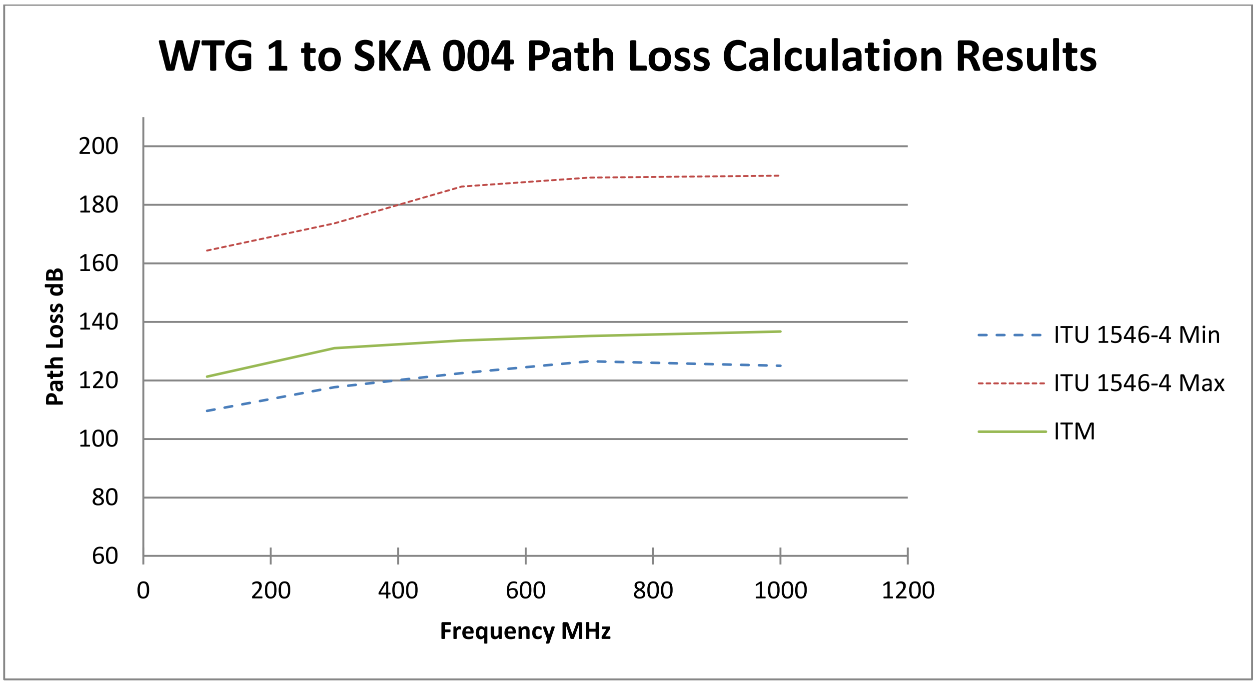
10.2 PATH LOSS CALCULATIONS

The path loss was calculated using the parameters as specified in Table 5: Path loss input data.

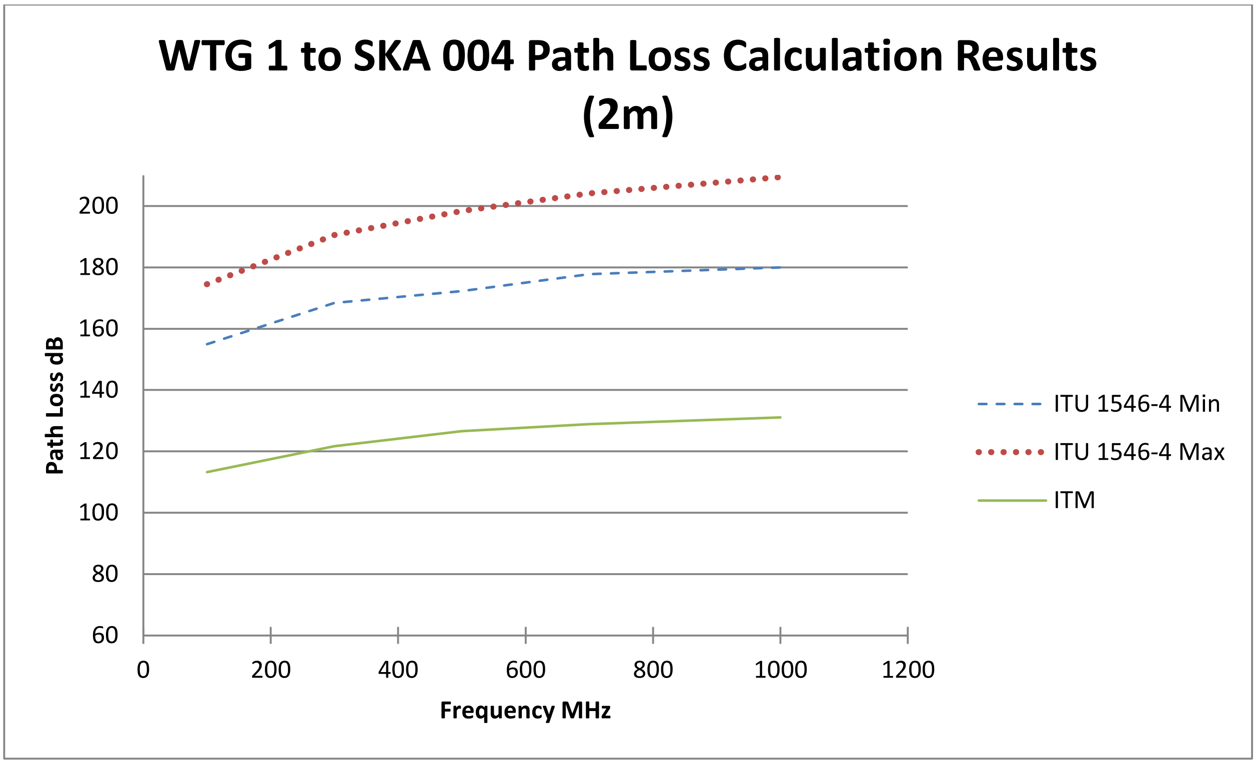
Parameter	Description	Quantity	Comment
Source/ Victim separation distance	SKA 004 to WTG 31	44.63km	Line of sight conditions
Frequency	Frequencies assessed	100MHz, 300MHz, 500MHz, 1000MHz, 3000MHz, 6000MHz	Free space loss increases with frequency.
SARAS	Protection level	dBm/Hz = -17.2708 log 10 (f) -192.0714 for f<2GHz	Government Gazette 10 February 2012

Location	WTG 31	Latt: -29.860263° Long: 22.360129°	Waypoint received from Biotherm Energy (Pty) Ltd
Location	SKA 004	Latt: -30.262608 Long: 22.221794	Waypoint received from SKA SA (Pty) Ltd
TX height	Nacelle Base	100m 2m	Height of nacelle eqp Height of base eqp
RX height	All SKA receivers	15m	Height used for SKA receive horn

Table 5: Path loss input data



Graph 1: WTG 1 (100m height) to SKA 004 Path Loss Calculation result



Graph 2: WTG 1 (2m) to SKA 004 Path Loss Calculation result

Graph 1 and Graph 2 shows worst case path loss calculations for the nacelle equipment emissions at 100m hub height and for base equipment at a 2m height. Although not the worst case, these values were used for the analysis as they are within 6dB of the WTG 1 to SKA ID 1895 values. SKA 004 is however a SKA 1 installation and SKA ID 1895 is a SKA 2 installation.

SPLAT! (Signal Propagation, Loss And Terrain) analysis was used to calculate the ITM path loss values. SPLAT! Is based on the Longley –Rice Irregular Terrain Model and Irregular Terrain With Obstruction Model. The digital elevation model resolution data used was 3-arc –seconds.

The ITU 1546-4 was calculated with Monte Carlo based ITU 1546-4 path loss software to obtain a minimum and maximum path loss values.

A factor of 10 $\log_{10}$ N where N = the number of turbines to account for cumulative emissions is normally account for.

10.3 SIGNAL LIST

Following are the WTG Signal lists. Not all signals are considered critical and not all signals will therefore be analyzed or measured.

10.3.1 Base to Nacelle

Ref		From		To		Signal description	Voltage	Length	Wire type	Transient Voltage Protection	Filter	Shield
		Unit	Connector	Unit	Connector							
1027781	WTM9.4/9.5/9.6/9.7/9.8/9.9/9.10/9.11/9.12: rotor cable	Converter	U2,V2,W2	Generator	K,L,M			112	RZ1-K 1,8/3kV 1x300mm² Al - BT*	Converter manual		No
1027781	WTM9.4/9.5/9.6/9.7/9.8/9.9/9.10/9.11/9.12: rotor cable	Converter	U2,V2,W2	Generator	K,L,M			112	RZ1-K 1,8/3kV 1x300mm² Al - BT*			No
1027781	WTM9.4/9.5/9.6/9.7/9.8/9.9/9.10/9.11/9.12: rotor cable	Converter	U2,V2,W2	Generator	K,L,M			112	RZ1-K 1,8/3kV 1x300mm² Al - BT*			No
1027781	WTM9.4/9.5/9.6/9.7/9.8/9.9/9.10/9.11/9.12: rotor cable	Converter	U2,V2,W2	Generator	K,L,M			112	RZ1-K 1,8/3kV 1x300mm² Al - BT*			No
1027781	WTM9.4/9.5/9.6/9.7/9.8/9.9/9.10/9.11/9.12: rotor cable	Converter	U2,V2,W2	Generator	K,L,M			112	RZ1-K 1,8/3kV 1x300mm² Al - BT*			No
1027781	WTM9.4/9.5/9.6/9.7/9.8/9.9/9.10/9.11/9.12: rotor cable	Converter	U2,V2,W2	Generator	K,L,M			112	RZ1-K 1,8/3kV 1x300mm² Al - BT*			No
1027781	WTM9.4/9.5/9.6/9.7/9.8/9.9/9.10/9.11/9.12: rotor cable	Converter	U2,V2,W2	Generator	K,L,M			112	RZ1-K 1,8/3kV 1x300mm² Al - BT*			No
1027781	WTM9.4/9.5/9.6/9.7/9.8/9.9/9.10/9.1	Converter	U2,V2,W2	Generator	K,L,M			112	RZ1-K 1,8/3kV 1x300mm² Al - BT*			No

Ref		From Unit	Connector	To Unit	Connector	Signal description	Voltage	Length	Wire type	Transient Voltage Protection	Filter	Shield
	1/9.12: rotor cable											
1027781	WTM9.4/9.5/9.6/9.7/9.8/9.9/9.10/9.11/9.12: rotor cable	Converter	U2,V2,W2	Generator	K,L,M			112	RZ1-K 1,8/3kV 1x300mm² Al - BT*			No
1029193	WNS9.5: Generator encoder	Converter	XENC	Generator	1,2,3,4,5,6,7,8	Encoder specification		130	LiHCH 4x2x0.5mm² - BT*			Yes
1021307	WTC1.1: Safety system	Controlller	X3 (1A,1B,2A,2B,3A,3C,4A,4C,5A,5C,6A,6B,7A,7B)	TOP	X3 (19A,19B,201,20B,21A,21B,22A,22B,23A,23B)	Continuous	24V	130	LiHCH 14x0.5mm² - BT*			Yes
1008139	WTC0.1: Top controller auxiliaries	Controlller	X2	TOP	X2 (1,2,3,4)	Sinewave	230V	130	H07ZZ-F 5G6mm² - LT*			No
1029099	WTB1.1: Optic fiber	Controller	U52 (TX,RX)	TOP	U20 (TX,RX)			130	Fibra óptica 4xMM G50/125 OM2 - BT*			-
1043064	WTM1.1 T5 400V power supply cable	TOP	X1 (1)	Controller	X1.1	Sinewave	400V	112	DZ-F 0.6/1kV 1x50mm² BT*	400V filter		No
1043064	WTM1.2 T5 400V power supply cable	TOP	X1 (2)	Controller	X1.1	Sinewave	400V	112	DZ-F 0.6/1kV 1x50mm² BT*			No
1043064	WTM1.3 T5 400V power supply cable	TOP	X1 (3)	Controller	x1.1	Sinewave	400V	112	DZ-F 0.6/1kV 1x50mm² BT*			No

Table 6: Base to Nacelle signal list

10.3.2 Base Signals

Ref		From		To		Signal description	Voltage	Length	Wire type	Transient Voltage Protection	Filter	Shield
		Unit	Connector	Unit	Connector							
1009528	WGM0.4/0.5 /0.6: 630kVA transformer 690V side - Power converter power supply	Converter	Q1 (1,3,5)	Transformer	3U/3V/3W	Sinewave	690V	7	RZ1-K 0,6/1KV 1x300mm² - BT*	Converter manual		No
1008141	WGC2.8: Switch cabinet (12kV drive circuit breaker failure) - power converter	Converter	X24 (14,12)	Switch Cabinet	11/9	Digital	24V	11	RC4Z1-K 2x1mm² - BT* (Azul - marrón)			Yes
1008141	WGC2.9: Switch cabinet (stator contactor feedback) - power converter	Converter	X24(2,10)	Switch Cabinet	R (13,14)	Digital	24V	11	RC4Z1-K 2x1mm² - BT* (Azul - marrón)			Yes
1008141	WGC2.6: Switch cabinet (line protection no trip) - power converter	Converter	X24 (1,11)	Switch Cabinet	S(8,4)	Digital	24V	11	RC4Z1-K 2x1mm² - BT* (Azul - marrón)			Yes
1024946	WGC2.5: Switch cabinet (stator current measureme	Converter	XIS(1,2,3,4, 5,6)	Switch Cabinet	BPMA(2,4,6,8)	Analogical		11	RC4Z1-K 2x1mm² - BT* (Azul - marrón)			Yes

Ref		From		To		Signal description	Voltage	Length	Wire type	Transient Voltage Protection	Filter	Shield
		Unit	Connector	Unit	Connector							
	nt) - power converter											
1028656	WGC2.1: Switch cabinet (stator connection order) - power converter	Converter	X4 (1A,1B)	Switch Cabinet	TM (1,2)	Signal	230V	11	RC4Z1-K 2x1mm² - BT* (Azul - marrón)			Yes
1028656	WGC2.14: Stator emergency oppening contactor (converter-switch cabinet control box)	Converter	X4 (1C,1D)	Switch Cabinet	TM(5,6)	Signal	230V	11	RZ1-K 0,6/1kV 2x1,5mm² - BT*			Yes
1008141	WGC2.7: Switch cabinet (overcurrent relay trip) - power converter	Converter	X24 (5,6)	Switch Cabinet	RS(4,3)	Digital	24V	11	RC4Z1-K 2x1mm² - BT* (Azul - marrón)			Yes
1010682	WGB3.1: optical fiber power converter - ground controller	Converter	XOP (1,2)	Controller	U6 (X1, X2))			10	Fibra óptica 4xHCS + 4x50MM con cubierta de poliuretano LSZH - BT*			-
1008145	WGC2.3: Switch cabinet (grid voltage measurement) - power converter	Converter	XMED (4,5,6,7)	Switch Cabinet	1T(1,2,3,4)	Analogical	0..110V	11	RC4Z1-K 4x0,5mm² - BT*			Yes

Ref		**From**		**To**		**Signal description**	**Voltage**	**Length**	**Wire type**	**Transient Voltage Protection**	**Filter**	**Shield**
		Unit	**Connector**	**Unit**	**Connector**							
1008145	WGC2.4: Switch cabinet (stator voltage measurement) - power converter	Converter	XMED (1,2,3)	Controller	2T(1,2,3)	Analogical	0..110V	11	RC4Z1-K 4x0,5mm^2 - BT*			Yes
1008159	WGC3.4: Safety system power converter - Ground controller	Converter	X3 (1A,1B,2A,2B,3A,3C,4A,4C,5A,5C)	Controller	X3 (8A,8B,9A,9B,10A,10B,11A,11B,12A,12B)	Continuous	24V	8	LiHCH 12x0,5mm^2 - BT*			Yes
1028659	WGM3.1: 230V power supply ground controller (UPS) - power converter	Converter	XUPS (1,2,pe)	Controller	X2 (3A,3B,3PE)	Sinewave	230V	8	RZ1-K 0,6/1kV 3G2,5mm^2 - BT*			No

Table 7: Base signals

10.3.3 Nacelle Signals

Ref		From		To		Signal description	Voltage	Length	Wire type	Transient Voltage Protection	Filter	Shield
		Unit	Connector	Unit	Connector							
1028662	WNM7.8: Yaw motor 6	TOP	X1 (38U,38V,38W,38PE)	Yaw motor	U6 (M6)	Sinewave	400V	10.5	RZ1-K 0,6/1kV 4G2,5mm^2 - BT*	400V filter		No

Ref		From		To		Signal description	Voltage	Length	Wire type	Transient Voltage Protection	Filter	Shield
		Unit	Connector	Unit	Connector							
1028661	WNM7.14: Yaw motor electric brake 6	TOP	X1 (44U, 44V, 44W)	Yaw motor	U6 (Y6)	Sinewave	400V	10.5	RZ1-K 0,6/1kV 4G2,5mm^2 - BT*			No
1028662	WNM7.7: Yaw motor 5	TOP	X1 (37U, 37V, 37W)	Yaw motor	U5 (M5)	Sinewave	400V	6.5	RZ1-K 0,6/1kV 4G2,5mm^2 - BT*			No
1028661	WNM7.13: Yaw motor electric brake 5	TOP	X1 (43U, 43V, 43W)	Yaw motor	U5 (Y5)	Sinewave	400V	10.5	RZ1-K 0,6/1kV 4G2,5mm^2 - BT*			No
1028662	WNM7.3: Yaw motor 1	TOP	X1 (33U,33V,33W)	Yaw motor	U1 (M1)	Sinewave	400V	13	RZ1-K 0,6/1kV 4G2,5mm^2 - BT*			No
1028661	WNM7.9: Yaw motor electric brake 1	TOP	X1 (39,39V,39W)	Yaw motor	U1 (Y1)	Sinewave	400V	12	RZ1-K 0,6/1kV 4G2,5mm^2 - BT*			No
1028662	WNM7.4: Yaw motor 2	TOP	X1 (34U,34V,34W)	Yaw motor	U2 (M2)	Sinewave	400V	8.5	RZ1-K 0,6/1kV 4G2,5mm^2 - BT*			No
1028661	WNM7.10: Yaw motor electric brake 2	TOP	X1 (40U,40V,40W)	Yaw motor	U2 (Y2)	Sinewave	400V	8.5	RZ1-K 0,6/1kV 4G2,5mm^2 - BT*			No
1028662	WNM7.5: Yaw motor 3	TOP	X1 (35U, 35V, 35W)	Yaw motor	U3 (M3)	Sinewave	400V	8.5	RZ1-K 0,6/1kV 4G2,5mm^2 - BT*			No
1028661	WNM7.11: Yaw motor electric brake 3	TOP	X1 (41U, 41V, 41W)	Yaw motor	U3 (Y3)	Sinewave	400V	8.5	RZ1-K 0,6/1kV 4G2,5mm^2 - BT*			No
1028662	WNM7.6: Yaw motor 4	TOP	X1 (36U, 36V, 36W)	Yaw motor	U4 (M4)	Sinewave	400V	6.5	RZ1-K 0,6/1kV 4G2,5mm^2 - BT*			No
1028661	WNM7.12: Yaw motor electric brake 4	TOP	X1 (42U, 42V, 42W)	Yaw motor	U4 (Y4)	Sinewave	400V	6.5	RZ1-K 0,6/1kV 4G2,5mm^2 - BT*			No

Ref		From		To		Signal description	Voltage	Length	Wire type	Transient Voltage Protection	Filter	Shield
		Unit	Connector	Unit	Connector							
1028662	WNM0.1: Hoist power supply	TOP	X1(7U, 7V, 7W)	Hoist	KM1	Sinewave	400V	15.00	RZ1-K 0,6/1kV 4G2,5mm² - BT*			No
1018336	WNM10.1: Pitch pump motor	TOP	X1(4,5,6)	Hydraulic system	14	Sinewave	400V	13.50	Cable 300/500V 4G25mm² AS			No
1018337	WNM10.2: Brake pump motor	TOP	X1 (10U, 10V, 10WW)	Hydraulic system	20	Sinewave	400V	6.50	Cable 300/500V 4G25mm² AS			No
1018337	WNM10.3: Intercooler fan motor	TOP	X1(11U, 11V, 11W)	Hydraulic system	29	Sinewave	400V	6.5	Cable 300/500V 4G25mm² AS			No
1028662	WNM8.6: Gearbox intercooler Motor 1 (high speed)	TOP	x1 (15U, 15V, 15W)	Gearbox	X2	Sinewave	400V	4.5	RZ1-K 0,6/1kV 4G2,5mm² - BT*			No
1028662	WNM8.5: Gearbox intercooler Motor 1 (low speed)	TOP	X1 (14u, 14v)	Gearbox	X2	Sinewave	400V	4.5	RZ1-K 0,6/1kV 4G2,5mm² - BT*			No
1028662	WNM8.11: Gearbox lubrication motor (low speed)	TOP	X1 (8U, 8V, 8W)	Gearbox	X1	Sinewave	400V	4.5	RZ1-K 0,6/1kV 4G2,5mm² - BT*			No
1028662	WNM8.12: Gearbox lubrication motor (high speed)	TOP	X1 (9U, 9V, 9W)	Gearbox	X1	Sinewave	400V	4.5	RZ1-K 0,6/1kV 4G2,5mm² - BT*			No
1028662	WNR8.1: Gearbox oil warming resistance	TOP	X1 (19U, 19V, 19W)	Gearbox	X3	Sinewave	400V	4.5	RZ1-K 0,6/1kV 4G2,5mm² - BT*			No
1028662	WNM9.2:Generator fan low speed	TOP	X1 (21U, 21V, 21W)	Generator	X1	Sinewave	400V	14	RZ1-K 0,6/1kV 4G2,5mm² - BT*			No

Ref		From		To		Signal description	Voltage	Length	Wire type	Transient Voltage Protection	Filter	Shield
		Unit	Connector	Unit	Connector							
1028662	WNM9.1:Generator fan high speed	TOP	X1 (18U, 18V, 18W)	Generator	X1	Sinewave	400V	14	RZ1-K 0,6/1kV 4G2,5mm² - BT*			No
1028658	WNR8.3: Gearbox cooling motor anticondensation 1	TOP	X2 (13l, 13N)	Gearbox	X4	Sinewave	230V	5.00	RZ1-K 0,6/1kV 3G1,5mm² - BT*			No
1028658	WNR8.2: Gearbox lubrication motor anticondensation resistance	TOP	X2 (9L, 9N)	Gearbox	X4	Sinewave	230V	5.00	RZ1-K 0,6/1kV 3G1,5mm² - BT*			No
1028658	WNR9.2: Generator slip rings warming resistance	TOP	X2 (8L, 8N)	Generator	X1	Sinewave	230V	14.00	RZ1-K 0,6/1kV 3G1,5mm² - BT*			No
1028658	WNR9.1: Generator windings warming resistance	TOP	x2 (7l, 7n)	Generator	X1	Sinewave	230V	14.00	RZ1-K 0,6/1kV 3G1,5mm² - BT*			No
1030551	WNC1.1: Generator emergency button (left)	TOP	X3 (7A,7B,7C,8A,8B,8C)	Nacelle	SB1	Digital	24V	13	LiHCH(AS) 6x0,5mm2 - BT*			Yes
1030551	WNC1.2: Generator emergency button (right)	TOP	X3 (9A,9B,9C,10A,10B,10C)	Nacelle	SB2	Digital	24V	14	LiHCH(AS) 6x0,5mm2 - BT*			Yes
1030551	WNC1.3: Frame emergency button	TOP	X3 (11A,11B,11C,12A,12B, 12C)	Nacelle	SB3	Digital	24V	8	LiHCH(AS) 6x0,5mm2 - BT*			Yes
1008141	WNC1.6: Speed shaft	TOP	X3 (13C,14A)	Nacelle	A71	Digital	24V	10	LiHCH(AS) 6x0,5mm2 - BT*			Yes

Ref		From		To		Signal description	Voltage	Length	Wire type	Transient Voltage Protection	Filter	Shield
		Unit	Connector	Unit	Connector							
	brake thermistor 2											
1023464	WNC4.1: Front vibration sensor	TOP	X1 (9U,9V,9W)	Nacelle	X3 (1C,2A,2B,2C,3A,3B,3C,4A,4B,4C,5C,6A,6B,6C,24A,24B,25A,25B)	Analogical		12	LiHCH 12x2x0,22mm^2 - BT*			Yes
1028656	WNS5.5: Wind sensors power supply	TOP	X4 (14A,14B)	Anemo	CSA	Continuous	24V	19	RZ1-K 0,6/1kV 2x1,5mm^2 - BT*			Yes
1018338	WNC10.1 (sensors power supply)	TOP	X4(12A,12B)	Hydraulic system	C	Continuous	24V	12	Cable 3G1.5mm^2			Yes
1018330	WNB11.1 (CAN group-Rotatory joining)	TOP	D89	Sensors	U11CAN_L/H/GND/34/SH	CAN		12	Cable CAN (1x2x0.21mm^2 +1x2x0.33mm^2) apantallado			Yes
1018327	WNV11.1 (electrovalves power supply)	TOP	X4 (1A,1,B,2A,2B,3A,3B)	Hydraulic system	C5.1	Continuous	24V	11	Cable 12G1.5mm^2 apantallado			Yes
1018323	WNV10.1: Electro-valve power supply	TOP	X4 (7A,7B,8A,8B,9A,9B,10A,10B,11A,11B)	Hydraulic system	C	Continuous	24V	16	Cable 12G1.5mm^2			Yes
1018330	WNB10.1 (CAN group-Top)	TOP	D89	Hydraulic system	A4 CONECTARO A	CAN		12	Cable CAN (1x2x0.21mm^2 +1x2x0.33mm^2) apantallado			Yes
1018338	WNV10.7 (electrovalves 2 power supply)	TOP	X4 (5A,5B)	Hydraulic system	C(1,2)	Continuous	24V	16	Cable 3G1.5mm^2			Yes

Ref		From		To		Signal description	Voltage	Length	Wire type	Transient Voltage Protection	Filter	Shield
		Unit	Connector	Unit	Connector							
1030557	WNB5.1: RS485 Wind sensor 1 (anemometer box - top)	TOP	X4 (15A,15B)	Inductive sensors junction box	CSA.1	Analogical		19	LiHCH 2x2x0,5mm² - BT*			Yes
1008156	WNC1.5: Slow shaft inductive sensor. TOG	TOP	X6 (21+,21-,21s)	Inductive box	A6(1,2,3)	Continuous	24V	5.5	LiHCH 3x0,34mm² - BT*			Yes
1030355	WNS2.2: T back bearing	TOP	X8(24A/24B)	Nacelle PT100	pt100	Current		2.5	Sonda PT100 2 hilos L=2500mm			Yes
1008155	WNS2.3:PT A6 box - TOP	TOP	X8(23A/23B)	Inductive box	A6 (9,10)	Current		5	LiHCH 2x0,5mm² - BT*			Yes
1030356	WNS5.1: PT100 nacelle	TOP	X8(28A/28B)	Nacelle PT100	pt100	Current		2.5	Sonda PT-100 con 3m de cable (2 hilos)			Yes
1008156	WNS6.1: Slow shaft inductive sensor. Control	TOP	X6 (2A,2B,2C)	Inductive box	A6 (5,6,7,8)	Continuous	24V	5.5	LiHCH 3x0,34mm² - BT*			Yes
1008163	WNS7.2: Yaw cam sensor	TOP	X6 (5S, 5+)	Limit switches block	U7 (S1)	Digital	24V	6.5	LiHCH 8x0.75mm² - BT*			Yes
1015158	WNS8.2: Gearbox PT100 temperature sensors	TOP	X8 (25A,25B,26A,26B,27A,27B)	Gearbox	X7	Current		4	LiHCH 14x0.5mm² - BT*			Yes
1021307	WNS8.1: Gearbox sensors (level, filters,...)	TOP	X6	Gearbox	X5(1,2,3,4,5,6)	Digital	24V	4	Cable LIHCH(AS) 6x0,34mm2 - BT*			Yes
1015158	WNS9.3: Generator PT100	TOP	X8 (22B,22A)	Generator	X2 (39,41)	Current		13	LiHCH 2x0,5mm² - BT*			Yes

Ref		From		To		Signal description	Voltage	Length	Wire type	Transient Voltage Protection	Filter	Shield
		Unit	Connector	Unit	Connector							
	temperature sensors											
1030550	WNS9.2: Generator PT100 temperature sensors	TOP	X8 (9A,9B,10A,10B,11A,11B,12A,12B,13A,13B,14A,14B)	Generator	X2 (10,12,13,15,16,18,19,21,25,27,31,33)	Current		13	LiHCH(AS) 12x0,34mm2 - BT*			Yes
1008155	WNS9.4: Generator braid wear indicator sensor	TOP	X6 (20+,20S)	Generator	X2 (37,38)	Current		13	LiHCH 2x0,5mm² - BT*			Yes
1008155	WNS12.2 A6 - TOP	TOP	X6 (6+,6S)	Inductive box	A6	Continuous	24V	8	Sensor Inductivo Omron			Yes
1014092	WNS7.5: inductivo yaw reset vuelta posición nacelle	TOP	X6(25+,25-,25s)	Nacelle	30295Q2	Continuous	24V	2	Cable 4x0.34mm²			Yes
1029392	WNS11.1: Bursting disc power supply and signal	TOP	Hydraulic system	Hydraulic system	c5.3	Digital	24V	10.5	2 cores +PE; 3.18 mm2/AWG12. Fieldbus: Conductor: 0.60 mm2/AWG20; separately shielded. Alarm wires 0.5 mm2. Outer shield braided			Yes
	Beacon power	TOP										

Table 8: Nacelle signals

11. EMISSION ANALYSIS

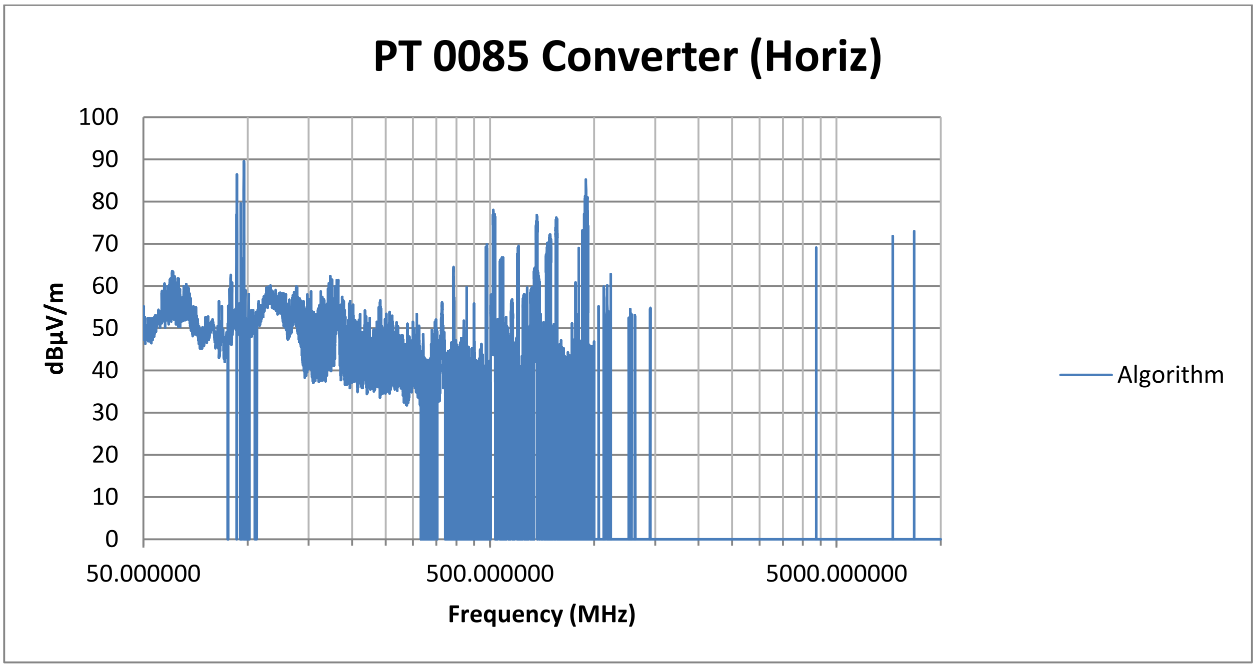
11.1 RADIATED EMISSIONS

The CISPR 22 Class B limit line adjusted to the requirement at 1m will be 50dBµV/m below 230MHz and 57dBµV/m above 230MHz.

11.1.1 Converter Cabinet

Picture 3: PT0085 Converter cabinet measurements

The converter cabinet can be divided into three major blocks, Grid Cell, Converter Cell and Machine Cell.

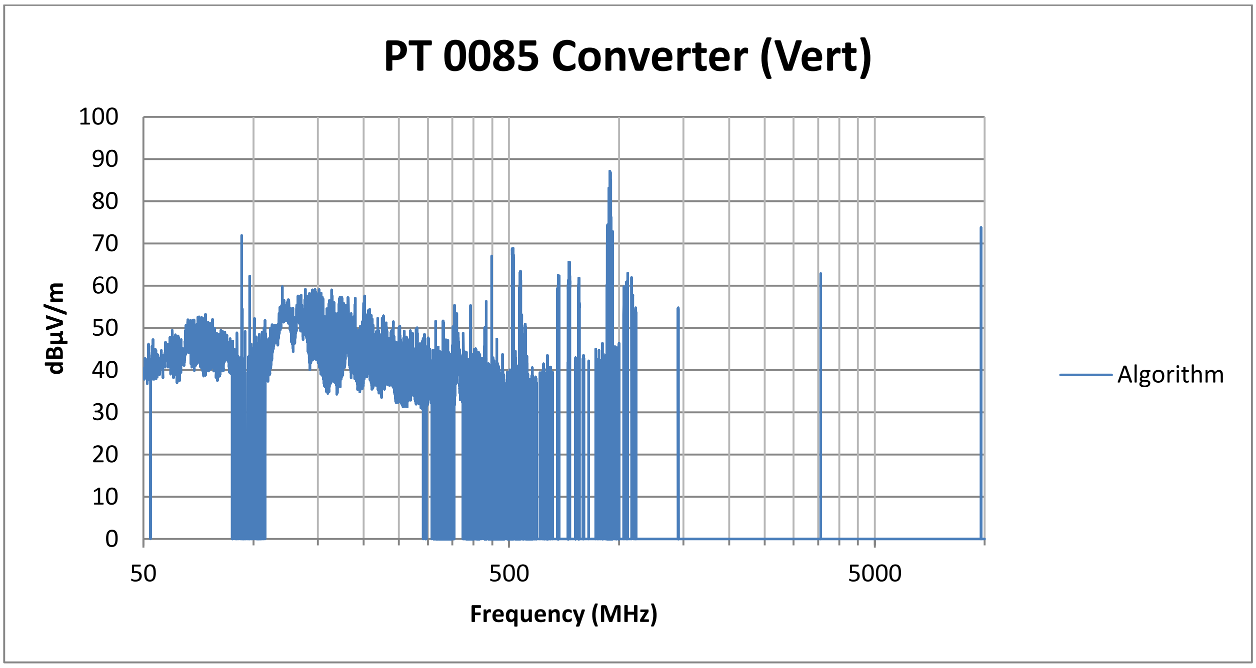


Graph 3: PT0085 Converter with ambient algorithm (Horizontal)

The following algorithm was used to represent the horizontally polarized radiated emissions from the PT0085 converter as shown in Graph 3. The vertically polarized radiated emissions are shown in Graph 4.

If radiated emissions machine side > radiated emissions grid, then plot machine; else plot grid.
If (radiated emissions – ambient) < 3dB then plot 0; else plot radiated emissions.

There is a 30dB to 40dB increase in the ambient emissions when the converter is switched on. Although the conducted emissions indicated little emissions above 200MHz, the radiated emission results indicates emissions at frequencies into the GHz range.

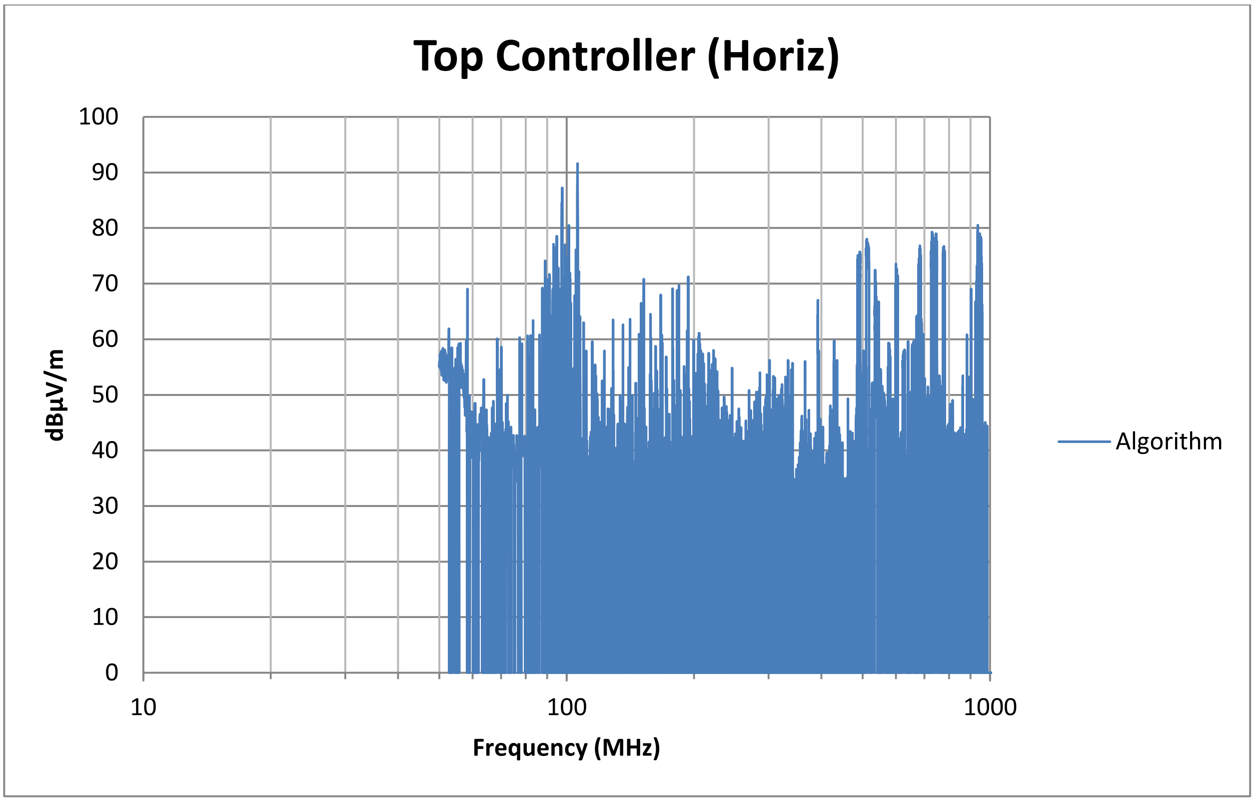


Graph 4: PT0085 Converter with ambient algorithm (Vertical)

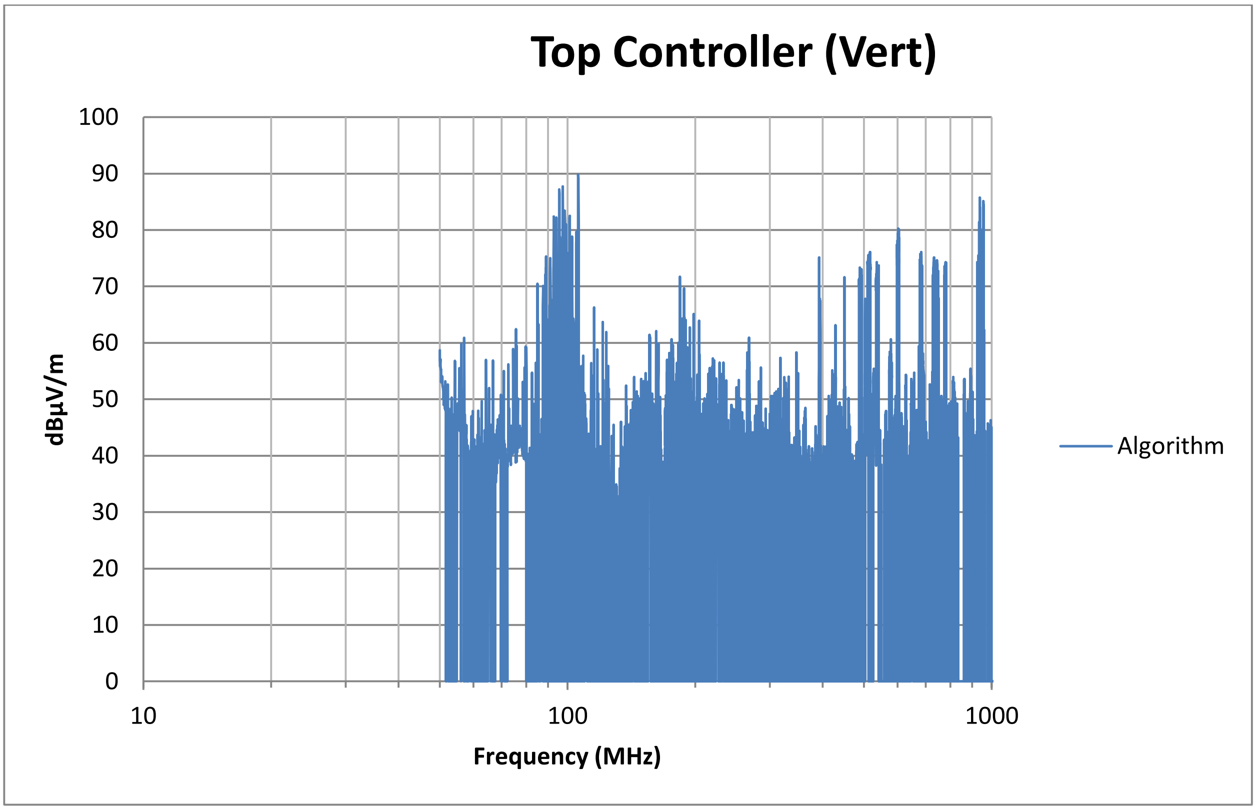
11.1.2 Top Controller (Measurement distance = 1m)

Picture 4: Top Controller

The top control cabinet can be divided in two segments, ie. the power side and the control side. Comparing the results in Report (NIE) 49577REM.001 for the power and control side it is shown that the control side emissions were worst case. (Graphs 29 to 34 of Report (NIE) 49577REM.001).



Graph 5: Top Controller (Horizontal @ 1m)

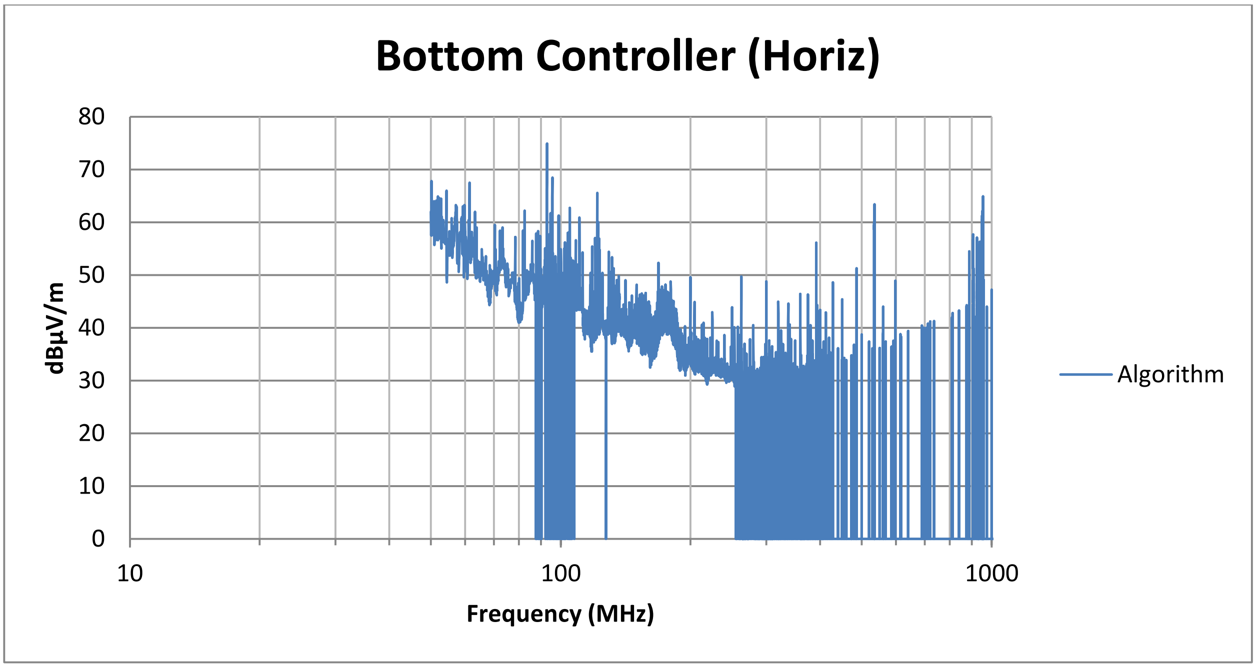


Graph 6: Top controller (Vertical @1m)

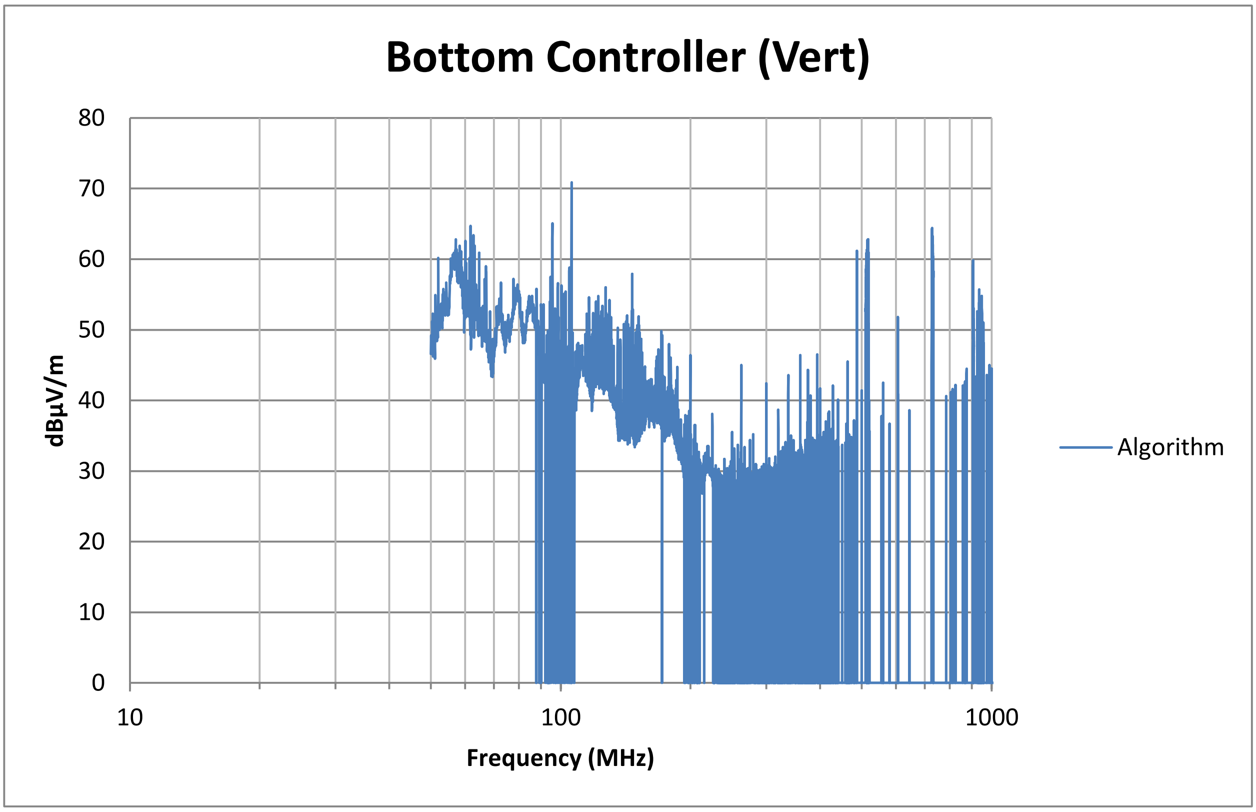
11.1.3 Bottom Controller (Measurement distance = 1m)

Picture 5: Bottom Controller

The Bottom Control Cabinet is an upright configuration and not side by side as the Top Control Cabinet configuration.



Graph 7: Bottom Controller (Horizontal @1m)



Graph 8: Bottom Controller (Vertical @ 1m)

11.2 CONDUCTED EMISSIONS

Critical cables were measured in an installation to characterize the emissions and to determine the likelihood of the cable acting as a radiator.

As a rule of thumb, a common mode current value of 14dBµA can potentially cause radiated emissions in excess of 37dBµV/m (CISPR Class B radiated emission limit at 10m distance). This will only be valid for cables in free space and when the cable has resonant properties at a given frequency.

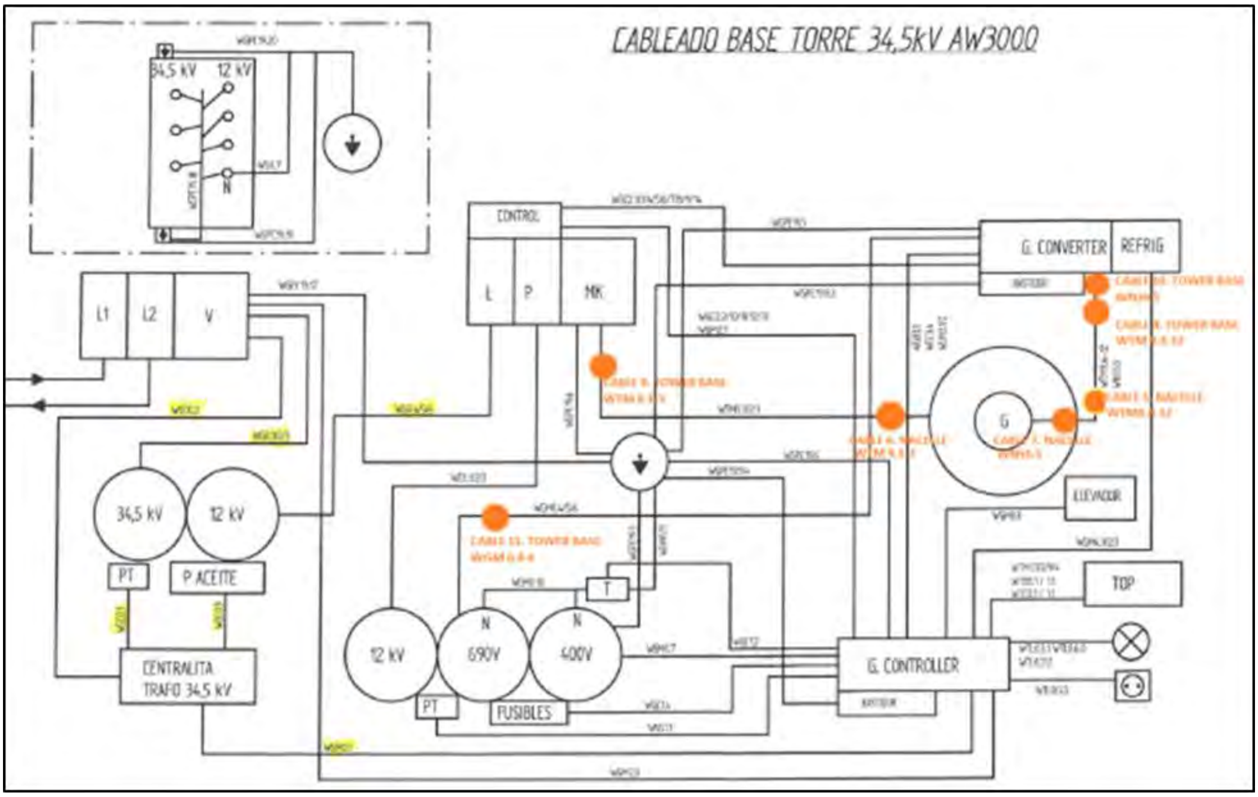
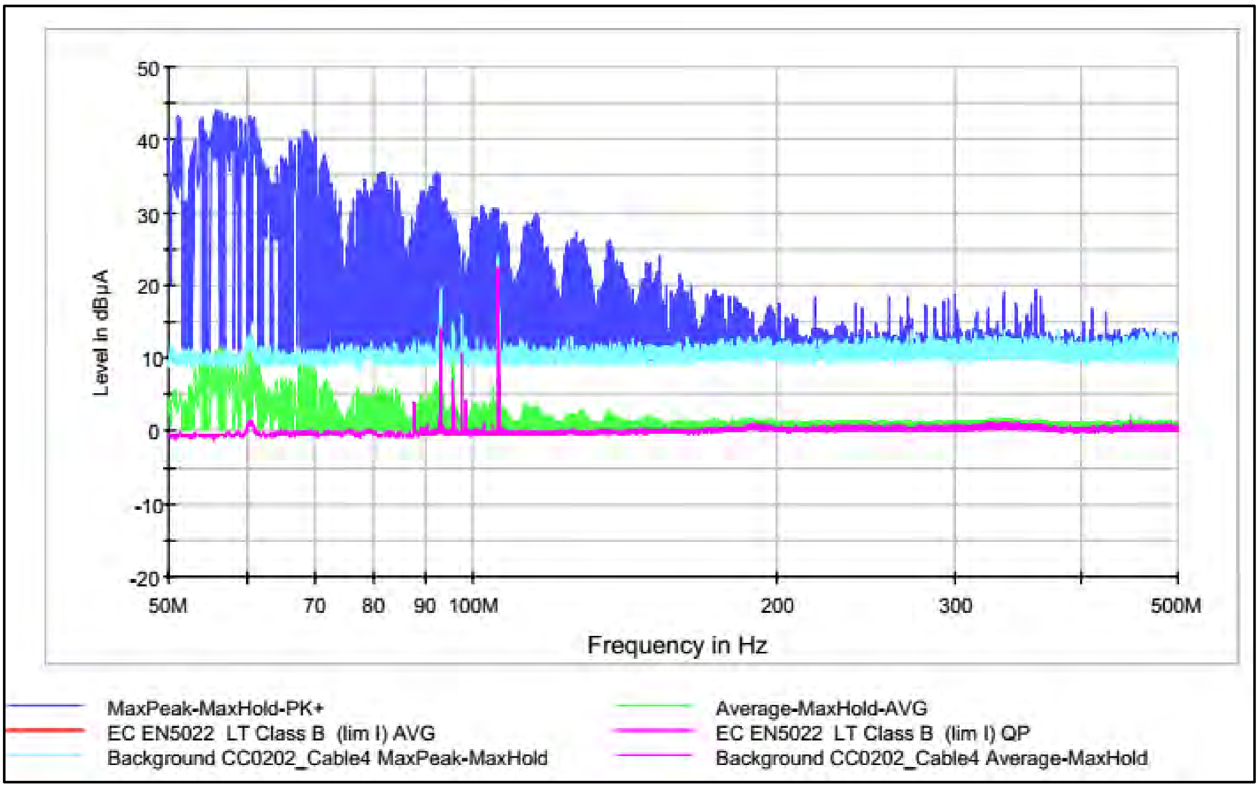


Figure 21: Conducted emission test locations

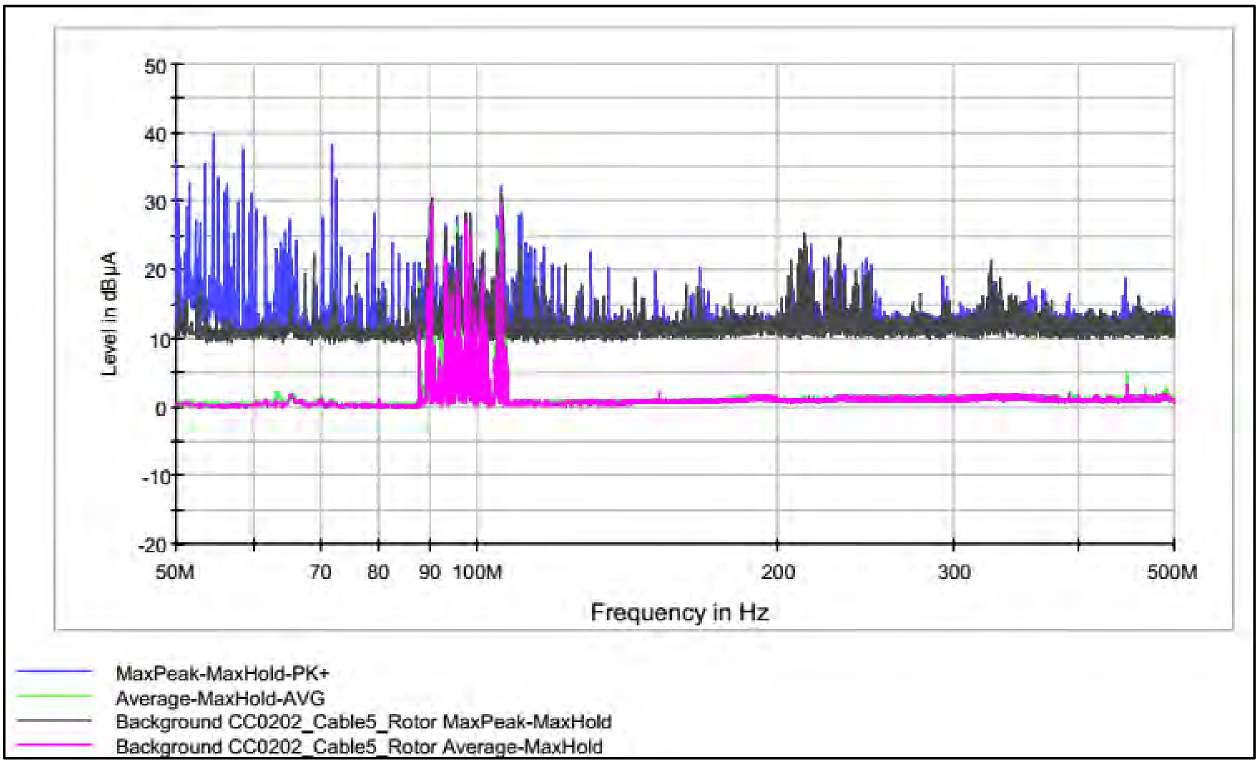
11.2.1 Converter

The converter was previously identified as a significant risk due to the following:

i. High dV and dI values
ii. Cable connection from converter in the base to the rotor in the nacelle
iii. Unshielded cable used between the converter (base) and rotor (nacelle)



Graph 9: Rotor cable measured in the base between converter in the base and rotor in nacelle

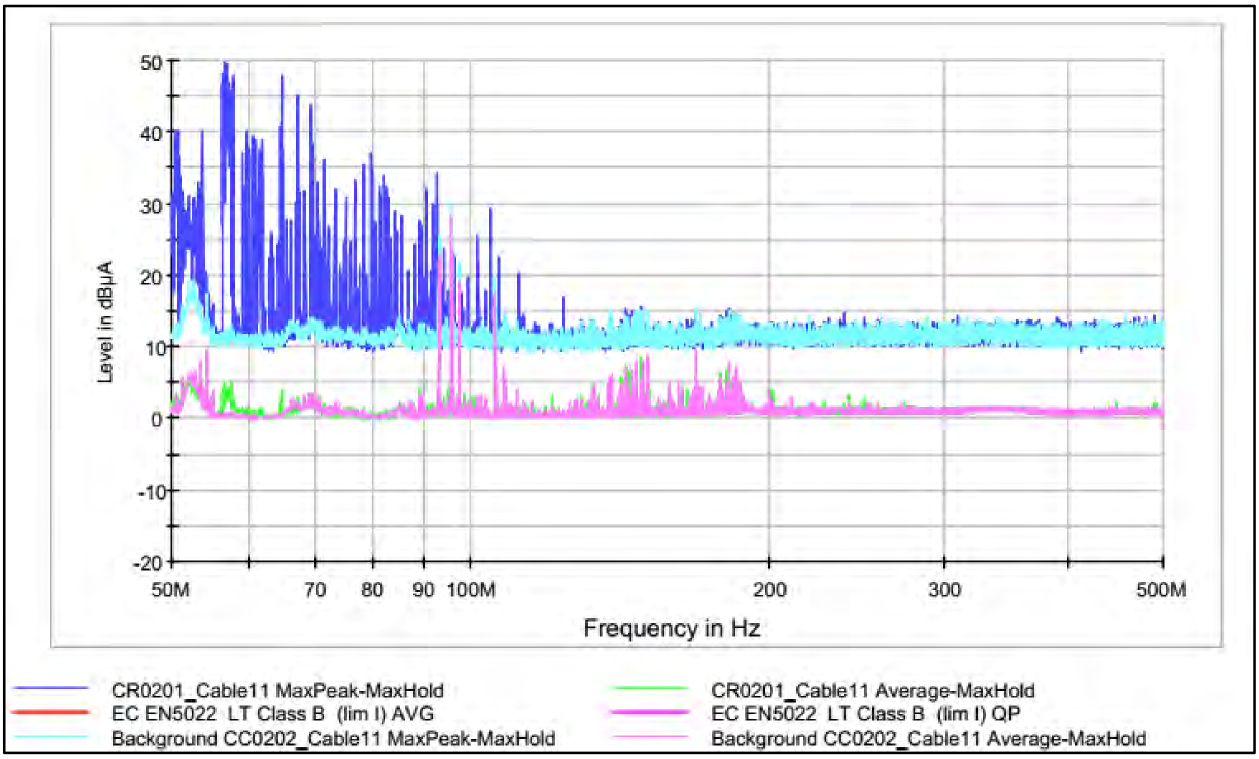


Graph 10: Rotor cable measured in the nacelle between converter in the base and rotor in nacelle

From Graph 9 and Graph 10, it is evident that the converter to rotor cable emissions is below 15dBµA in the higher frequency range.

When comparing the two graphs, the effect of cable length (inductance) on the signal is clear.

The spectrum envelope in Graph 9 is typical of a periodic signal. This was expected and is a function of the converter switching frequency of 2.75 kHz and cable properties. The amplitude decay is however more than 40dB/decade, indicating that the rise time of the signal is more than 6.3nS.

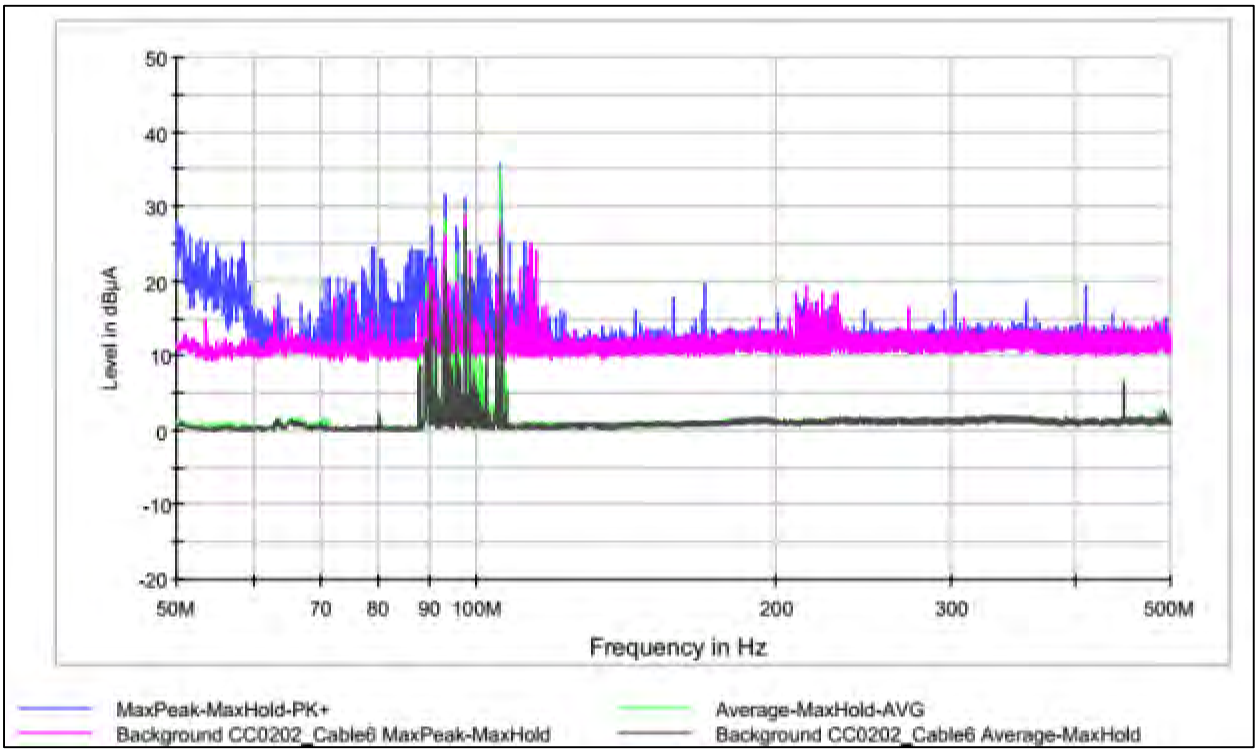


Graph 11: Converter cable between the converter and auxiliary transformer measured in base

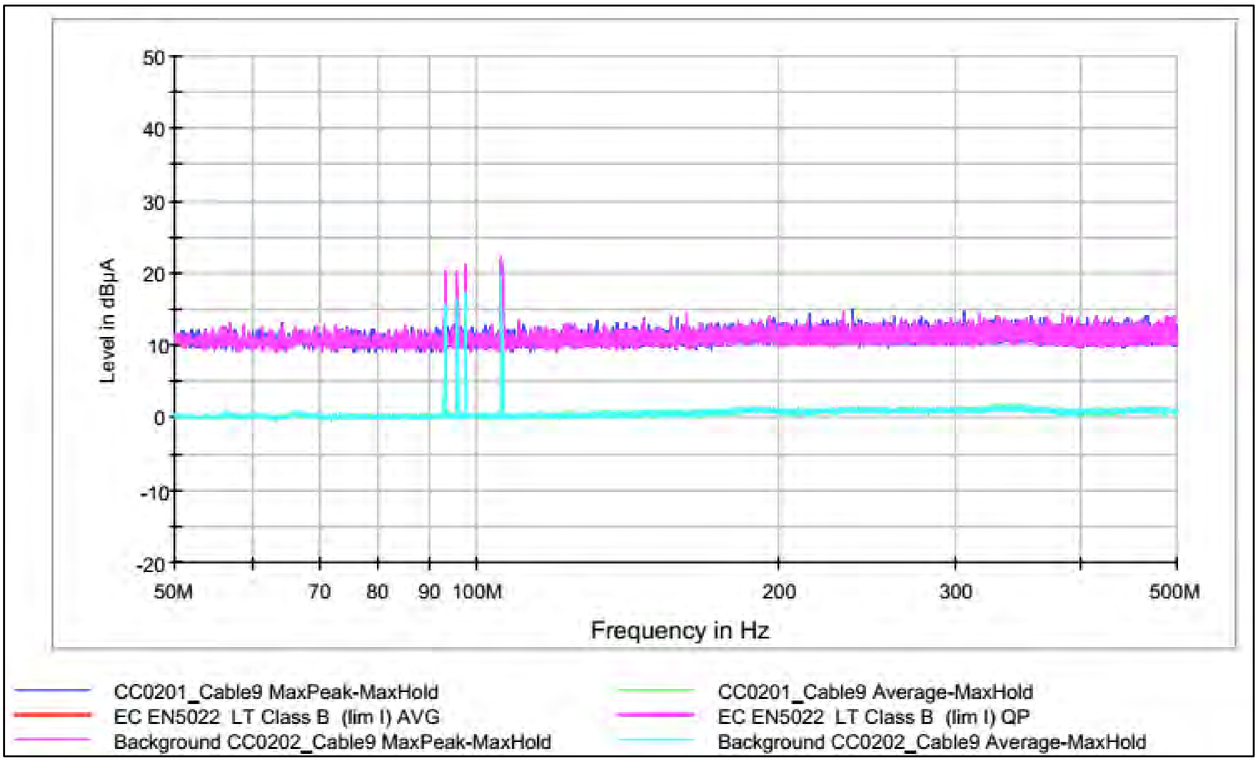
Graph 11 shows emissions on the transformer side of the converter. This confirms that conducted emissions from the converter are relative low in frequency. Although high in amplitude, this cable is inside the base with added path loss due to proximity to the ground.

11.2.2 Stator

The stator cables run from the bottom control cabinet in the base to the stator in the nacelle. The emissions from stator cables in the nacelle (Graph 12) are less than the rotor cables (Graph 10). The stator cables are currently shielded.



Graph 12: Stator cable in nacelle between bottom control cabinet in base and stator in nacelle

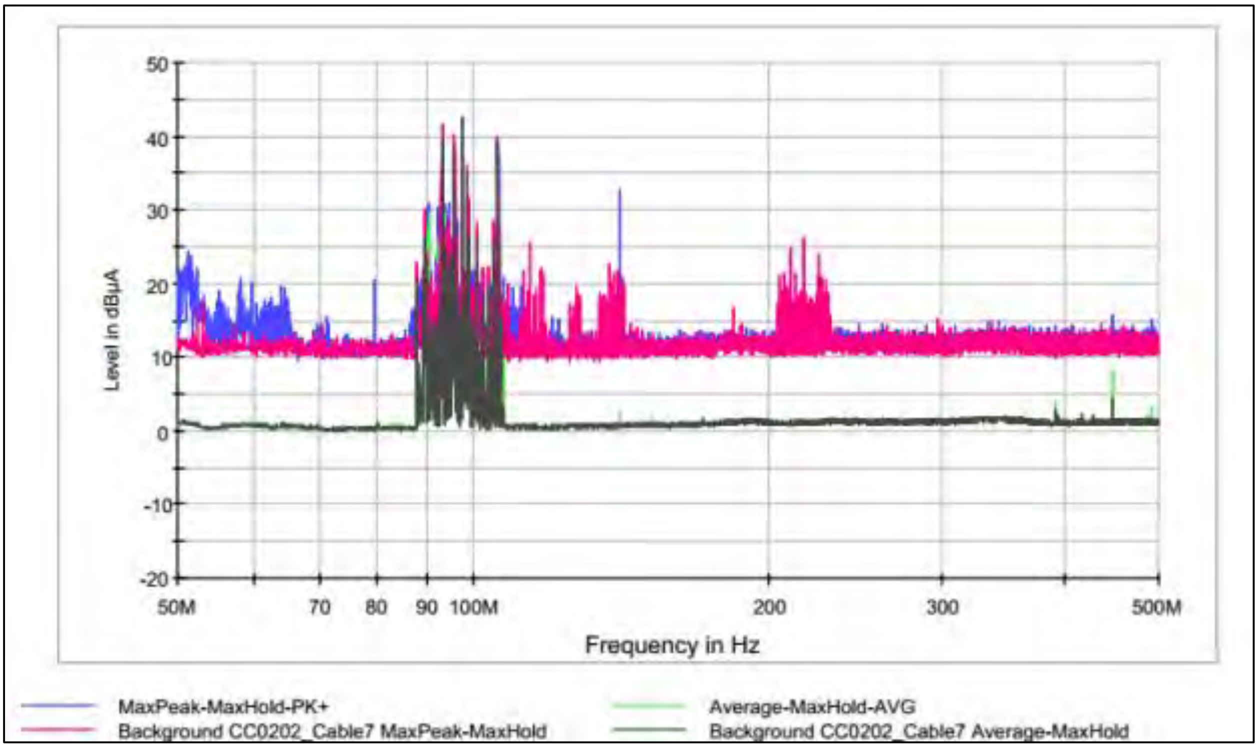


Graph 13: Stator cable in base between bottom control cabinet in base and stator in nacelle

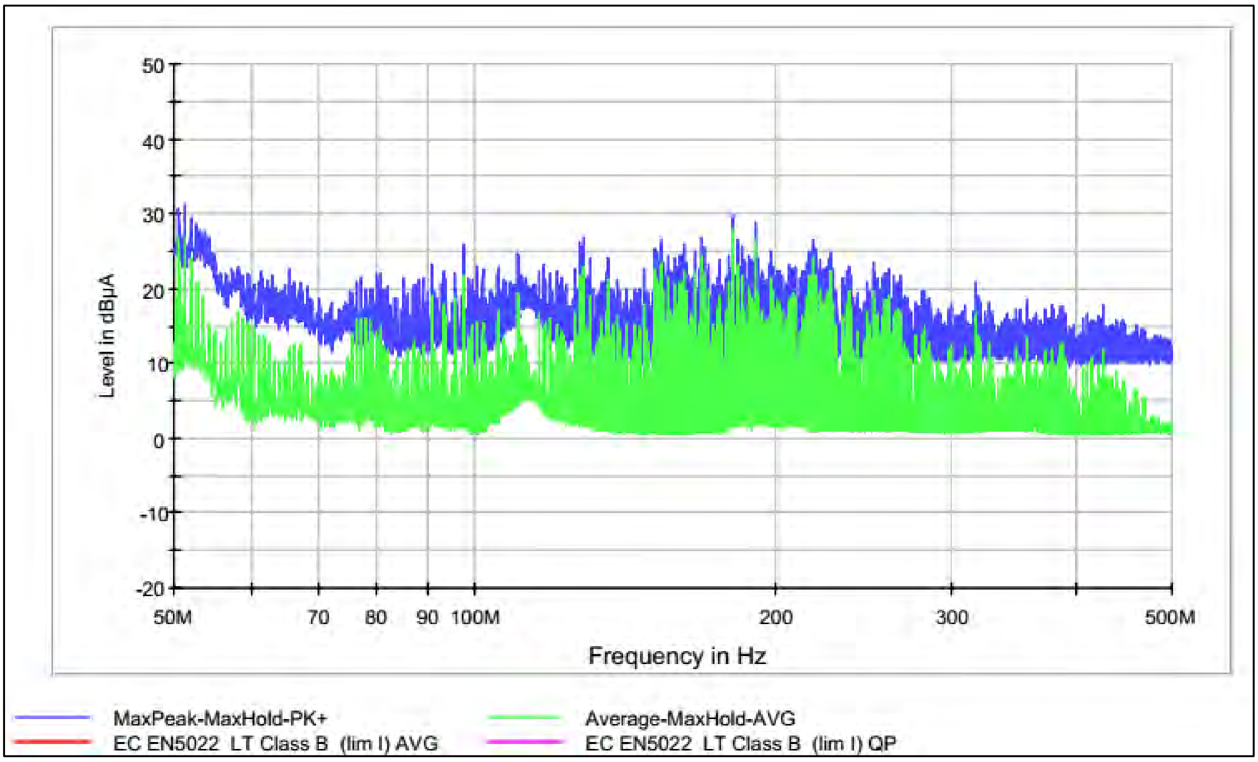
As the signal amplitudes are higher in the nacelle (Graph 12) than in the base (Graph 13), the conclusion would be that the source of the emissions is in the nacelle.

11.2.3 Encoder signal cable

The encoder signal cable runs between the generator and converter. It is a shielded cable and the common mode currents on the shield were measured.



Graph 14: Encoder cable in the nacelle

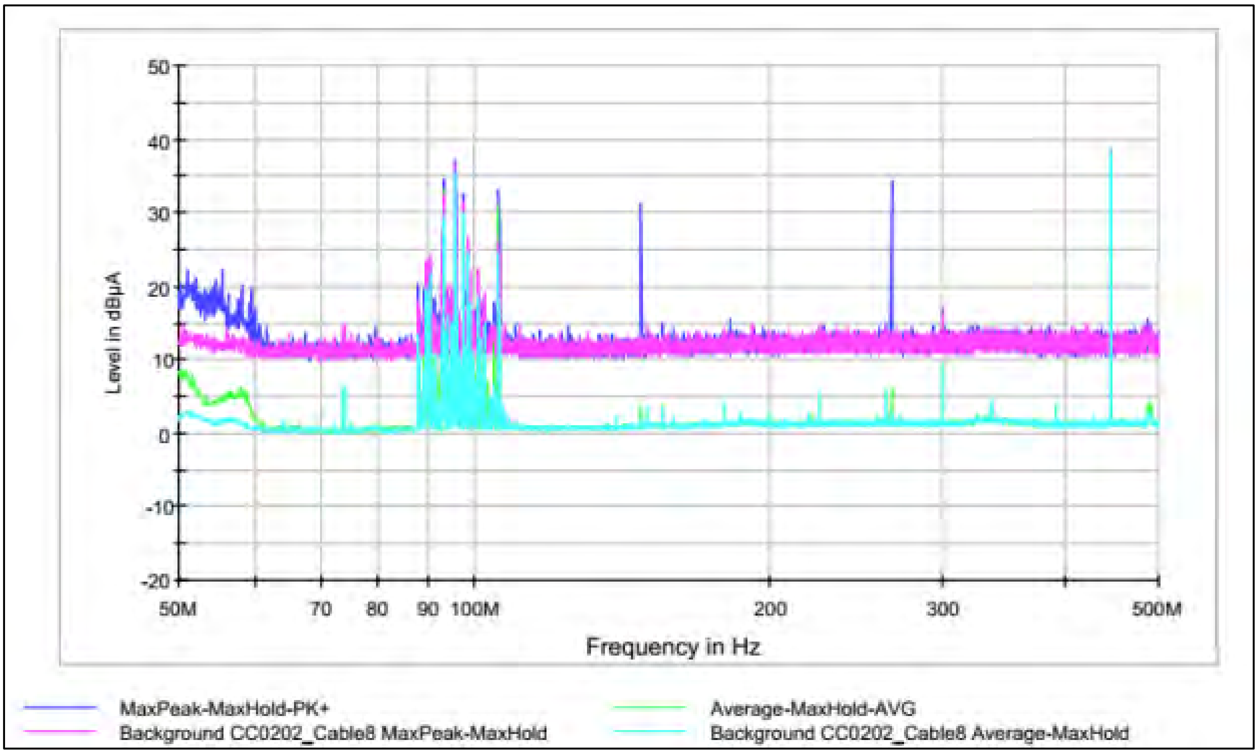


Graph 15: Encoder cable in the base

A significantly denser spectrum was measured in the base (Graph 15) than in the nacelle (Graph 14). It would therefore be fair to assume that the source is in the converter cabinet in the base.

11.2.4 CAN Bus (Nacelle)

The CAN bus is also a shielded cable and carries the different sensor data, such as the electro valves, pitch position sensor etc. in the nacelle.



Graph 16: CAN Bus in the nacelle

The profile of the emissions below 60MHz is similar to the shielded encoder cable (Graph 14) in the nacelle. Site conditions limited the number of tests and investigations that could be done.

11.3 TOWER SHIELDING EFFECTIVENESS

The minimum shielding effectiveness of the tower was found to be 5.2dB at the door. The electrical contact between the door and door frame can be improved to increase this figure, but the 5.85dB of the concrete will still be the limiting factor.

Vertical Polarization						
Frequency (MHz)	**Distance (m)**	**Reference (dBm)**	**Door (dBm)**	**Concrete (dBm)**	**SE Door (dB)**	**SE Concrete (dB)**
80	2.5		-31.51	-32.62	6.28	7.39
110	2.5		-38.52	-33.89	16.77	12.14
300	2.5		-4.69	5.51	16.05	5.85
500	2.5		-27.4	0.99	36.69	8.3
700	2.5		-18.93	-1.24	24.12	6.43
1000	2.5		-40.05	-9.08	41.11	10.14

Table 9: Shielding effectiveness – Vertical Polarization

Horizontal Polarization						
Frequency (MHz)	**Distance (m)**	**Reference (dBm)**	**Door (dBm)**	**Concrete (dBm)**	**SE Door (dB)**	**SE Concrete (dB)**
80	2.5		-43.55	-34.05	23.93	14.43
110	2.5		-27.77	-36.11	5.2	13.54
300	2.5		-5.95	5.28	18.95	7.72
500	2.5		-16.89	3.51	27.75	7.35

Horizontal Polarization						
Frequency (MHz)	**Distance (m)**	**Reference (dBm)**	**Door (dBm)**	**Concrete (dBm)**	**SE Door (dB)**	**SE Concrete (dB)**
700	2.5		-17.24	0.43	23.93	6.26
1000	2.5		-28.09	-8.99	28.48	9.38

Table 10: Shielding effectiveness – Horizontal Polarization

The shielding effectiveness values will be used as input to the Risk Matrix.

12. MITIGATION

Although site measurements were done, there is always the risk of interference signals (A) being masked by a higher amplitude interference signal (B). Signal A will then only become apparent once signal B has being mitigated.
As the wind turbine generator and control equipment is a matured design, mitigation will be limited to non-invasive techniques.

Further analysis of the highest peaks of Graph 17 to Graph 22 revealed that they can be attributed to FM radio stations, TV and GSM intentional transmitters. However, not all signals that require attenuation could be attributed to intentional transmitters beyond doubt.

12.1 CONDUCTED EMISSIONS TECHNIQUES

12.1.1 Shielding of base to nacelle cables

- Enclosed conduit as shown in Par 13.1.
- Flexible conduit as shown in Par 13.2.
- Termination on gland plate.

12.1.2 Absorption of common mode currents

Where feasible, emissions from cables should be absorbed with ferrite material rather than to install filters, especially in the nacelle.

12.2 RADIATED EMISSIONS

As mitigation techniques are source and coupling path specific, tests were be done on a current WTG to confirm the suspected noise sources.

The results indicated shielding required at frequencies in the FM Radio band as well as other controlled frequency bands, especially in the nacelle area.

Parameter	Description	Comment
Frequency	50MHz to 1GHz	Measured (CISPR 22 parameters except distance = 1m)
EIRP	EIRP(dBm)=dBµV/m+20log(d)-106.93+2.15 [where d=1m]	Calculated from measurement
Path Loss	Aletta WTG 1 to SKA 004 at 46.52km, TX height 2m AGL, RX height 15m AGL. (119dB to 137dB)	Calculated with SPLAT! (Longley-Rice Irregular Terrain Model) at 5 frequencies, linear interpolated
Margin	10dB	Measurement and path loss uncertainty

Table 11: Bottom Equipment shielding requirement parameters

Parameter	Description	Comment
Frequency	50MHz to 1GHz	Measured (CISPR 22 parameters except distance = 1m)
EIRP	EIRP(dBm)=dBμV/m+20log(d)-106.93+2.15 [where d=1m]	Calculated from measurement
Path Loss	Aletta WTG 1 to SKA ID 1895 at 46.52km, TX height 100m AGL, RX height 15m AGL. (115dB to 134dB)	Calculated with SPLAT! (Longley-Rice Irregular Terrain Model) at 5 frequencies, linear interpolated
Margin	10dB	Measurement and path loss uncertainty

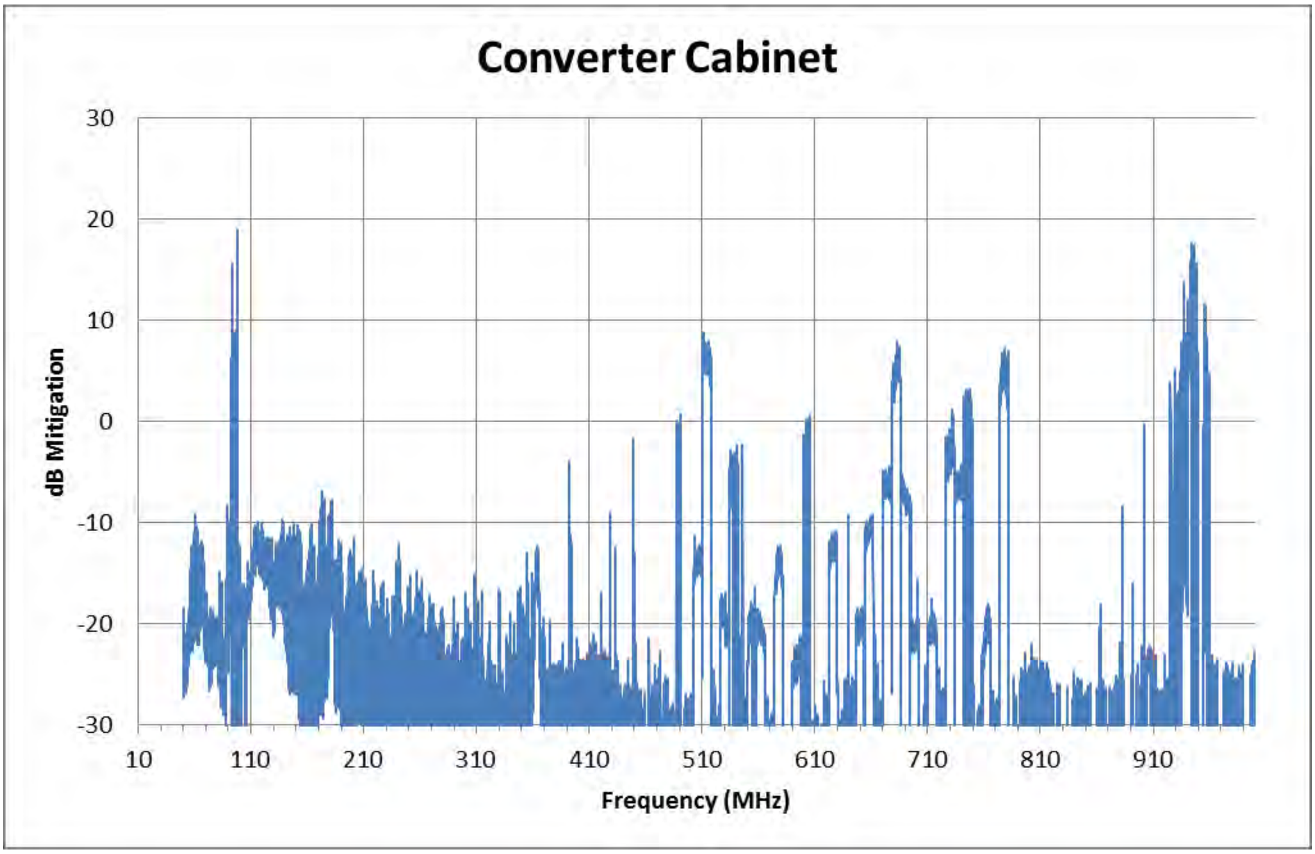
Table 12: Nacelle Equipment shielding requirement parameters

The only difference between Table 11 and Table 12 is the transmitter height. The Aletta WTG 1 was chosen as the transmitter site as at 46.52km from SKA 004 it is the closest to the SKA 1 infrastructure.

12.2.1 Converter Cabinet

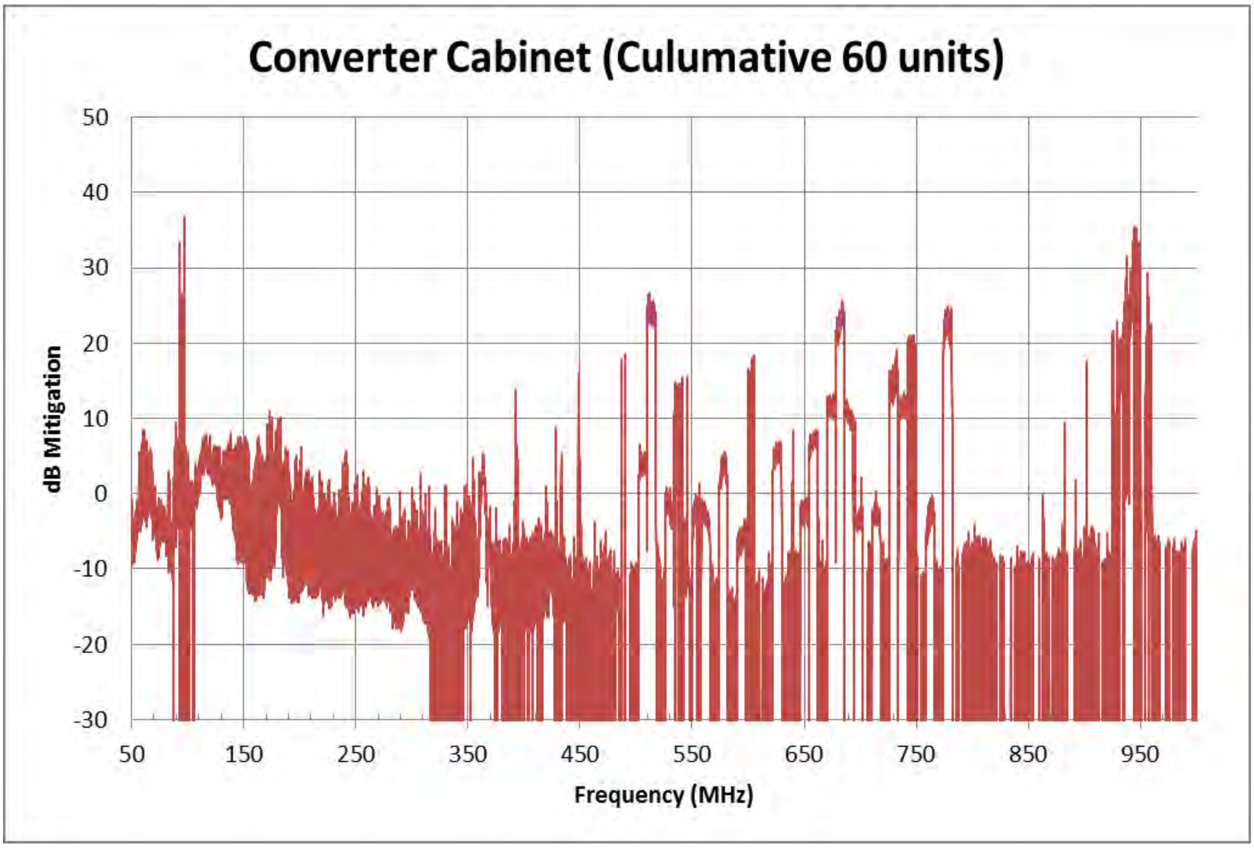
The converter cabinet is in the base of tower. The 6dB to 10dB shielding provided by the concrete tower is currently not included in the results.

The shielding required is calculated based in the information in Table 11.



Graph 17: Converter Cabinet Attenuation required

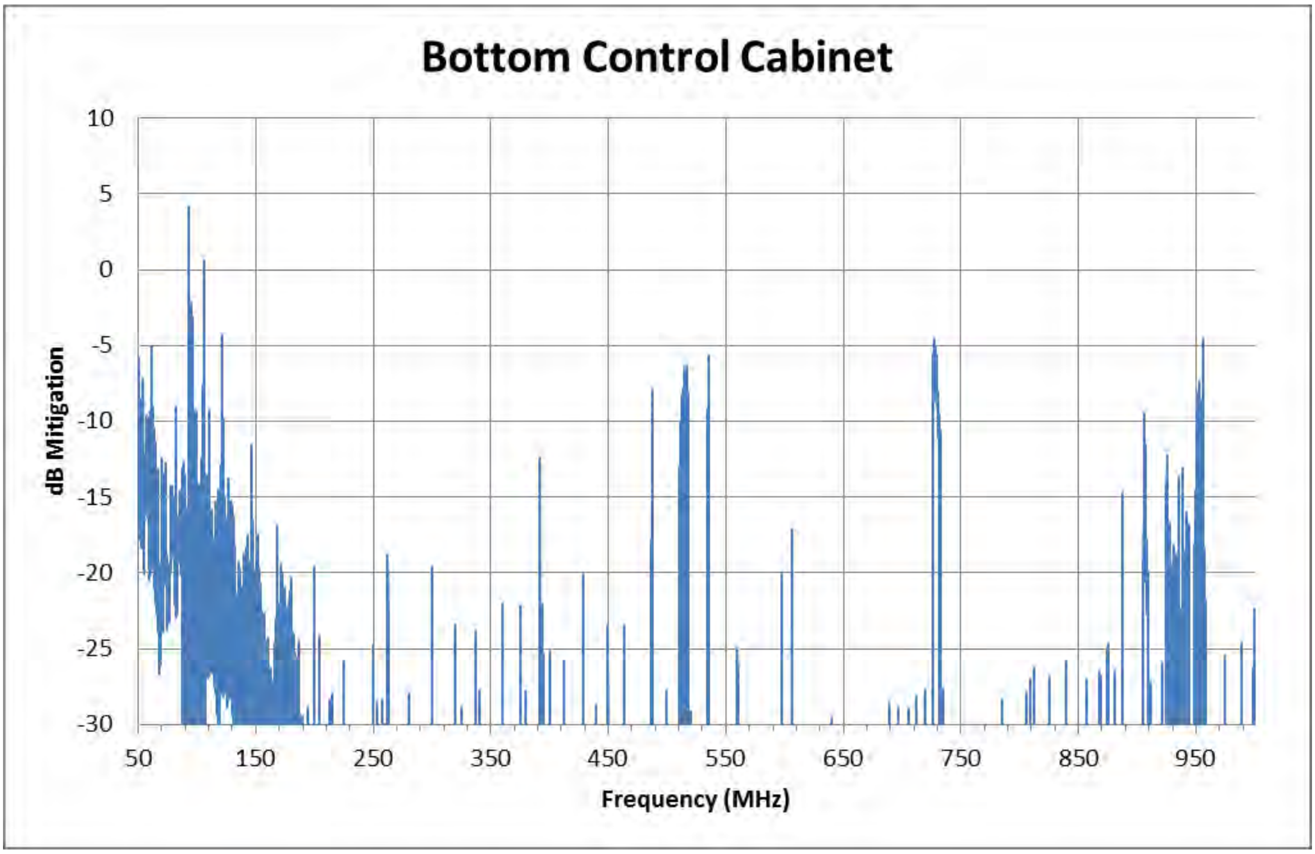
Test results obtained at the current installation including a 10dB safety margin (Graph 17) shows no additional attenuation is required for signals other than most likely FM radio stations, TV and GSM intentional transmitters. Adding a 17.8dB requirement to accommodate cumulative effect highlighted a few frequencies that will require additional attenuation as shown in Graph 18. The shielding effectiveness of the concrete tower (Table 9 and Table 10) was not taken into account.



Graph 18: Converter Cabinet Attenuation required including cumulative effect

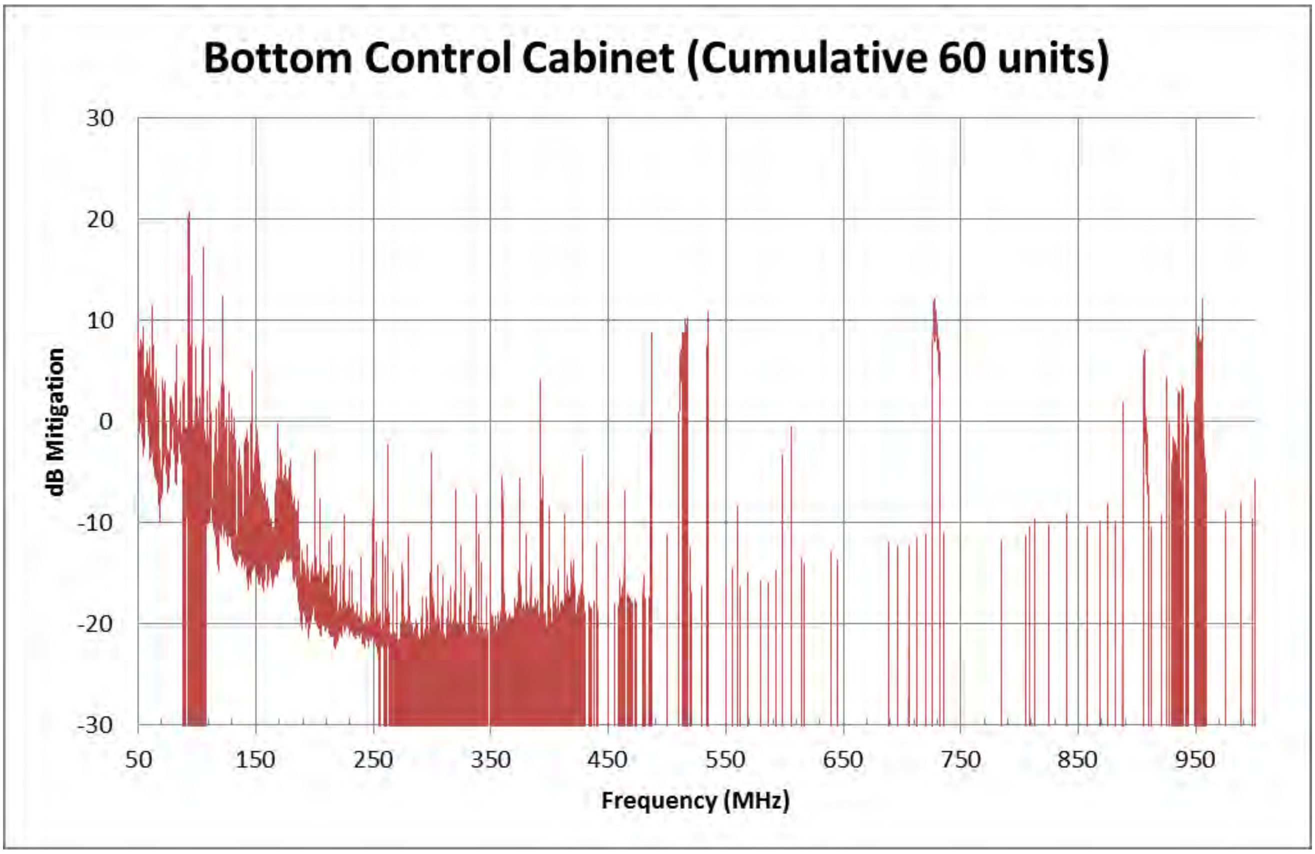
12.2.2 Bottom Control Cabinet

The calculated shielding required for the Bottom Control Cabinet was based on the data as shown in Table 11. The 6dB to 10dB shielding provided by the concrete tower is currently not included in the results.



Graph 19: Bottom Control Cabinet Attenuation required

Test results obtained at the current installation including a 10dB safety margin (Graph 19) shows that no additional attenuation is required. Adding a 17.8dB requirement to accommodate cumulative effect (Graph 20), highlighted the frequencies that will require additional attenuation of 12dB maximum excluding the FM radio frequencies. Little additional shielding of the bottom control cabinet would therefore be required.



Graph 20: Bottom Control Cabinet Attenuation required including cumulative effect

12.2.3 Top Control Cabinet

The Top Control Cabinet is mounted in the nacelle. The calculated shielding required for the Top Control Cabinet was based on the data as shown in Table 12.

12.2.4 Top Controller Mitigation Action Plan

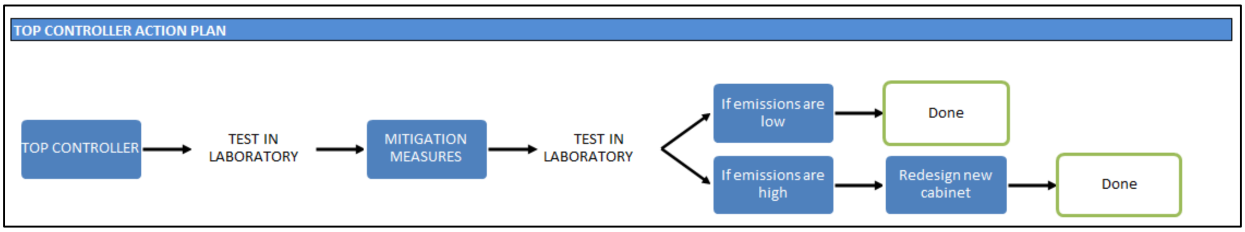
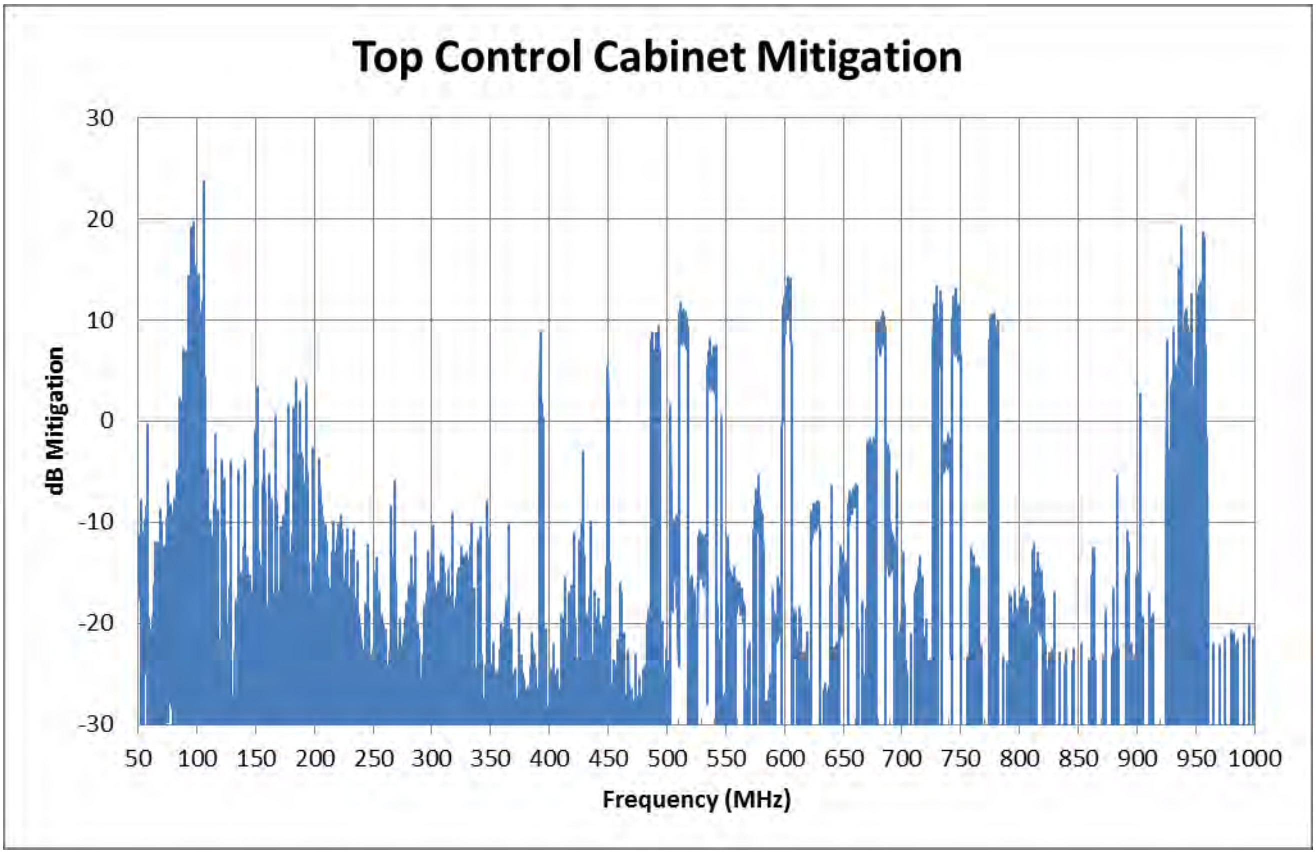
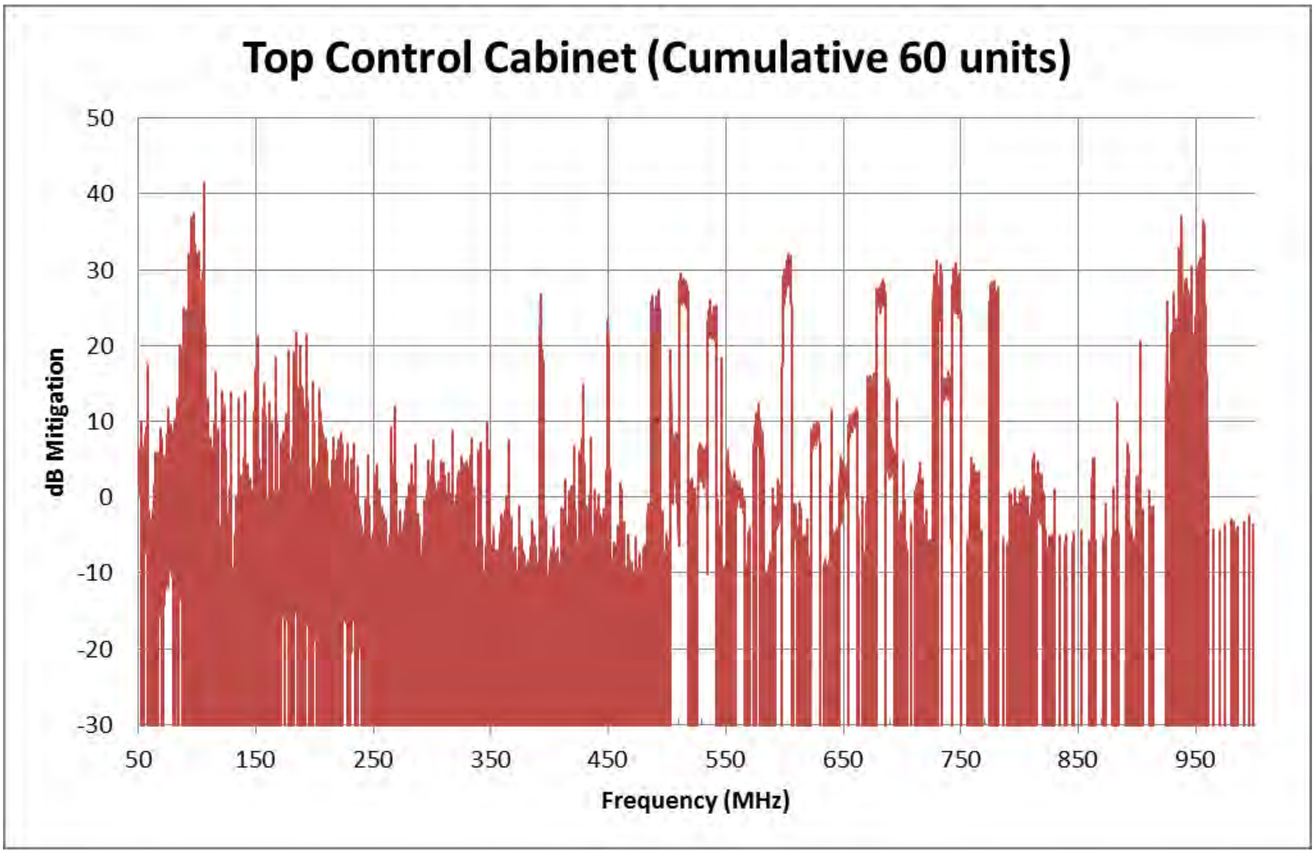


Figure 22: Top Controller Mitigation Action Plan

Figure 22 summarizes the top controller mitigation action plan. The top controller will be tested in an accredited EMC Test laboratory to confirm the extend of mitigation required. Mitigation measures will then be applied and the effectiveness will be confirmed in the laboratory. Should the retrofitting of the top controller be unsuccessful, the top controller cabinet mechanics will be redesigned to ensure sufficient shielding.



Graph 21: Top Control Cabinet Attenuation required



Graph 22: Top Control Cabinet mitigation required including cumulative effect

When taking cumulative effect into consideration, a significant amount of shielding is required. This is the combined effect of the cables entering and exiting the Top Control Cabinet and equipment mounted in the cabinet.
Further analysis of the highest peaks of Graph 22 revealed that they can be attributed to FM radio stations, TV and GSM intentional transmitters. However, not all signals that require attenuation could be attributed to intentional transmitters.
Given that the nacelle houses different equipment in a confined space and the difficulty in performing tests in the nacelle while the system is operational mitigation should include shielded cabinets, shielded cable trays and the use of absorptive cable sleeves.

Laboratory tests should be considered too narrow down the source possibilities.

12.3 MITIGATION PRINCIPLES

The mitigation principles are shown in Table 13.

Principle	Solution	Comment
Cable emissions (DM)	Shield wires	Can be implemented by using metal wiring ducts with duct cover (Par 13.1 refers). Although not designed for shielding, the shielding effectiveness could be enough for this application. Shielded flexible conduits can be used to terminate onto duct end covers for cable exits and onto the receiving end. (Par 13.2 refers).
	Control loop areas	By using the closed metal wiring duct and bonding them to earth, the loop area between cables and ground plane is reduced.
Cable emissions (CM)	Ferrites and absorbers	Ferrite loaded sleeve to convert common mode currents to heat
	Control loop areas	By using the closed metal wiring duct and bonding them to earth, the loop area between cables and ground plane is reduced
Enclosure Radiation	Improve shielding • EMC Gaskets • Conductive viewing aperture • Cooling aperture shield	

Table 13: Mitigation Principles

By implementing the suggested mitigation measures, the impact on the SKA project will be reduced. Where possible, the mitigation measures will be verified by means of laboratory tests.

To prevent an impact on the SKA Project, Biotherm Energy has reviewed the facility lay-out to increase the distance from the closest turbine to the closest SKA infrastructure from 20km to 25km. The number of turbines has also been reduced from the initial 125 turbines to 60 turbines.

12.4 TESTS AT THE NEW SITE

To verify overall windfarm emissions, ambient measurements should be done at the new site before construction starts. Tests points should be carefully selected based on test equipment sensitivity with the objective to observe the increase in ambient emissions as construction progresses.

12.5 FINAL SITE TESTS

Final site tests will be done on completion of the project and results should be compared to results in Par 11 to proof the effectiveness of the mitigation techniques.

13. APPENDIX A: EXAMPLE OF MITIGATION PRODUCTS

13.1 ENCLOSED METAL WIRING DUCT WITH DUCT COVER

WIRING DUCT - LAY-IN WIRING RETICULATION

All Cabstrut Ducting, Splices and Accessories are pre-punched with fixing holes that make installation a whole lot easier and quicker SAVING YOU TIME AND THAT MEANS MONEY!

Secondly NO POWER REQUIRED when running full lengths, just a rivet gun and the correct sized rivets.

And to make life even easier, the pre-punched holes are slotted so there's no need to struggle locating the rivet* especially when the duct isn't straight and level.

Comes as standard on: P8200 / P8300 / P8000 / P7810 / P9000 / P9800 / P9810

No pulling of cables necessary, all accessory covers are fitted after the wiring is complete!

Suitable for all reticulation including lighting

Can be customised for special projects

New universal splices suitable for all duct sizes from 76x50 to 127x100. Simply bend on site for smaller profiles.

Traditional U shaped **FOLD-FROM-FLAT**™ splices are also pre-punched and available as an option.

ONE SPLICE SUITS ALL DUCT SIZES
(Not suitable for P8100 Duct)

P8300 - 5A Socket outlets at 1500mm staggered centres.

Other centres to order. **P9000, P7100, P8000** and **P8300** can be manufactured to order with various outlets, e.g. 16A switched, 16A unswitched, 5A, 13A, etc. at centres specified.

P2200 - 20mm knockouts staggered on both sides at 150mm centres.

Capacity of Wireways Ducting vs. Conduit
DERIVED FROM SABS 0142-1981

DUCTING TYPE	EQUIVALENT No. OF CONDUITS				
	20Ø	25Ø	32Ø	40Ø	50Ø
P3300	3	2	1	-	-
P4000	4	2	2	1	-
P1000	7	5	3	2	1
P2000	8	5	3	2	1
P2200	12	8	5	3	2
P8100	9	6	4	2	2
P8200	18	11	7	4	3
P8300	23	14	9	5	4
P8000	27	17	11	7	4
P7000	34	21	13	8	5
P9000	46	29	18	11	7

Duct Covers

Standard finish (duct and cover): Galvanised (PG)

Covers are also available in grey and white PVC

P7184 and P2200 covers in (PG) only

Wiring Duct Sizes

P1000 41 x 41 x 2,5
Std. Length 5m
P1184 Cover
40 x 2500mm x 0,5

P2000 41 x 41 x 1,0
P2000 41 x 41 x 1,5
Std. Length 5m
P1184 Cover
40 x 2500mm x 0,5

P4000 41 x 20 x 1,5
Std. Length 5m
P1184 Cover
40 x 2500mm x 0,5

P3300 41 x 20 x 2,5
Std. Length 5m
P1184 Cover
40 x 2500mm x 0,5

P2200 51 x 51 0,8
Std. Length 3m
Biscuit Tin Lid
52 x 3000mm x 0,8

P8100 76 x 25 x 0,8
Std. Length 3m
P8184 Cover
75 x 3000mm x 0,5

P8200 76 x 51 x 0,8
Std. Length 3m
P8184 Cover
75 x 3000mm x 0,5

P8300 76 x 63 x 0,8
Std. Length 3m
P8184 Cover
75 x 3000mm x 0,5

P8000 76 x 76 x 0,8
Std. Length 3m
P8184 Cover
75 x 3000mm x 0,5

P7810 100 x 76 x 0.8
Std. Length 3m
P8184 Cover
75 x 3000mm x 0,5

P9810 127 x 100 x 0.8
Std. Length 3m
P8184 Cover
75 x 3000mm x 0,5

P9000 127 x 76 x 0.8
Std. Length 3m
P9184 Cover
125 x 3000mm x 0,5

P9800 127 x 76 x 0.8
Std. Length 3m
P8184 Cover
75 x 3000mm x 0,5

Trunking & Ducting Certification Approved
IN ACCORDANCE WITH SANS 61084-1

Cabstrut **FOLD-FROM-FLAT**™ Accessories
Hand made on-site in seconds
Accessories are easy to use and take up virtually no space in your store
Fold upwards towards raised bubbles
Bend-over tabs lock cover in place
Accessories for all ducts are available
Standard finish: Galvanised (PG)

Fold From Flat Standard Accessories

- External Elbow
- Internal Elbow
- Horizontal Elbow
- 3 Way Tee
- 4 Way Crossover
- Standard Splice
- Universal Splice
- End Cap

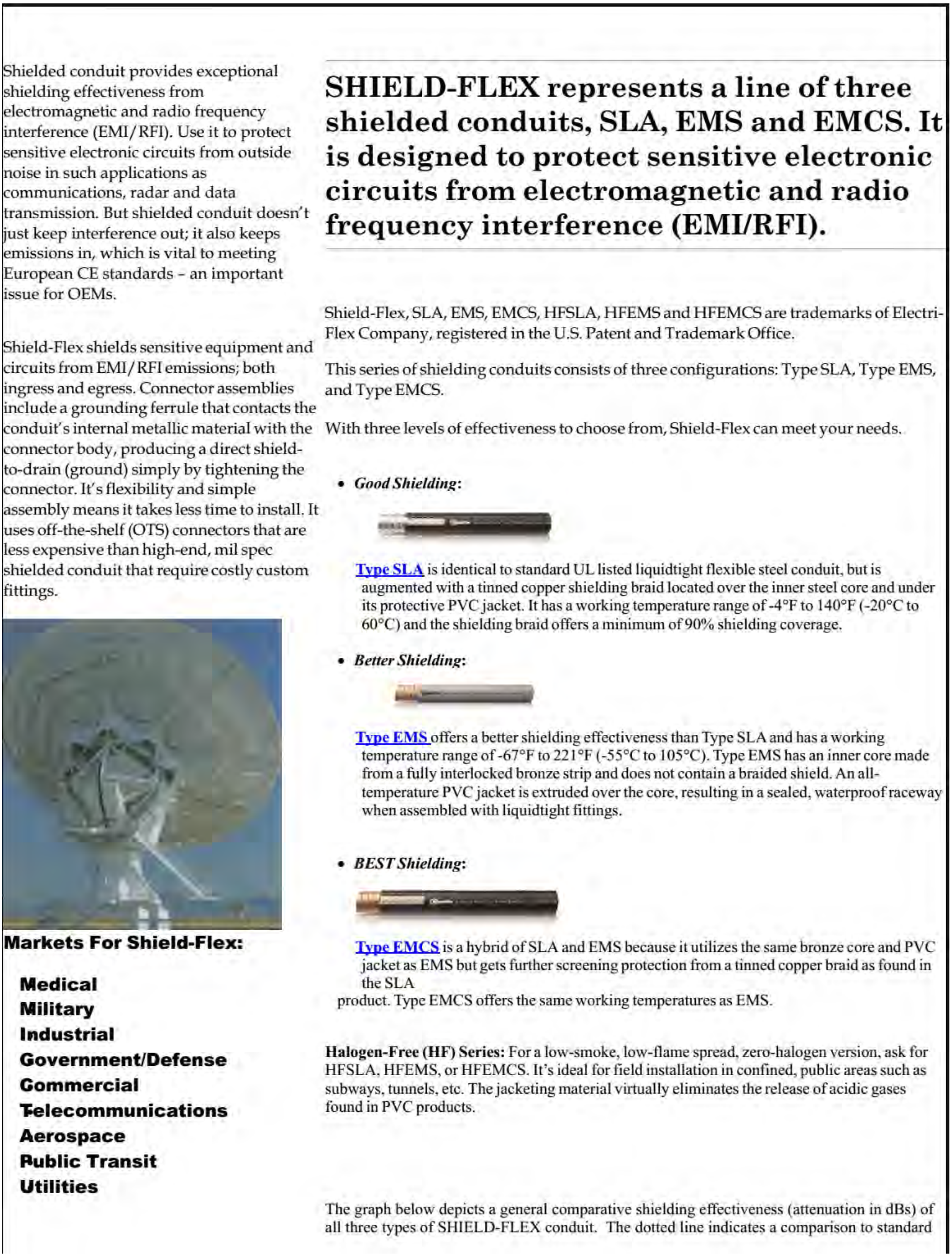
Fold From Flat Radiused Accessories (Complete With Cover)

- External Elbow
- Internal Elbow
- Horizontal Elbow
- Tee Radiused
- Crossover Radiused
- Distribution Outlet
- Hanger

Standard Solid Accessories

- External Elbow
- Internal Elbow
- Horizontal Elbow
- 3 Way Tee
- 4 Way Crossover
- Standard Splice
- Hanger
- End Cap

13.2 SHIELDED FLEXIBLE CONDUIT



Shielded conduit provides exceptional shielding effectiveness from electromagnetic and radio frequency interference (EMI/RFI). Use it to protect sensitive electronic circuits from outside noise in such applications as communications, radar and data transmission. But shielded conduit doesn't just keep interference out; it also keeps emissions in, which is vital to meeting European CE standards – an important issue for OEMs.

Shield-Flex shields sensitive equipment and circuits from EMI/RFI emissions; both ingress and egress. Connector assemblies include a grounding ferrule that contacts the conduit's internal metallic material with the connector body, producing a direct shield-to-drain (ground) simply by tightening the connector. It's flexibility and simple assembly means it takes less time to install. It uses off-the-shelf (OTS) connectors that are less expensive than high-end, mil spec shielded conduit that require costly custom fittings.

Markets For Shield-Flex:

- **Medical**
- **Military**
- **Industrial**
- **Government/Defense**
- **Commercial**
- **Telecommunications**
- **Aerospace**
- **Public Transit**
- **Utilities**

SHIELD-FLEX represents a line of three shielded conduits, SLA, EMS and EMCS. It is designed to protect sensitive electronic circuits from electromagnetic and radio frequency interference (EMI/RFI).

Shield-Flex, SLA, EMS, EMCS, HFSLA, HFEMS and HFEMCS are trademarks of Electri-Flex Company, registered in the U.S. Patent and Trademark Office.

This series of shielding conduits consists of three configurations: Type SLA, Type EMS, and Type EMCS.

With three levels of effectiveness to choose from, Shield-Flex can meet your needs.

- ***Good Shielding*:**

  Type SLA is identical to standard UL listed liquidtight flexible steel conduit, but is augmented with a tinned copper shielding braid located over the inner steel core and under its protective PVC jacket. It has a working temperature range of -4°F to 140°F (-20°C to 60°C) and the shielding braid offers a minimum of 90% shielding coverage.

- ***Better Shielding*:**

  Type EMS offers a better shielding effectiveness than Type SLA and has a working temperature range of -67°F to 221°F (-55°C to 105°C). Type EMS has an inner core made from a fully interlocked bronze strip and does not contain a braided shield. An all-temperature PVC jacket is extruded over the core, resulting in a sealed, waterproof raceway when assembled with liquidtight fittings.

- ***BEST Shielding*:**

  Type EMCS is a hybrid of SLA and EMS because it utilizes the same bronze core and PVC jacket as EMS but gets further screening protection from a tinned copper braid as found in the SLA product. Type EMCS offers the same working temperatures as EMS.

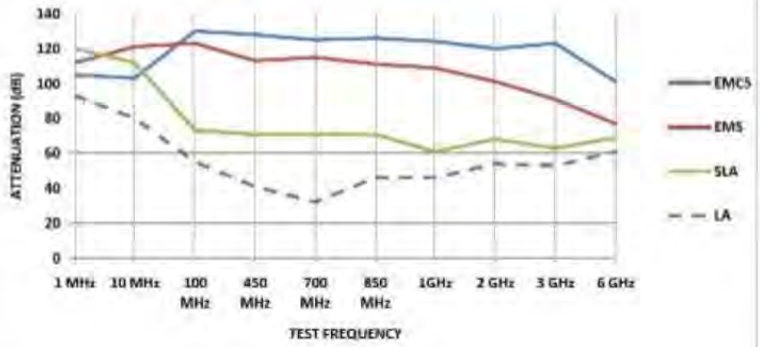
Halogen-Free (HF) Series: For a low-smoke, low-flame spread, zero-halogen version, ask for HFSLA, HFEMS, or HFEMCS. It's ideal for field installation in confined, public areas such as subways, tunnels, etc. The jacketing material virtually eliminates the release of acidic gases found in PVC products.

The graph below depicts a general comparative shielding effectiveness (attenuation in dBs) of all three types of SHIELD-FLEX conduit. The dotted line indicates a comparison to standard

Applications / Vertical Markets

- **Air handling equipment (HVAC)**
- **Test & Measurement Equipment**
- **Data Centers**
- **Variable Speed Drives**
- **Commercial-off-the-shelf (COTS) (CAGE Code: 09641)**
- **GE – European EMI Requirements**
- **Radio Broadband/Antenna**
- **Solar / Wind Energy**
- **Ship Building**
- **Medical Diagnostic Equipment**
- **Wireless Communications**
- **Healthcare / Medical**

unshielded liquidtight flexible conduit Type LA. The spectrum of test frequency is from 1 MHz to 10 MHz Electric Field, to 100 MHZ to 1 GHz Planewave Field and 2 GHz to 6 GHz Microwave Field. Tests were performed per MIL-STD-285 on 1" trade size conduit using standard liquidtight fittings from Thomas & Betts series 5300. Results are based on controlled laboratory conditions and may vary in actual field installed conditions.



13.3 CABLE SHIELDING

Z-SHIELD®

- ▶Excellent EMI Shielding (10 MHz to 20 GHz)
- ▶High Flexibility Applications
- ▶Flame-Retardant Polyurethane Jacket
- ▶Easy Installed Adhesive Closure

Z-Shield® is a wrap around EMI-shielded jacket made of fire retardant Polyurethane film, EMI shielding cloth or foil and an adhesive closure. This combination provides excellent electromagnetic shielding of wires and cables in applications requiring outstanding flexibility, flame-retardancy and good dielectric strength. Extremely useful in electronics applications where space may require a thin and flexible shielding. Z-Shield® can be configured to fit most Round, Flat or Rectangular cable configurations and is available with or without a drain wire installed.

✓ RoHS

Z-SHIELD® PRODUCT LINE

Z-Shield®
F.R. Polyurethane Jacket with Z-3250-CN EMI Shield

Z-Shield® (AL)
F.R. Polyurethane Jacket with SH1 EMI Shield

Z-Shield® (5080)
F.R. Polyurethane Jacket with Z-5080-CN EMI Shield

Z-Shield® (2L)
Dual Wall F.R. Polyurethane Jacket with Z-3250-CN EMI Shield

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