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PATH LOSS REPORT FOR STRAUSSHEIM PV PLANT

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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 Kilometre Array

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1. INTRODUCTION

The SKA is a stakeholder mentioned in the Environmental Authorisation of the Straussheim Photovoltaic project. The proposed AMDA Alpha, Bravo and Charlie PV Energy Facilities will each have a maximum generation capacity (contracted capacity) of 75MW.

In order to determine whether the planned facility could have any influence on the SKA, AMDA Developments (Pty) Ltd 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 then enable one to estimate the maximum permissible radiated emissions from the equipment installed within the Straussheim Photovoltaic Facility. The proposed AMDA Alpha, Bravo and Charlie Facilities respectively, will connect to the national electricity grid via the Niewehoop MTS sub-station. The proposed distribution and transmission infrastructure includes the construction of an on-site substation and a 132kV overhead power line from the on-site substation.

1.1 REFERENCED AND APPLICABLE DOCUMENTS

[1] Regulations on Radio Astronomy Protection Levels in Astronomy Advantage Areas Declared 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] CISPR 11: Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurement.
[4] NTIA Report 82-100: A guide to the use of the ITS Irregular Terrain Model in the Area Prediction Mode

2. METHODOLOGY

This phase of assessment consists of a theoretical analysis to determine technology risks (power conversion, wireless control systems etc) of the renewable energy system. 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 closest SKA 2 telescope location.
SARAS receiver protection levels against expected received amplitudes from the renewable power technology are determined and plotted. The CISPR 11 Class A emission standards [3] are also provided as reference.

The expected loss as determined by the Irregular Terrain Model [4] (Longley Rice model applicable for frequencies between 20MHz and 20GHz) between the proposed site and nearest SKA stations is presented in Graph 1. 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.

Should test reports be available containing measurement data for equipment to be installed at the Straussheim facility, it can be evaluated in terms of test methods used, accreditation status of facility that performed the tests, credibility of test results and the usability of the report.

Although reference is made to CISPR 11 in this document, it should be noted that the quasi-peak detector used for CISPR tests will result in low amplitudes being recorded for signals with a low pulse repetition rate. Due to the number of potential sources on the plant (illustrative number of 72 used) and the characteristics of a radio telescope, peak detection (max hold function) should be used when evaluating impulse signals with low repetition rates.

3. TECHNOLOGY DESCRIPTION (STRAUSSHEIM SOLAR ENERGY FACILITY)

Photovoltaic (PV) panels convert the energy delivered by the sun to direct current (DC) electric energy. The array of PV modules is connected to an inverter by means of a network of cables. The DC power is inverted to alternating current (AC) power by a grid-tied inverter. The AC power can then be added to the national electricity network (grid). The voltage at which power is generated is stepped up to the required voltage and frequency of the national grid by using a transformer. The electricity is distributed from the on-site transformers (substation) via distribution lines to the nearest ESKOM substation. From the ESKOM substation the electricity is fed into the national (ESKOM) grid. The infrastructure of the facility includes the ground-mounted structures, solar PV modules, cables, inverter rooms, access roads, auxiliary roads, an on-site substation, and a distribution line. The primary input of the system is sunlight, which is converted to electricity. In the case of sun tracker technology the facility may also utilize auxiliary electricity from the Eskom grid to power tracker motors in order to optimize the amount of sunlight on the solar PV infrastructure. In addition to auxiliary power being used for powering tracker motors, small amounts of auxiliary power would be used for on-site items such as, but not limited to, security and site office energy requirements. A tracking system is ground-mounted and follows the sun's path with the use of typically single or dual-axis technology in order to maximize the amount of direct sunlight on the Solar PV modules. By following the sun, the tracked array rises quickly to full power and stays there on a clear sunny day, while the fixed array only maintains maximum power for a few hours in the middle of the day. Main industrial equipment in the PV plant is the following:

- Photovoltaic generator
- PV tracker system
- Inverters.
- Power Station (transformer + MV cubicles)
- Electrical inter-connection system
- Electrical protections
- Evacuation infrastructure

In addition, some typical equipment will be installed according to the final client preferences: SCADA system, Security system, firefighting system, etc.

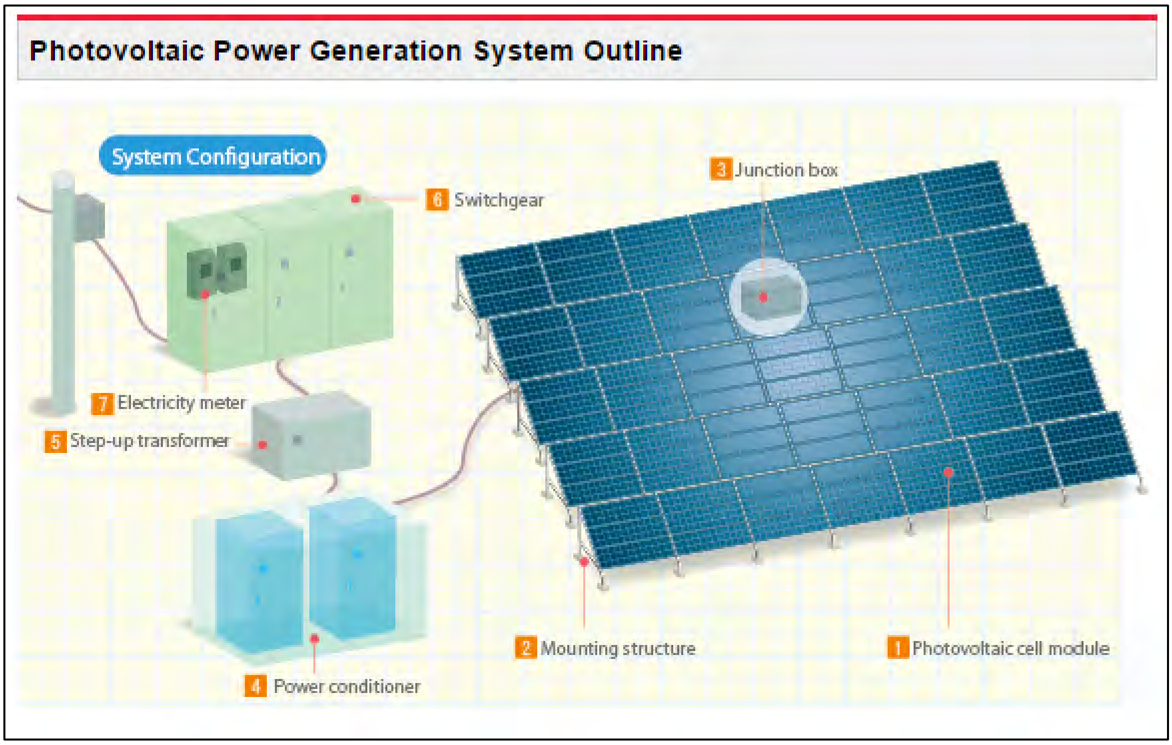


Figure 1: System block diagram (Hitachi System example)

4. RISK IDENTIFICATION

4.1 TECHNOLOGY RISKS

The following building blocks are viewed as potential interference sources:

- PV tracker system
- Inverters (AC as well as DC path)
- PV Generator control and management
- Control and operations centre (computer equipment)

4.1.1 PV Tracker System

Relevant tracking system components are listed below:

- Drive unit for solar tracking.
- Internal communication system (PLC).

All components used should be compliant to CISPR 11 Class A less the mitigation required per unit (Table 2) based on cumulative effect requirements for 72 units (4.1.5 refers) and the fact that the expected (calculated) path loss is less than the required path loss as shown in column 8 of Table 2.

4.1.2 Inverter

Different inverter technologies are in use worldwide. Metal enclosures should be used for components installed at each panel. All components used should be compliant to CISPR 11 Class A less the mitigation required per unit based on cumulative effect requirements for 72 units (4.1.5 refers) and the fact that the expected (calculated) path loss is less than the required path loss as shown in column 8 of Table 2.

4.1.3 PV Generator control and management

The communications infrastructure that enables the transfer of information between the various elements connected to the network, such as the local office of the SCADA and PLCs. Can typically be a MODBUS RS485 protocol using multimode optical fibre cable that will interconnect all the nodes (PLCs and SCADA local post).

4.1.4 Control and operations centre

Equipment installed in the control and operations centre shall comply with CISPR 22 Class B. The control and operations building shielding effectiveness should be at least 20dB, unless a 20dB safety margin is added to the CISPR 22 Class B limit.

4.1.5 Cumulative emissions

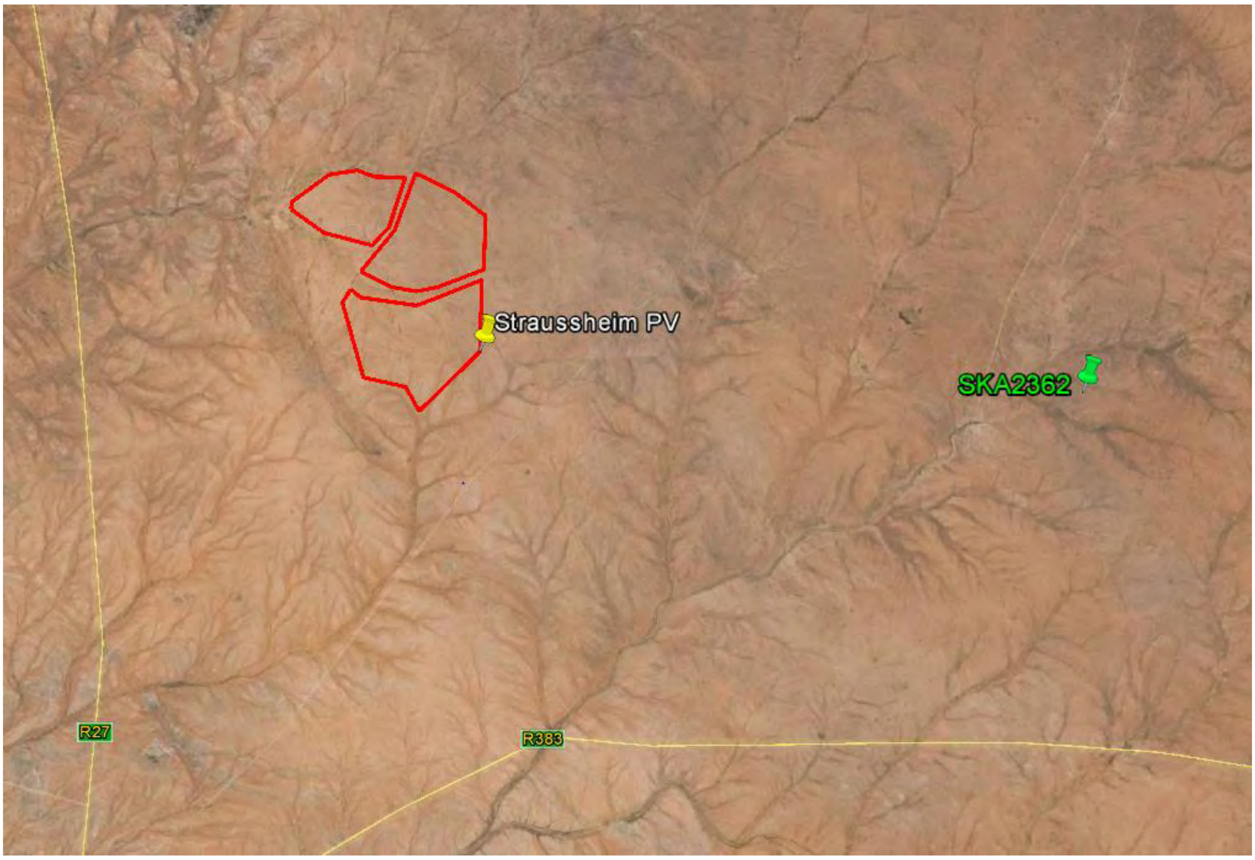
A large number of non-correlated noise sources (inverters, PV panel controls etc.) could increase the noise floor at a receiving site distant from the noise sources. This will however be included in the measurement data of a single PV plant. Adding more plants will result in a theoretical increase of 10 log N dB where N equals the number of plants. For an additional 3 plants (4 in total) a margin of 6dB can be added to the expected emission field strength from a single plant.

4.2 SITE LOCATION

4.2.1 Area Map

Picture 1: Area Map showing Straussheim and SKA core area

4.2.2 Local Map



Picture 2: Local map showing closest SKA Station

4.2.3 Elevation Map

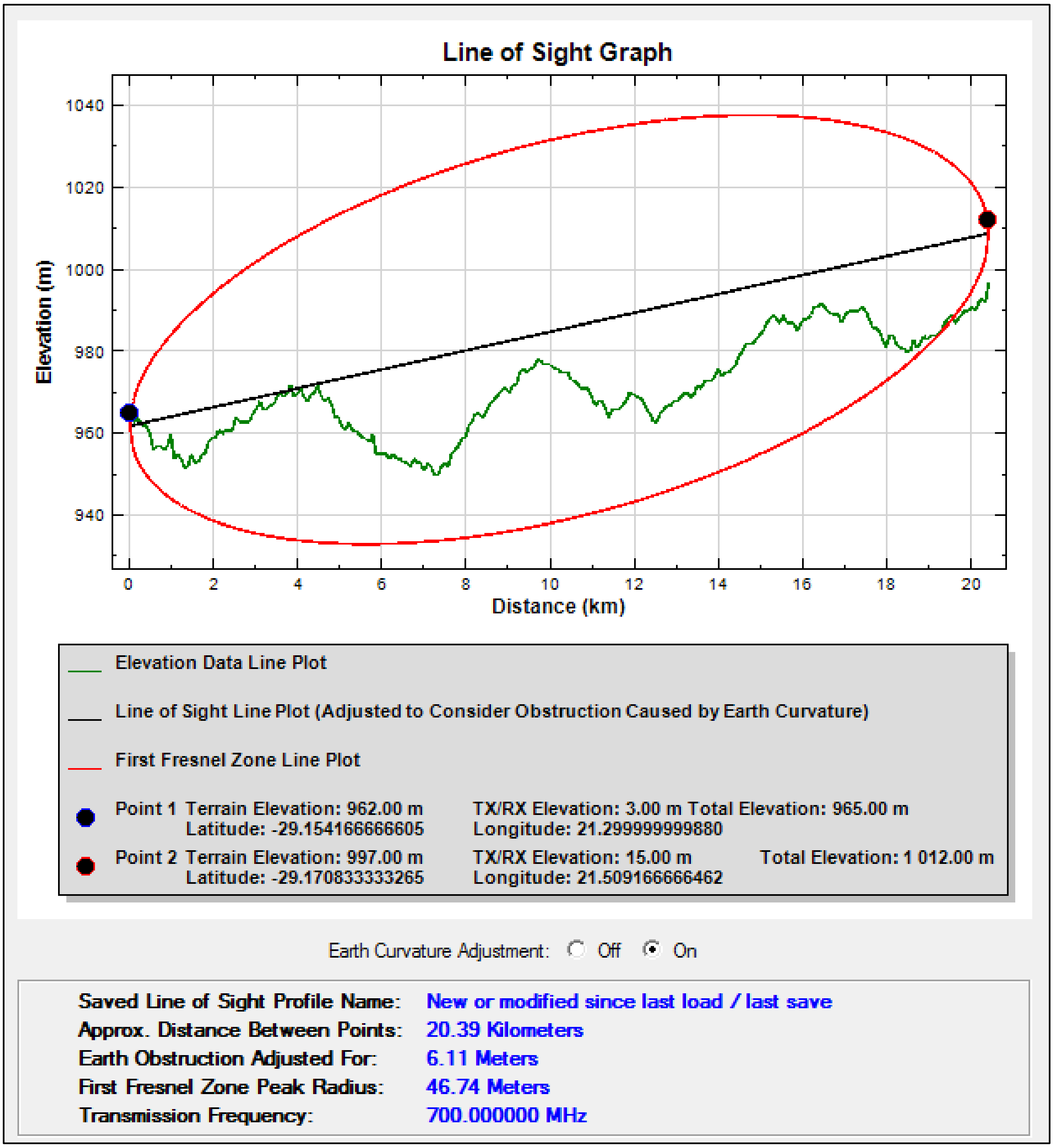


Figure 2: Straussheim to SKA ID 2362

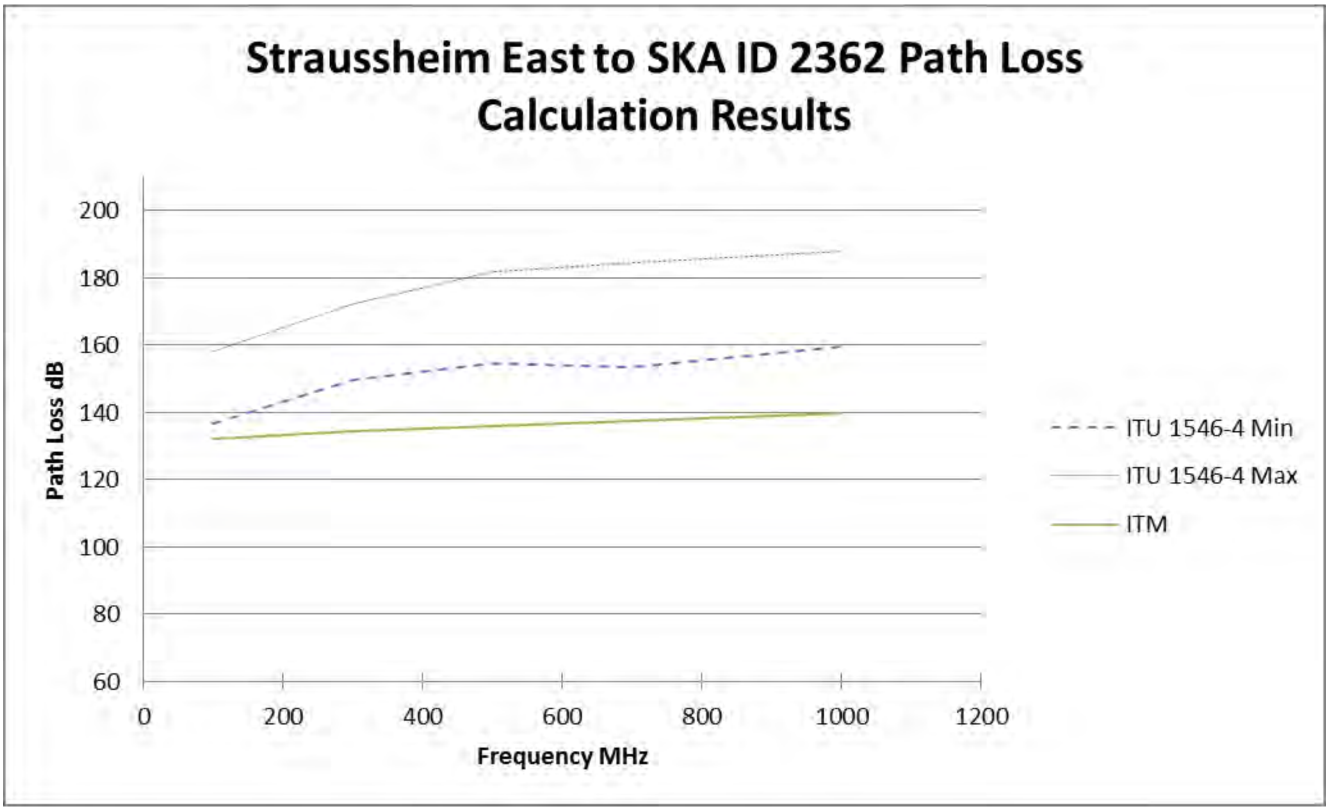
4.3 INPUT DATA

Parameter	Description	Quantity	Comment
Source/ Victim separation distance	SKA ID 2362 to Straushein Eastern development border	20.39km	
Frequency	Frequencies assessed	100MHz, 230MHz, 300MHz, 500MHz, 700MHz, 1000MHz, 3000MHz and 6000MHz	Free space loss increases with frequency.
TX Power	EN CISPR 11 Class A @ 10m	40 dBμV/m for >230MHz 47 dBμV/m for <230MHz	Based on the allowable emission limit for Class A 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
Location	Straussheim	Latt: -29.171179° Long: 22.396263	Development area received from AMDA Developments (Pty) Ltd
Location	SKA ID 2362	Latt: -29.171179° Long: 21.509627°	Waypoint received from SKA SA (Pty) Ltd
TX height	Inverter / Tracker	3m	Height of the inverter/ control electronics enclosure
RX height	All SKA receivers	15m	Height used for SKA receive horn

Table 1: Parameters used for calculations

4.4 PATH LOSS CALCULATIONS (ITU-R P.1546-4 AND ITM)

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



Graph 1: Straussheim East to SKA 2362 Path Loss Calculation Results

Graph 1 shows the expected loss as determined by the Irregular Terrain Model (Longley Rice model applicable for frequencies between 20MHz and 20GHz) and the minimum and maximum values of the ITU-R P.1546-4 Land Path propagation model statistical simulation based on the Monte-Carlo method.
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.

5. MITIGATION REQUIRED

Based on compliance of the equipment to CISPR 11 Class A additional attenuation per unit will be required as shown in Table 2.

Straussheim to SKA ID 2362							
Frequency	**CISPR 11 Class A [dBW]**	**Saras [dBW/Hz]**	**Required path loss if CISPR 11 Class A compliant [dB]**	**Path Loss (Measured or calculated) [dB]**	**Number of units in facility**	**Mitigation required for facility [dB]**	**Mitigation required per unit [dB]**
70	-84.80	-253.94	128.35	131.64	72	-3.29	15.28
230	-84.80	-262.86	137.27	133.68	72	3.59	22.16
230	-77.80	-262.86	144.27	133.68	72	10.59	29.16
1000	-77.80	-273.88	155.29	139.56	72	15.73	34.31
1000	-55.26	-273.88	158.63	139.56	72	19.07	37.64
3000	-55.26	-279.09	163.84	149.06	72	14.78	33.35
3000	-51.26	-279.09	167.84	149.06	72	18.87	37.35
6000	-51.26	-279.11	167.86	154.43	72	13.43	32.00

Table 2: System analysis based on CISPR 11 Class A compliance

The mitigation required for the facility (column 7) is the result of the calculated path loss between the SKA ID 2362 (column 5) and the facility being higher or lower than the required path loss (column 4). The mitigation required per unit is due to an illustrative number of 72 inverter or control units for the facility. Should the mitigation per unit be achieved, the mitigation required for the facility will also be met. In the absence of detailed design information and test reports for the tracker system and inverters to be used, it is assumed that the emissions of the tracker and the inverter are the maximum allowed by CISPR 11 Class A. This is not necessarily the case, especially at the higher frequencies where the emissions from the tracker system and inverters will most likely be less.

6. MITIGATION

Shielding and filtering solutions are available to ensure installed plant equipment emissions remain within SKA risk tolerances. From laboratory test experience it is known that insufficiently shielded cabling (looms) account for most of the non-compliance to specification levels. It would therefore be recommended to shield and correctly terminate the shields of all cables installed on the PV project site. The shielding can be achieved with braids, but it is often easier to make use of a shielded conduit system as individual wires can be replaced without compromising the shielded integrity.

7. CONCLUSION

Based on the current SKA location information, a first order impact analysis shows a possible interference scenario between the Straussheim Solar PV Energy Facility and the SKA installation as shown. In order to negate the risk to an acceptable level, all equipment to be installed on site must comply with levels of 40dB below the CISPR 11 Class A limit as the primary mitigation measure to accommodate cumulative effect of the high number of potential sources. Where equipment exceeds this threshold, additional shielding and filtering should be implemented to reduce the electromagnetic emissions from the PV facility. Off the shelf shielding and filtering solutions are available to ensure the required 40dB below CISPR 11 Class A for equipment is reached.

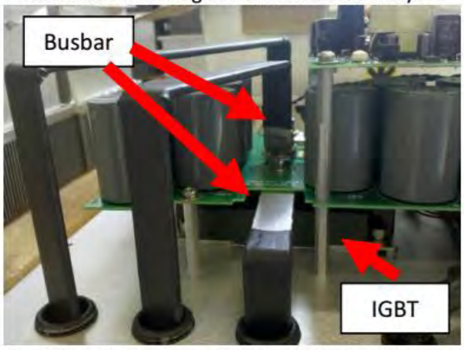
8. APPENDIX A: GENERIC MITIGATION METHODS (SOURCE SOLECTRIA RENEWABLES)

Solid Grounding

Controlled Wire Routing

Board Level Filtering and EMI Reduction Layout

Wire Twisting



Stack Configuration for Reduced Stray Inductance

Power Electronics Enclosure for EMI Shielding

Analog Signal Conditioning using Ferrite Beads

DC side High Power Wiring for EMI shielding