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REPORT ADDRESSING ELECTROMAGNETIC INTERFERENCE (EMI), PATH LOSS AND RISK ASSESSMENT FOR POFADDER WIND ENERGY FACILITY 1

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Notice

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Abbreviations and Acronyms

Abbreviation	Definition
AC	Alternating Current
AM	Amplitude Modulation
AMA	Astronomy Management Authority
CAL	Calibration
CCW	Counterclockwise
CISPR	International Special Committee on Radio Interference
CM	Common Mode
dBµV/m	Two terminal voltage developed across an antenna with an electrical length of 1m, referred to 1µV due to the electrical field strength. (Unit of measure)
E-Fields	Electric Fields
Electrical Equipment	Any electrical machinery, electrical systems, appliances, or devices, including any wireless data communications used for the operation of these facilities, used for construction, distribution and transmission power systems, exploring, framing, household, manufacturing, maintenance, or mining purposes
Electrical Infrastructure	Any infrastructure or facility, including any wireless data communications used for the operation of the electrical infrastructure, to be used in any way for electricity generation, electricity distribution, electricity transmission, or for a distribution or transmission power system, and electrical facilities and equipment used for these applications
EM	Electro Magnetic
EMC	Electro Magnetic Compatibility
EMI	Electro Magnetic Interference
Eq	Equation
Eqp	Equipment
EUT	Equipment Under Test
Existing Electrical Equipment and Infrastructure	Electrical equipment and infrastructure that is in operation or in use or where construction on site has started, prior to the date on which these regulations are promulgated by publication in the Government Gazette
Fr	Resonant frequency
H-Fields	Magnetic Fields
IEEE	Institute of Electrical and Electronic Engineers
ITM	Irregular Terrain Model
MIL-STD	Military Standard
PSU	Power Supply Unit
R&S	Rohde and Schwarz
RF	Radio Frequency
SE	Shielding Effectiveness
SELDS	Shielding Effectiveness Leak Detection System
SKA	Square Kilometer Array
SKA Infrastructure Territory	The protection corridors within the Karoo Central Astronomy Advantage Area 1 as depicted and described in Annexure A of the Schedule D Regulations and the 20km radius circular area around the SKA Virtual Centre
WEF	Wind Energy Facility

TABLE OF CONTENTS

TABLE OF TABLES

TABLE OF FIGURES

1. INTRODUCTION

An area about 140 km North-West from the SKA radio telescope project in the Northern Cape Province, has been identified for the Pofadder Wind Energy Facility 1.

The Karoo area is ideally suited for the installation and commissioning of renewable energy projects, but it is also host to the Department of Science and Technology's SKA radio telescope project. Due to the sensitivity of the telescope receivers, there is a risk that unintentional emissions from the systems associated with renewable energy projects will desensitise the SKA receivers resulting in interference to celestial observations and/or data loss. Such interference is typically referred to as 'Radio Frequency Interference (RFI)'. RFI is part of the EMC engineering discipline that includes electromagnetic emissions and electromagnetic immunity.

This report forms part of three separate reports, that focuses on the RFI that the Pofadder Wind Energy Facility cluster presents on the SKA radio telescope project. A pathloss study between the Pofadder Wind Energy Facility cluster and the SKA radio telescope project was conducted, and the results identify any mitigation that should be implemented.

No AMA permits will be required as the WEFs are located further than 50km away from the closest SKA infrastructure.

2. SCOPE

This assessment is a high-level desktop study and can be updated based on additional measurement results and design information as it becomes available. This specific report will focus on the Path-Loss results between Pofadder Wind Energy Facility 1 and the SKA telescope project. Each report will discuss two separate scenarios:

- Scenario 1 considers the maximum parameters being proposed for the environmental impact assessment (EIA), being Hub Height (HH) of 200 m and Rotor Diameter (RD) of 200 m; and

- Scenario 2 considers the turbine model N163/6.X anticipated for the earliest date when the projects will be bid ready. Therefore 120 m HH and 163 m RD.

2.1 INTENT

The intent of this evaluation is to ensure that the Pofadder Wind Energy Facility cluster poses a low risk of detrimental impact on the SKA by comparing the anticipated emissions from equipment complying to the CISPR 11/32 class B limits minus the path loss due to distance and terrain to the protection levels required by SARAO to ensure interference free operations. Should additional mitigation (shielding and filtering) be required it will be quantified in this report.

3. ASSESSMENT METHODOLOGY

i. Confirm Pofadder WEF location with POFADDER WIND FACILITY 1 (PTY) LIMITED.
ii. Confirm nearest SKA dish installation area with AMA.
iii. Assume equipment compliance with CISPR limits
iv. Plot line of sight graphs using the 200m hub height and 10m for the SKA dish between the SKA dish and nearest wind turbine generator (WTG).
v. Plot line of sight graphs using the 120m hub height and 10m for the SKA dish between the SKA dish and nearest wind turbine generator (WTG).
vi. Perform path loss calculations using the Irregular Terrain Model between the turbine and SKA dish.
vii. Use the CISPR 11/32 Class B radiated emission limits and subtract the total path loss to confirm the result is less than the protection level at the SKA dish installation location.
viii. If the result from vii exceeds the SARAS level, additional mitigation is required.

4. REFERENCES

4.1 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]	No 41321. Government Gazette 15 December 2017	Regulations on the Protection of the Karoo Central Astronomy Advantage Areas in terms of the Astronomy Geographic Advantage Act, 2007
[3]	N.R100017.R.01.009. Research Program – KR Hubbard	Radio Interference between the solar 400kV transmission line and the SKA.
[4]	CISPR 11 Edition 6.1 2016-06	Industrial, scientific, and medical equipment – Radio-frequency disturbances characteristics –Limits and methods of measurement
[5]	CISPR 32:2015 Edition 2	Electromagnetic compatibility of multimedia equipment – Emission requirements

4.2 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

5. TECHNOLOGY DESCRIPTION

A typical wind turbine system has the following building blocks elements:

- Rotor (Blades, hub, and pitch system).
- Nacelle housing the generator, gearbox if not direct drive, yaw system, monitoring/ control systems, power convertor, transformer.
- Tower (concrete or steel).

Some manufacturers choose to remove the power convertors and transformers from the nacelle and place it in the tower or separate facility next to the tower.

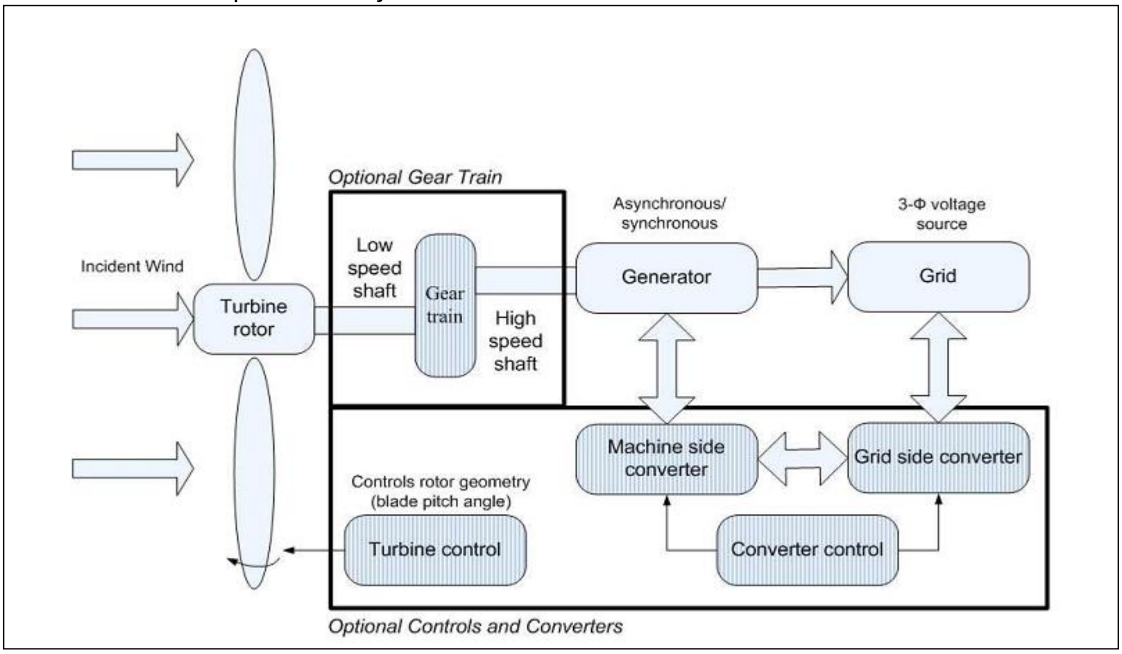

Figure 1: Generic wind turbine block diagram

6. RISK IDENTIFICATION

6.1 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).

6.1.1 Control/ monitoring systems

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

6.1.2 Control and operations centre

Equipment installed in the control and operations centre should comply with CISPR 32 Class B. No mitigation requirement for equipment installed in the control and operations centre.

6.1.3 Power Convertor

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

6.2 SITE WIDE COMMUNICATIONS

The communication among the wind turbines, the MET masts and wind turbines and the substation should be through an Ethernet optical fibre network to reduce radiated emissions from the site wide communications.

6.3 GRID CONNECTION INFRASTRUCTURE

Based on the study supported by Eskom under the research programme: EMC and EMI (N.R100017.R.01.009 [3] the grid connection infrastructure interference is not viewed as problematic given that no arcing or sparking occurs due to voltage gradients or substandard installation practices. The principle of no wireless reporting communication and wireless control of systems (e.g. Bluetooth, wi-fi, Zigbee etc) as applicable to the turbine installation should be maintained.

7. EMC ANALYSIS

7.1 SITE LOCATION

7.1.1 Pofadder Wind Energy Facility 1 Map

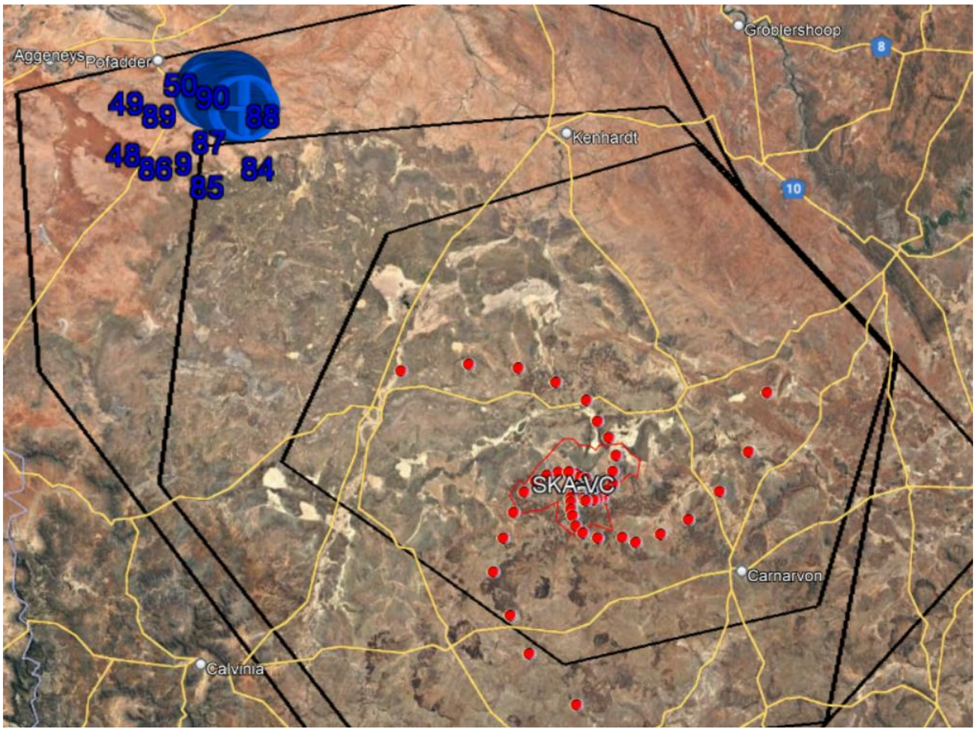

Figure 2 - Area Map with SKA and Pofadder Wind Energy Facility 1 Visible

Four separate wind turbines in Pofadder Wind Energy Facility 1 were identified for this study. The closest turbine, the turbine with the highest elevation above sea level, the turbine with the lowest pathloss to the SKA infrastructure in the spiral and the turbine with the lowest pathloss to a core SKA telescope. Each of these four points were subjected to two scenarios for the risk analysis desktop study. Scenario 1 where a Hub Heigh (HH) of 200m was used and Scenario 2 where a HH of 120m was used. The pathloss between the points for each scenario are tabulated in the result sections for each scenario.

8. POFADDER WIND ENERGY FACILITY 1 SCENARIO 1 RESULTS

SKA ID	Turbine ID	Description	Distance (km)
SKA 008	P 55	Closest point	141.38
SKA 008	P 9	Turbine with the highest elevation	146.80
SKA 008	P 53	Turbine with the lowest pathloss to the SKA site	141.85
M049 (Core)	P 55	Turbine with the lowest pathloss to the SKA core site	223.79

Table 1: Pofadder Wind Energy Facility 1 Layout distance from SKA infrastructure

8.1 ELEVATION MAPS

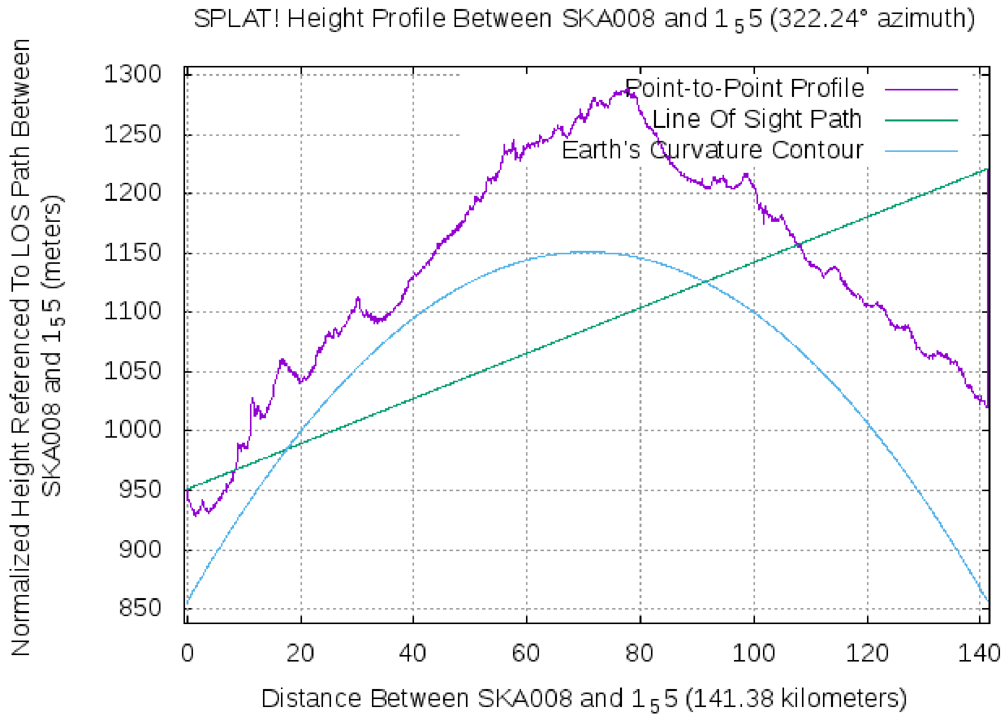

Figure 3 – Elevation Map Between SKA008 and P 55

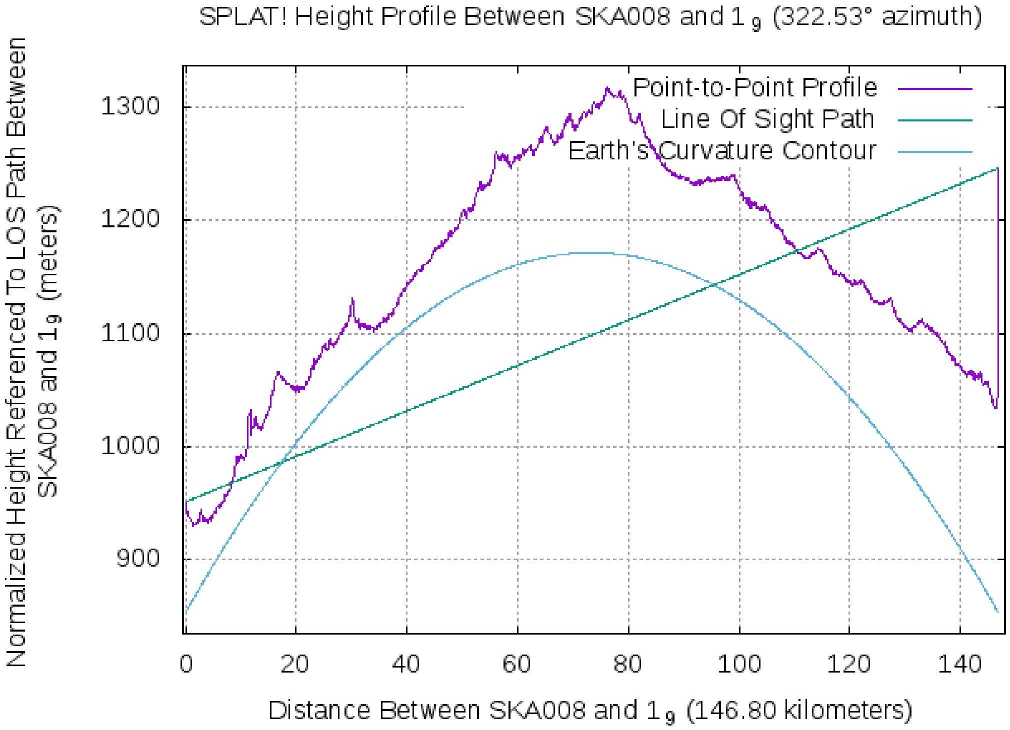

Figure 4 – Elevation map Between SKA008 and P 9

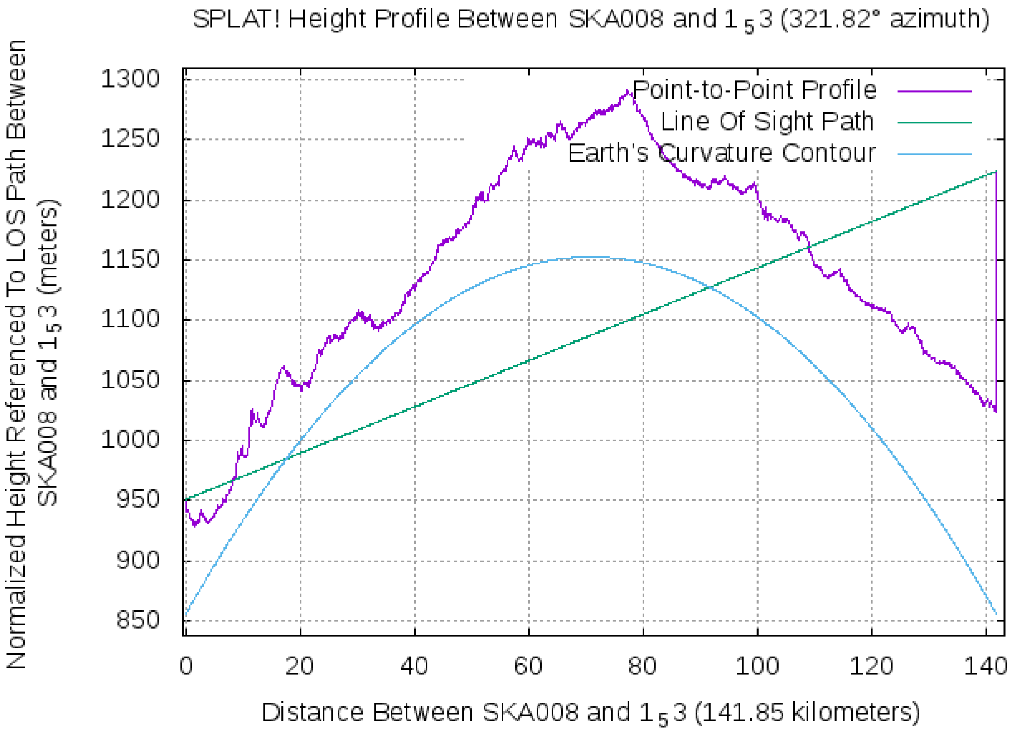

Figure 5 – Elevation Map Between SKA008 and P 53

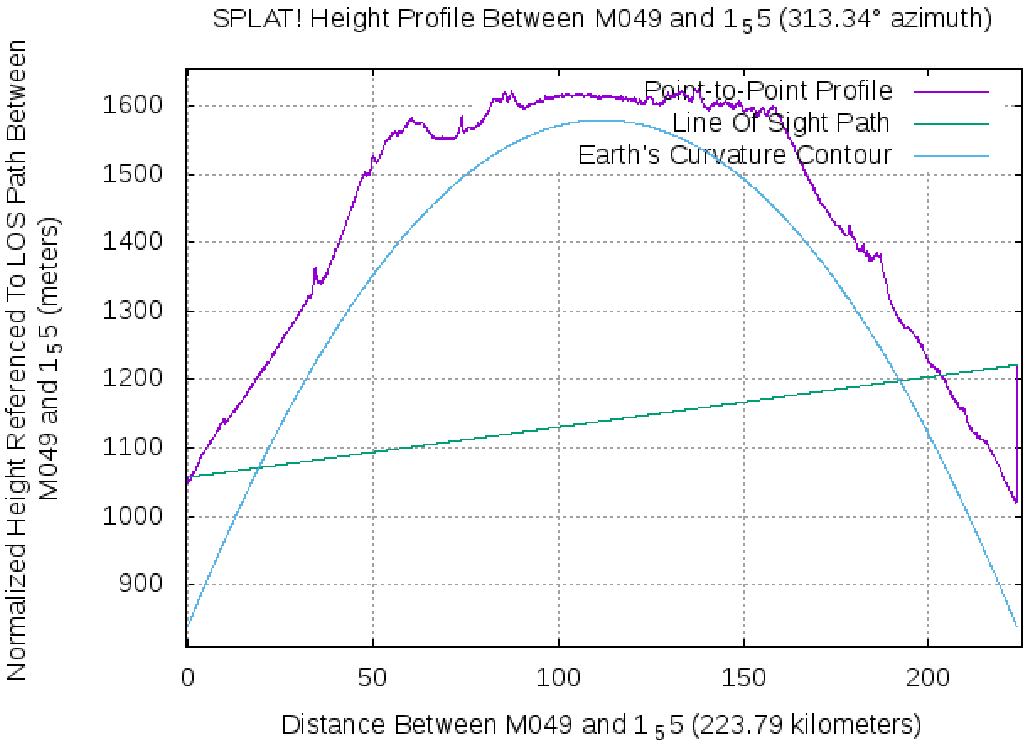

Figure 6 – Elevation Map Between M049 and P 55

8.2 PATH LOSS CALCULATIONS

The path loss was calculated using the parameters as specified in Table 2: Path loss input data.

Parameter	Description	Quantity	Comment
Source/ Victim separation distance	SKA008 to P55	141.38 km	Non line of sight
Source/ Victim separation distance	SKA008 to P9	146.80 km	Non line of sight
Source/ Victim separation distance	SKA008 to P53	141.85 km	Non line of sight
Source/ Victim separation distance	M049 to P55	223.79 km	Non line of sight
Frequency	Frequencies assessed	70MHz, 100MHz, 230MHz, 300MHz, 500MHz, 700MHz, 1000MHz, 3000MHz, 6000MHz	Free space loss increases with frequency. Terrain effects determine final value.
SARAS	Protection level	dBm/Hz = -17.2708 log 10 (f) -192.0714 for f<2GHz	Government Gazette 10 February 2012
TX height	Pofadder Turbines	200m	Hub Height of Turbines
RX height	All SKA receivers	10m	Height used for SKA receive horn
Earth dielectric Constant (Relative permittivity)		4.000	Constant
Earth Conductivity	Siemens per meter	0.001	Constant
Atmospheric Bending Constant	N-units	301.000	Constant
Fraction of situations	5% data loss acceptable for radio telescope	0.05	Constant
Fraction of time	5% data loss acceptable for radio telescope	0.05	Constant
Radio Climate	Desert	4	Constant
Polarization	Vertical	1	Constant

Table 2: Path loss input data

8.3 PATH LOSS RESULTS

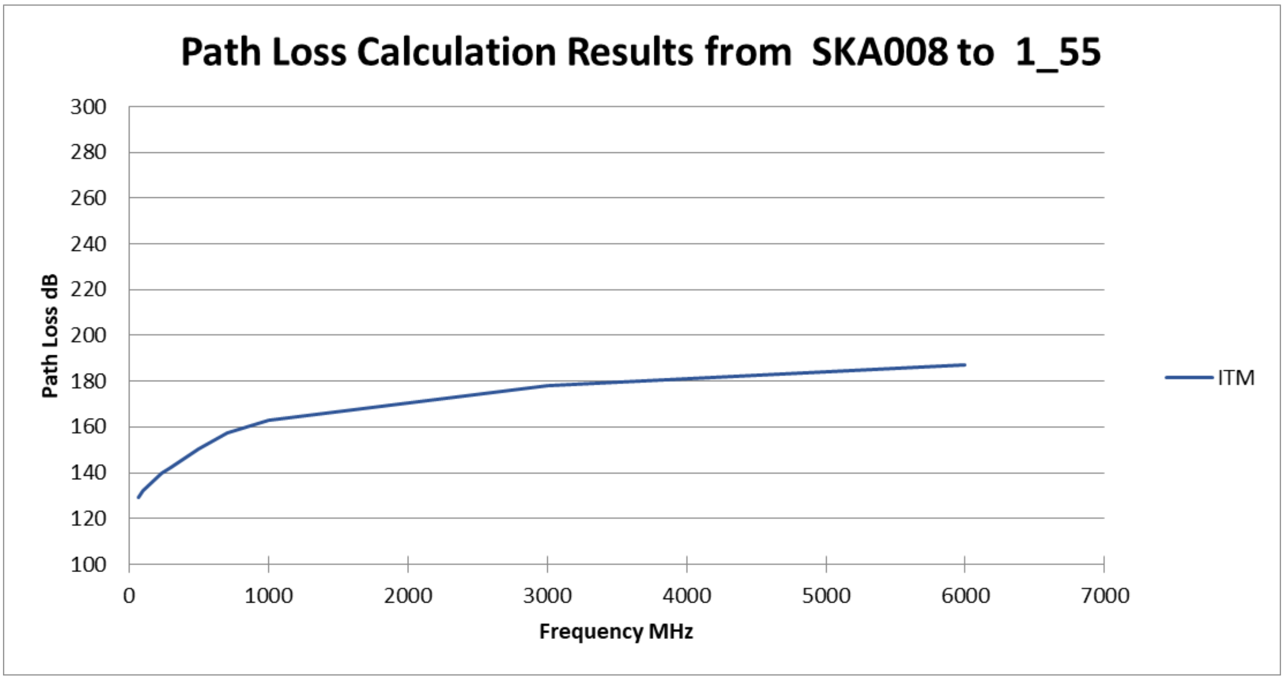

Figure 7 – Path Loss Calculation Results from Pofadder 55 to SKA008

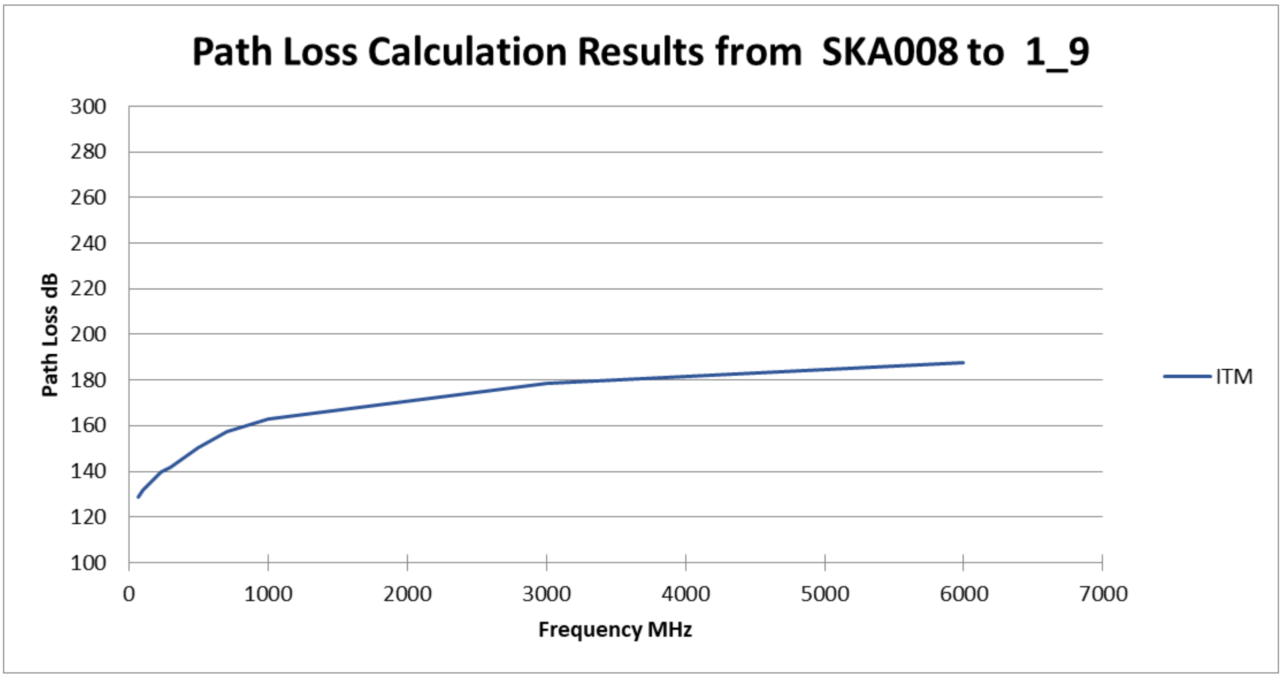

Figure 8 – Path Loss Calculation Results from Pofadder 9 to SKA008

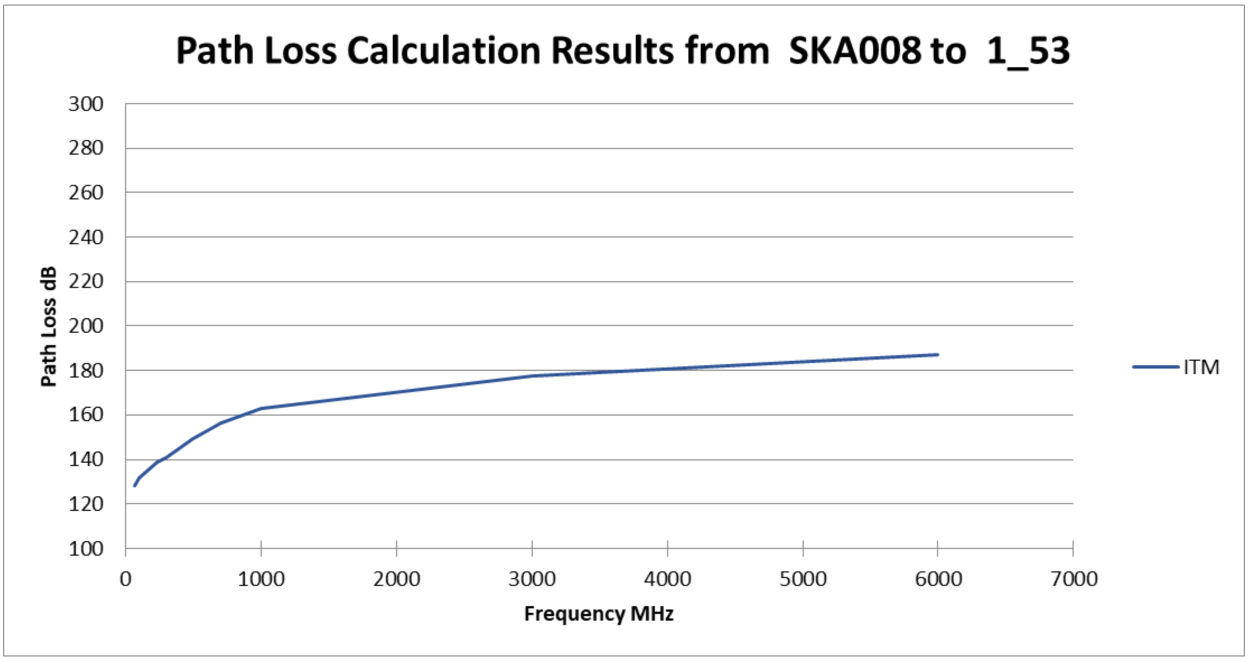

Figure 9 – Path Loss Calculation Results from Pofadder 53 to SKA008

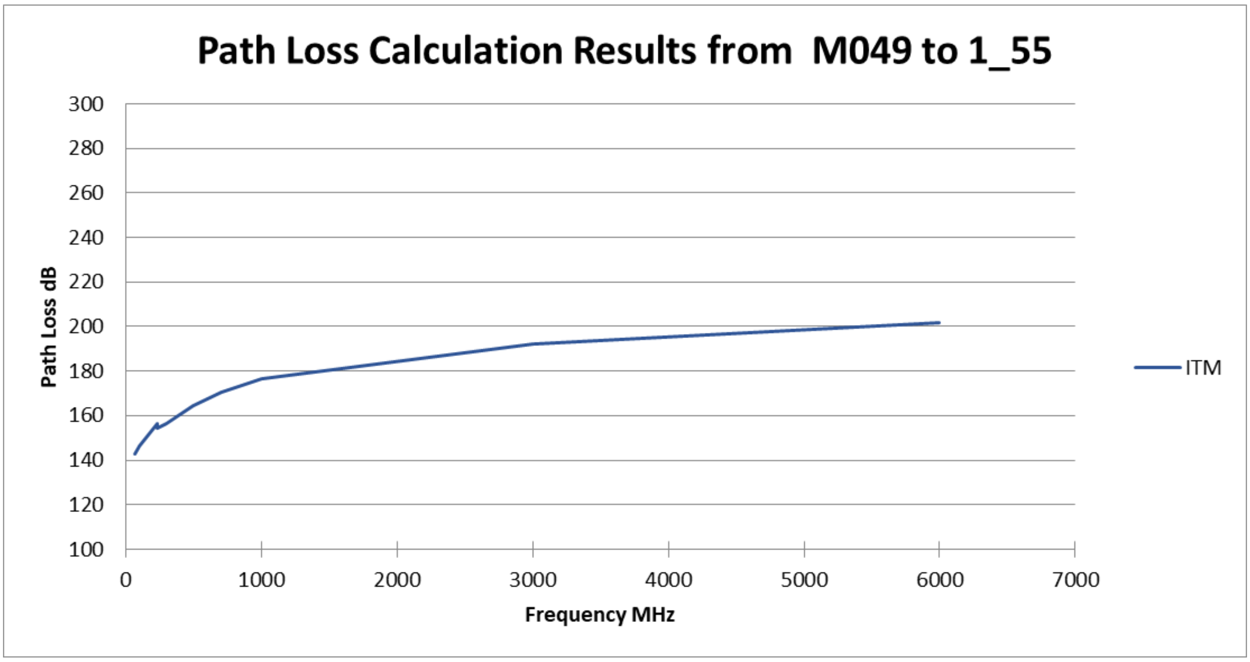

Figure 10 – Path Loss Calculation Results from Pofadder 55 to M049

Figures 7 to 10 show the path loss result calculated for Pofadder Wind Energy Facility 1 Scenario 1 equipment emissions at 200m HH.

SPLAT! (Signal Propagation, Loss And Terrain) analysis is based on the Longley –Rice Irregular Terrain Model. The digital elevation model resolution data used was 3-arc –seconds.

8.4 CUMULATIVE EFFECT

A standard factor of 10 $\log_{10}$ N, where N = the number of turbines for each Pofadder Wind Energy Facility separately, to account for cumulative emissions has been applied.

8.5 MITIGATION REQUIRED

8.5.1 Case 1: SKA008 to Pofadder 55 Mitigation requirement

SKA008 to Pofadder 55						
Frequency [MHz]	**SARAS Requirement [dBW/Hz]**	**Required Path Loss SARAS (incl 10dB) [dB]**	**Calculated Path Loss [dB]**	**Number of units**	**Facility Mitigation required [dB]**	**Unit Mitigation required [dB]**
70	-253.94	128.35	129.41	30	-1.06	13.71
100	-256.61	131.02	132.39	30	-1.37	13.40
230	-262.86	137.27	139.87	30	-2.60	12.17
230	-262.86	144.27	139.87	30	4.40	19.17
300	-264.85	146.26	142.05	30	4.21	18.98
500	-268.68	150.09	150.42	30	-0.33	14.44
700	-271.21	152.62	157.43	30	-4.81	9.96
1000	-273.88	155.29	162.85	30	-7.56	7.21
**1000*	-273.88	168.63	162.85	30	5.78	20.55
**3000*	-279.09	173.84	178	30	-4.16	10.61
**3000*	-279.09	177.84	178	30	-0.16	14.61
**6000*	-279.11	177.86	187.29	30	-9.43	5.34

Table 3: Case 1: SKA008 to Pofadder 55 mitigation requirement

** CISPR 32 levels*

Due to the cumulative effect of 30 Units in the facility, mitigation of 21dB at 1GHz would be required. The implication is that the radiated emission in the 100MHz to 1GHz band should be 21dB less than the CISPR 11/32 Class B radiated emission limit.

8.5.2 Case 2 SKA008 to Pofadder 9 requirement

SKA008 to Pofadder 9						
Frequency [MHz]	SARAS Requirement [dBW/Hz]	Required Path Loss SARAS (incl 10dB) [dB]	Calculated Path Loss [dB]	Number of units	Facility Mitigation required [dB]	Unit Mitigation required [dB]
70	-253.94	128.35	128.78	30	-0.43	14.34
100	-256.61	131.02	131.94	30	-0.92	13.85
230	-262.86	137.27	139.6	30	-2.33	12.44
230	-262.86	144.27	139.6	30	4.67	19.44
300	-264.85	146.26	141.84	30	4.42	19.19
500	-268.68	150.09	150.39	30	-0.30	14.47
700	-271.21	152.62	157.64	30	-5.02	9.75
1000	-273.88	155.29	163.16	30	-7.87	6.90
**1000*	-273.88	168.63	163.16	30	5.47	20.24
**3000*	-279.09	173.84	178.43	30	-4.59	10.18
**3000*	-279.09	177.84	178.43	30	-0.59	14.18
**6000*	-279.11	177.86	187.77	30	-9.91	4.86

Table 4: Case 2: SKA008 to Pofadder 9 mitigation requirement

** CISPR 32 levels*

Due to the cumulative effect of 30 Units in the facility, mitigation of 21dB at 1GHz would be required. The implication is that the radiated emission in the 100MHz to 1GHz band should be 21dB less than the CISPR 11/32 Class B radiated emission limit.

8.5.3 Case 3: SKA008 to Pofadder 53 Requirements

SKA008 to Pofadder 53						
Frequency [MHz]	SARAS Requirement [dBW/Hz]	Required Path Loss SARAS (incl 10dB) [dB]	Calculated Path Loss [dB]	Number of units	Facility Mitigation required [dB]	Unit Mitigation required [dB]
70	-253.94	128.35	128.42	30	-0.07	14.70
100	-256.61	131.02	131.47	30	-0.45	14.32
230	-262.86	137.27	138.88	30	-1.61	13.16
230	-262.86	144.27	138.88	30	5.39	20.16
300	-264.85	146.26	141	30	5.26	20.03
500	-268.68	150.09	149.22	30	0.87	15.64
700	-271.21	152.62	156.27	30	-3.65	11.12
1000	-273.88	155.29	162.73	30	-7.44	7.33
**1000*	-273.88	168.63	162.73	30	5.90	20.67
**3000*	-279.09	173.84	177.79	30	-3.95	10.82
**3000*	-279.09	177.84	177.79	30	0.05	14.82
**6000*	-279.11	177.86	187.05	30	-9.19	5.58

Table 5: Case 3: SKA008 to Pofadder 53 mitigation requirement

** CISPR 32 levels*

Due to the cumulative effect of 30 Units in the facility, mitigation of 21dB at 1GHz would be required. The implication is that the radiated emission in the 100MHz to 1GHz band should be 21dB less than the CISPR 11/32 Class B radiated emission limit.

8.5.4 Case 4: M049 to Pofadder 55 Requirements

M049 to Pofadder 55						
Frequency [MHz]	SARAS Requirement [dBW/Hz]	Required Path Loss SARAS (incl 10dB) [dB]	Calculated Path Loss [dB]	Number of units	Facility Mitigation required [dB]	Unit Mitigation required [dB]
70	-253.94	128.35	142.71	30	-14.36	0.41
100	-256.61	131.02	146.32	30	-15.30	-0.53
230	-262.86	137.27	156.57	30	-19.30	-4.53
230	-262.86	144.27	154.41	30	-10.14	4.63
300	-264.85	146.26	156.57	30	-10.31	4.46
500	-268.68	150.09	164.39	30	-14.30	0.47
700	-271.21	152.62	170.58	30	-17.96	-3.19
1000	-273.88	155.29	176.42	30	-21.13	-6.36
**1000*	-273.88	168.63	176.42	30	-7.79	6.98
**3000*	-279.09	173.84	192.29	30	-18.45	-3.68
**3000*	-279.09	177.84	192.29	30	-14.45	0.32
**6000*	-279.11	177.86	201.79	30	-23.93	-9.16

Table 6: Case 4: M049 to Pofadder 55 mitigation requirement

** CISPR 32 levels*

Due to the cumulative effect of 30 Units in the facility, mitigation of 7dB at 1GHz would be required. The implication is that the radiated emission in the 100MHz to 1GHz band should be 7dB less than the CISPR 11/32 Class B radiated emission limit.

8.6 CONCLUSION FOR SCENARIO 1

Due to the pathloss between Pofadder 53 and SKA008, the two points with the lowest pathloss between SKA and Pofadder Wind Energy Facility 1, a degradation of performance is expected unless the radiated emissions from each turbine installation can be reduced to 21dB below the CISPR 11/32 Class B limit across the 100MHz to 6GHz band.

8.7 TESTS AT THE NEW SITE

To verify overall WEF 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 and completion of the project.

8.8 FINAL SITE TESTS

Final site tests should be done on completion of the project to confirm the radiated emission levels.

9. POFADDER WIND ENERGY FACILITY 1 SCENARIO 2 RESULTS

SKA ID	Turbine ID	Description	Distance (km)
SKA008	P 55	Closest point	141.38
SKA008	P 9	Turbine with the highest elevation	146.80
SKA008	P 53	Turbine with the lowest pathloss to the SKA site	141.85
M049 (Core)	P 55	Turbine with the lowest pathloss to the SKA core site	223.79

Table 7 – Pofadder Layout distance from SKA infrastructure

9.1 ELEVATION MAPS

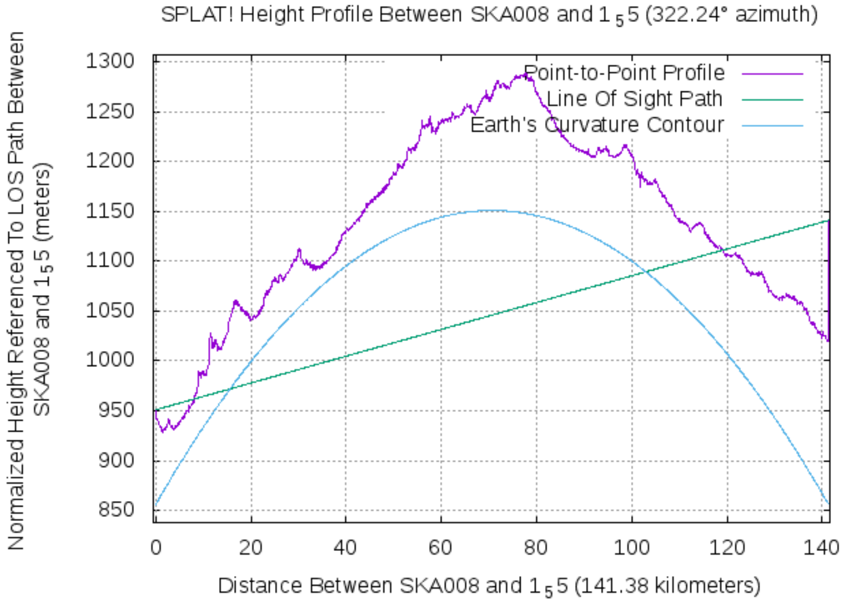

Figure 11 – Elevation map Between SKA008 and P 55

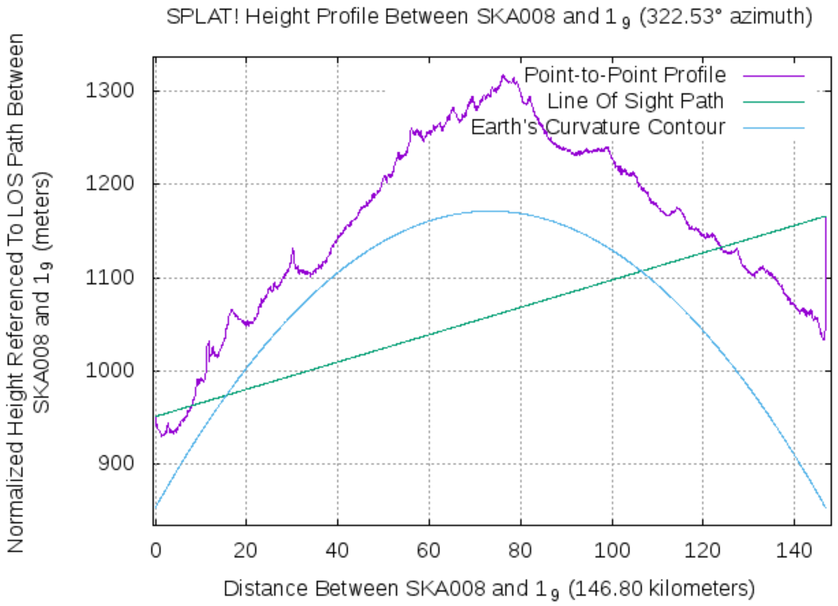

Figure 12 – Elevation map Between SKA008 and P 9

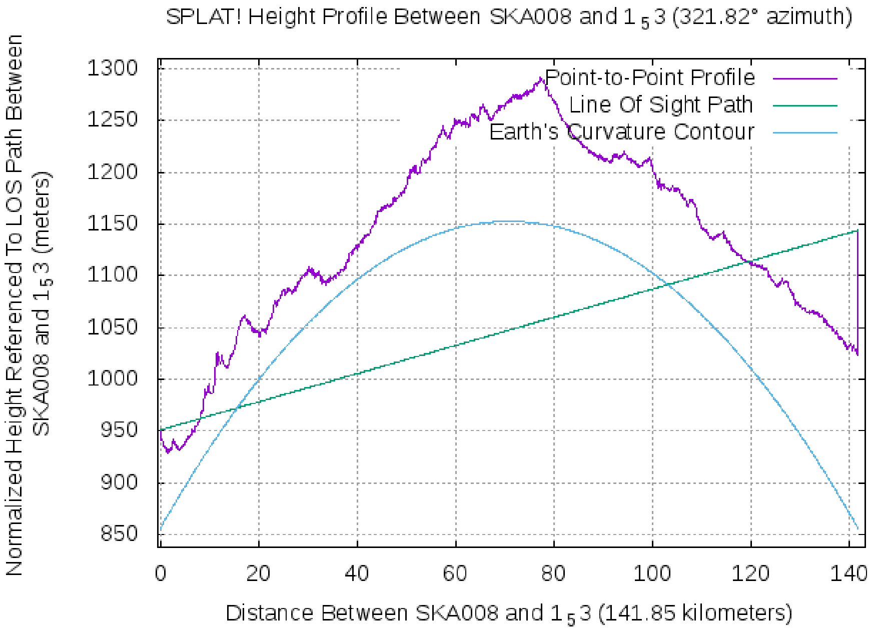

Figure 13 – Elevation map Between SKA008 and P 53

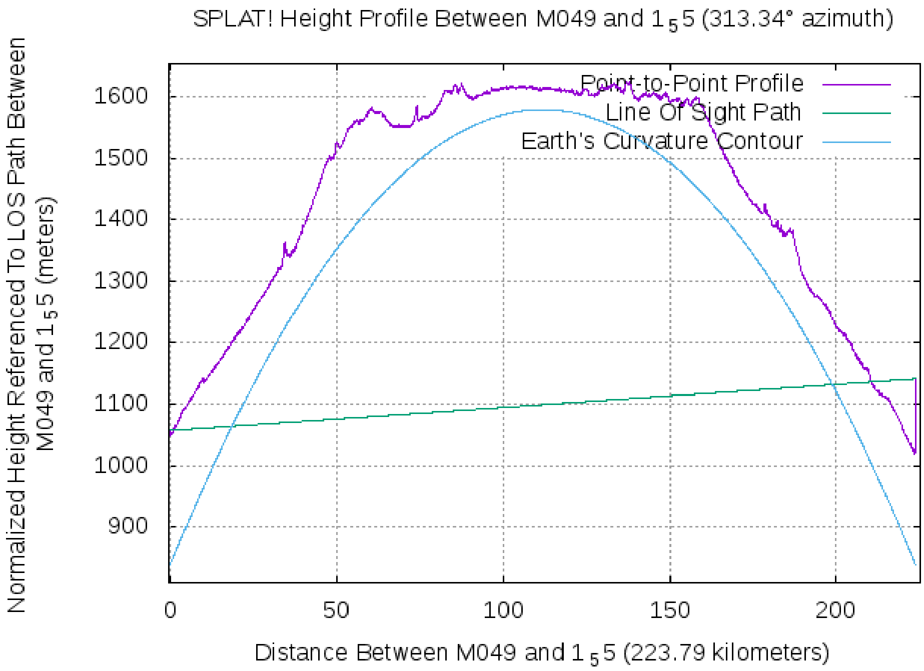

Figure 14 – Elevation map Between M049 and P 55

9.2 PATH LOSS CALCULATIONS

The path loss was calculated using the parameters as specified in Table 8: Path loss input data.

Parameter	Description	Quantity	Comment
Source/ Victim separation distance	P55 to SKA008	141.38 km	Non line of sight
Source/ Victim separation distance	P9 to SKA008	146.80 km	Non line of sight
Source/ Victim separation distance	P53 to SKA008	141.85 km	Non line of sight
Source/ Victim separation distance	P55 to M049 (Core)	223.79 km	Non line of sight
Frequency	Frequencies assessed	70MHz, 100MHz, 230MHz, 300MHz, 500MHz, 700MHz, 1000MHz, 3000MHz, 6000MHz	Free space loss increases with frequency. Terrain effects determine final value.
SARAS	Protection level	dBm/Hz = -17.2708 log 10 (f) -192.0714 for f<2GHz	Government Gazette 10 February 2012
TX height	Pofadder Turbines	120m	Hub Height of Turbines
RX height	All SKA receivers	10m	Height used for SKA receive horn
Earth dielectric Constant (Relative permittivity)		4.000	Constant
Earth Conductivity	Siemens per meter	0.001	Constant
Atmospheric Bending Constant	N-units	301.000	Constant
Fraction of situations	5% data loss acceptable for radio telescope	0.05	Constant
Fraction of time	5% data loss acceptable for radio telescope	0.05	Constant
Radio Climate	Desert	4	Constant
Polarization	Vertical	1	Constant

Table 8 – Path Loss Input Data

9.3 PATH LOSS RESULTS

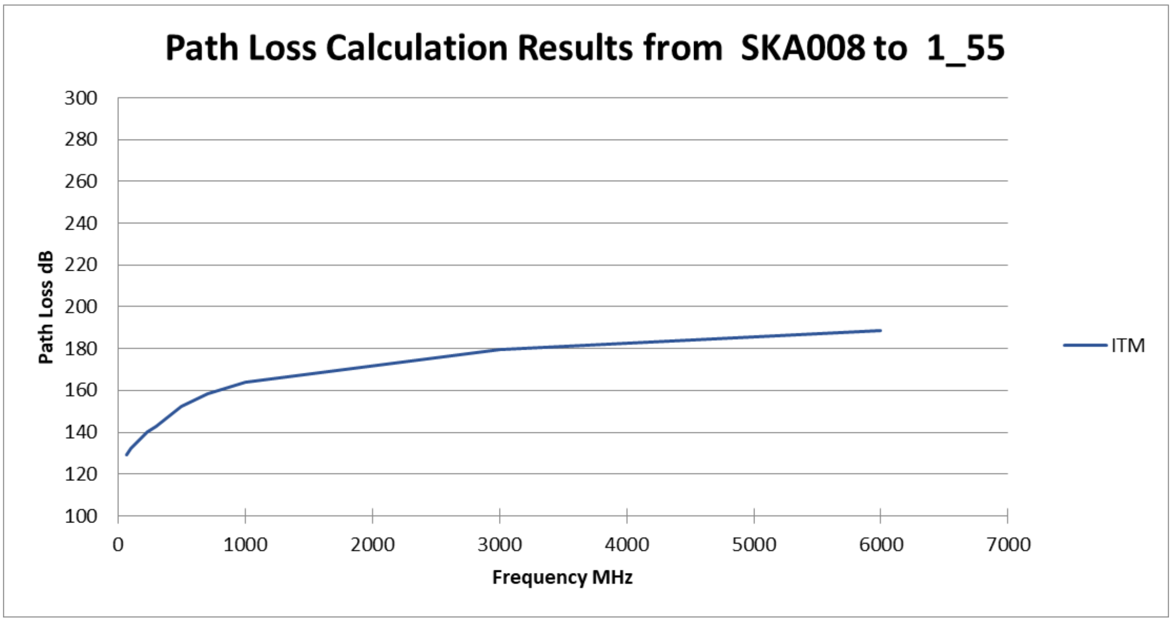

Figure 15 – Path Loss Calculation Results from Pofadder 55 to SKA008

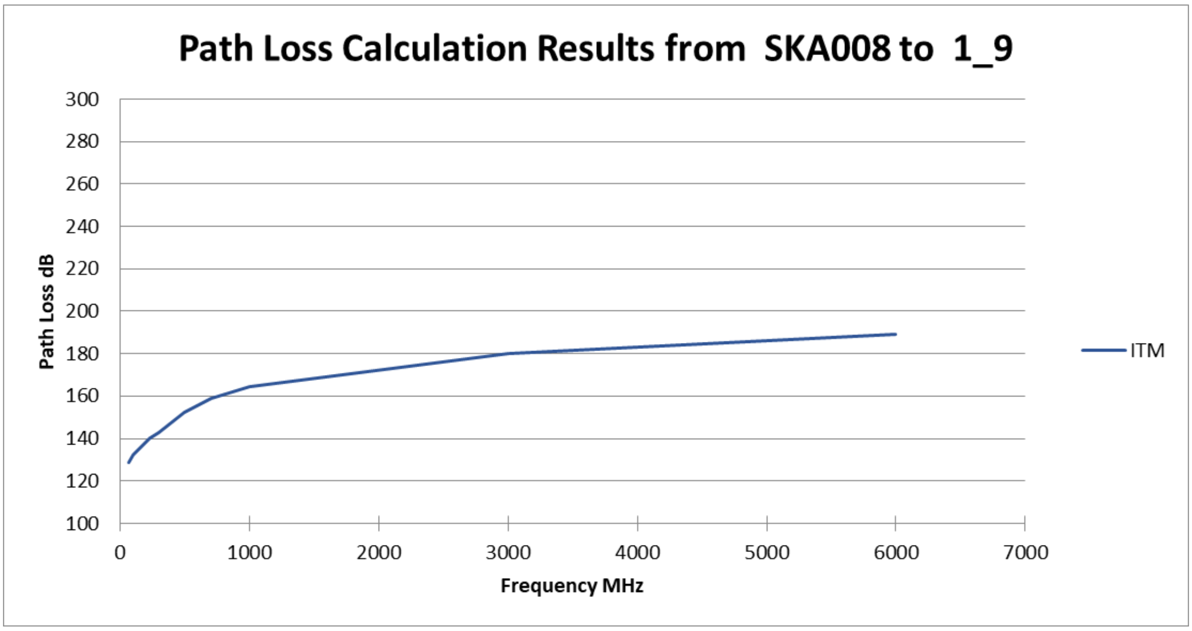

Figure 16 – Path Loss Calculation Results from Pofadder 9 to SKA008

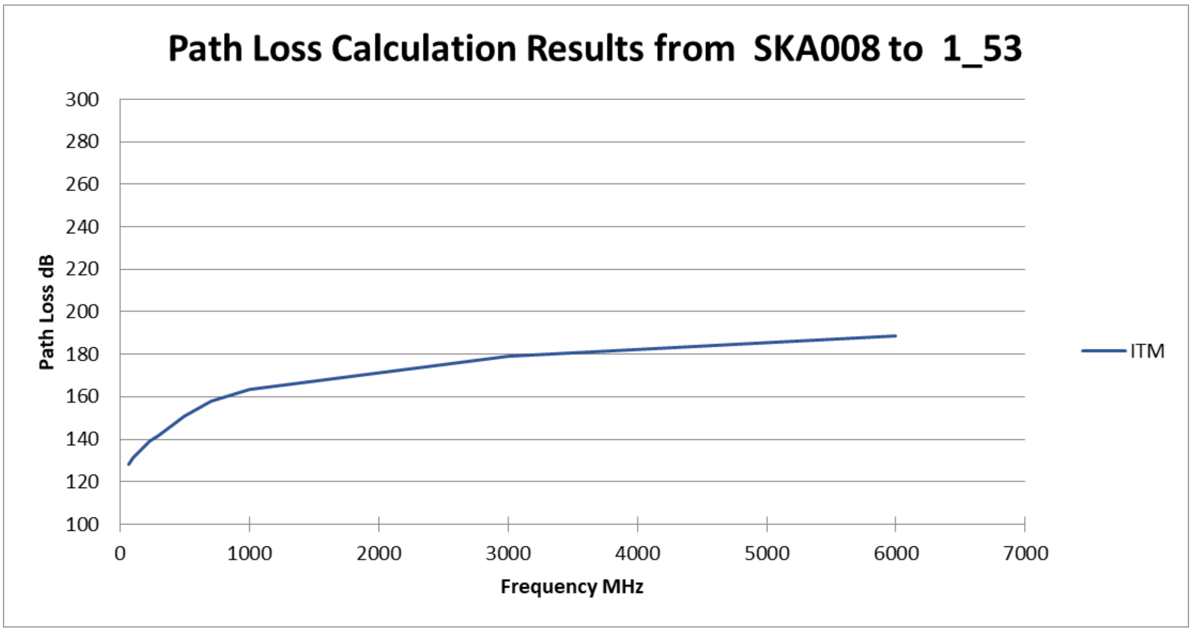

Figure 17 – Path Loss Calculation Results from Pofadder 53 to SKA008

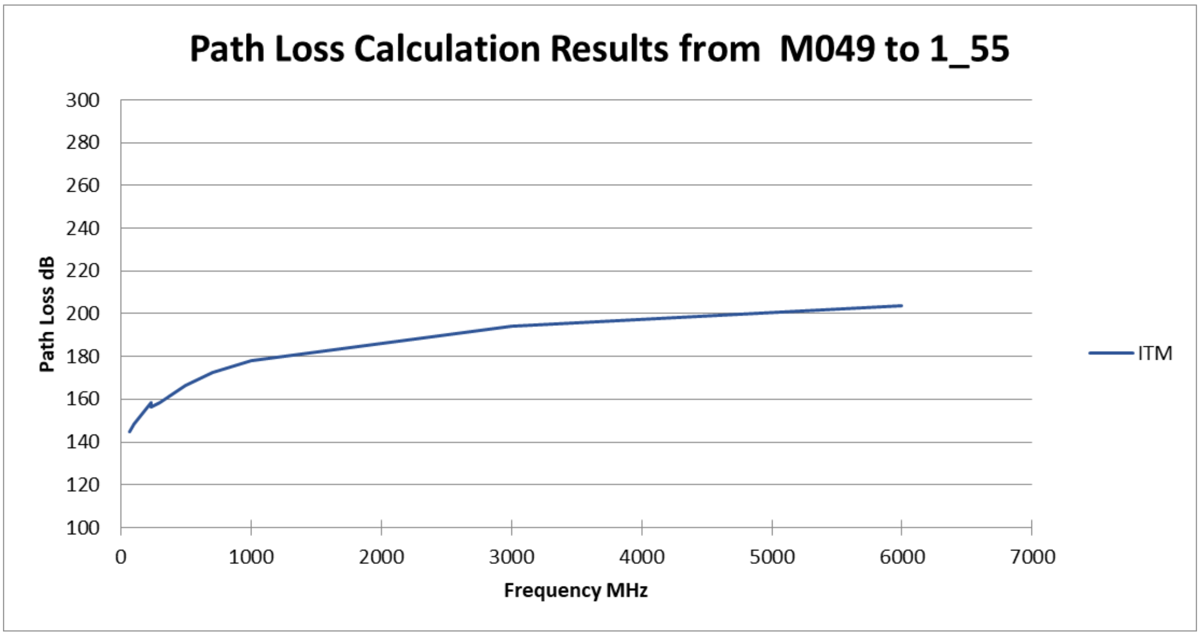

Figure 18 – Path Loss Calculation Results from Pofadder 55 to M049

Figures 15 to 18 show the path loss result calculated for Pofadder Wind Energy Facility 1 Scenario 2 equipment emissions at 120m HH.

SPLAT! (Signal Propagation, Loss And Terrain) analysis is based on the Longley –Rice Irregular Terrain Model. The digital elevation model resolution data used was 3-arc –seconds.

9.4 CUMULATIVE EFFECT

A standard factor of 10 $\log_{10}$ N, where N = the number of turbines for each Pofadder Wind Energy Facility separately, to account for cumulative emissions has been applied.

9.5 MITIGATION REQUIRED

9.5.1 Case1: SKA008 to Pofadder 55 Mitigation requirement

SKA008 to Pofadder 55						
Frequency [MHz]	SARAS Requirement [dBW/Hz]	Required Path Loss SARAS (incl 10dB) [dB]	Calculated Path Loss [dB]	Number of units	Facility Mitigation required [dB]	Unit Mitigation required [dB]
70	-253.94	128.35	129.28	30	-0.93	13.84
100	-256.61	131.02	132.32	30	-1.30	13.47
230	-262.86	137.27	140.49	30	-3.22	11.55
230	-262.86	144.27	140.49	30	3.78	18.55
300	-264.85	146.26	142.98	30	3.28	18.05
500	-268.68	150.09	152.14	30	-2.05	12.72
700	-271.21	152.62	158.31	30	-5.69	9.08
1000	-273.88	155.29	163.94	30	-8.65	6.12
**1000*	-273.88	168.63	163.94	30	4.69	19.46
**3000*	-279.09	173.84	179.46	30	-5.62	9.15
**3000*	-279.09	177.84	179.46	30	-1.62	13.15
**6000*	-279.11	177.86	188.88	30	-11.02	3.75

Table 9 – Case 1: Mitigation Requirements between SKA008 and Pofadder 55

** CISPR 32 levels*

Due to the cumulative effect of 30 Units in the facility, mitigation of 20dB at 1GHz would be required. The implication is that the radiated emission in the 100MHz to 1GHz band should be 20dB less than the CISPR 11/32 Class B radiated emission limit.

9.5.2 Case 2: SKA008 to Pofadder 9 Mitigation requirement

SKA008 to Pofadder 9						
Frequency [MHz]	**SARAS Requirement [dBW/Hz]**	**Required Path Loss SARAS (incl 10dB) [dB]**	**Calculated Path Loss [dB]**	**Number of units**	**Facility Mitigation required [dB]**	**Unit Mitigation required [dB]**
70	-253.94	128.35	128.73	30	-0.38	14.39
100	-256.61	131.02	131.98	30	-0.96	13.81
230	-262.86	137.27	140.43	30	-3.16	11.61
230	-262.86	144.27	140.43	30	3.84	18.61
300	-264.85	146.26	142.99	30	3.27	18.04
500	-268.68	150.09	152.29	30	-2.20	12.57
700	-271.21	152.62	158.66	30	-6.04	8.73
1000	-273.88	155.29	164.34	30	-9.05	5.72
**1000*	-273.88	168.63	164.34	30	4.29	19.06
**3000*	-279.09	173.84	179.94	30	-6.10	8.67
**3000*	-279.09	177.84	179.94	30	-2.10	12.67
**6000*	-279.11	177.86	189.39	30	-11.53	3.24

Table 10 – Case 2: Mitigation Requirements between SKA008 and Pofadder 9

** CISPR 32 levels*

Due to the cumulative effect of 30 Units in the facility, mitigation of 20dB at 1GHz would be required. The implication is that the radiated emission in the 100MHz to 1GHz band should be 20dB less than the CISPR 11/32 Class B radiated emission limit.

9.5.3 Case 3: SKA008 to Pofadder 53 Mitigation requirement

SKA008 to Pofadder 53						
Frequency [MHz]	SARAS Requirement [dBW/Hz]	Required Path Loss SARAS (incl 10dB) [dB]	Calculated Path Loss [dB]	Number of units	Facility Mitigation required [dB]	Unit Mitigation required [dB]
70	-253.94	128.35	128.24	30	0.11	14.88
100	-256.61	131.02	131.32	30	-0.30	14.47
230	-262.86	137.27	139.27	30	-2.00	12.77
230	-262.86	144.27	139.27	30	5.00	19.77
300	-264.85	146.26	141.71	30	4.55	19.32
500	-268.68	150.09	150.75	30	-0.66	14.11
700	-271.21	152.62	158.05	30	-5.43	9.34
1000	-273.88	155.29	163.66	30	-8.37	6.40
**1000*	-273.88	168.63	163.66	30	4.97	19.74
**3000*	-279.09	173.84	179.13	30	-5.29	9.48
**3000*	-279.09	177.84	179.13	30	-1.29	13.48
**6000*	-279.11	177.86	188.53	30	-10.67	4.10

Table 11 – Case 3: Mitigation Requirements between SKA008 and Pofadder 53

** CISPR 32 levels*

Due to the cumulative effect of 30 Units in the facility, mitigation of 20dB at 1GHz would be required. The implication is that the radiated emission in the 100MHz to 1GHz band should be 20dB less than the CISPR 11/32 Class B radiated emission limit.

9.5.4 Case 4: M049 to Pofadder 55 Mitigation Requirement

M049 to Pofadder 55						
Frequency [MHz]	SARAS Requirement [dBW/Hz]	Required Path Loss SARAS (incl 10dB) [dB]	Calculated Path Loss [dB]	Number of units	Facility Mitigation required [dB]	Unit Mitigation required [dB]
70	-253.94	128.35	144.65	30	-16.30	-1.53
100	-256.61	131.02	148.24	30	-17.22	-2.45
230	-262.86	137.27	158.59	30	-21.32	-6.55
230	-262.86	144.27	156.39	30	-12.12	2.65
300	-264.85	146.26	158.59	30	-12.33	2.44
500	-268.68	150.09	166.37	30	-16.28	-1.51
700	-271.21	152.62	172.51	30	-19.89	-5.12
1000	-273.88	155.29	178.3	30	-23.01	-8.24
**1000*	-273.88	168.63	178.3	30	-9.67	5.10
**3000*	-279.09	173.84	194.1	30	-20.26	-5.49
**3000*	-279.09	177.84	194.1	30	-16.26	-1.49
**6000*	-279.11	177.86	203.58	30	-25.72	-10.95

Table 12 – Case 4: Mitigation Requirements between M049 and Pofadder 55

** CISPR 32 levels*

Due to the cumulative effect of 30 Units in the facility, mitigation of 6dB at 1GHz would be required. The implication is that the radiated emission in the 100MHz to 1GHz band should be 6dB less than the CISPR 11/32 Class B radiated emission limit.

9.6 CONCLUSION FOR SCENARIO 2

Due to the pathloss between Pofadder 53 and SKA008, the two points with the lowest pathloss between SKA and Pofadder Wind Energy Facility 1, a degradation of performance is expected unless the radiated emissions from each turbine installation can be reduced to 20dB below the CISPR 11/32 Class B limit across the 100MHz to 6GHz band.

9.7 TESTS AT THE NEW SITE

To verify overall WEF 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 and completion of the project.

9.8 FINAL SITE TESTS

Final site tests should be done on completion of the project to confirm the radiated emission levels.

10. RESULT COMPARISON BETWEEN SCENARIO 1 AND SCENARIO 2

Table 13 below lists the mitigation results obtained for the two different scenarios in Pofadder Wind Energy Facility 1. The mitigation requirement difference between the two scenarios is minimal. In Pofadder Wind Energy Facility 1 the change in HH from 200m to 120m decreases the amount of mitigation required by 1 dB.

Table 13 - Summary of Results

	Scenario 1 dB Mitigation	Scenario 2 dB Mitigation
Closest point	21 dB	20 dB
Turbine with the highest elevation	21 dB	20 dB
Turbine with the lowest pathloss to the SKA site	21 dB	20 dB
Turbine with the lowest pathloss to the SKA core site	7 dB	6 dB

- END OF REPORT -