South African SKA Demonstrator Systems: Evolving RFI Mitigation Investigations

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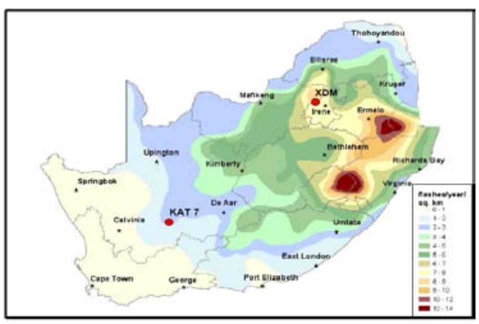
Abstract

The South African SKA demonstrator is founded on the Karoo Array Telescope (KAT). A holistic approach to radio frequency interference (RFI) mitigation has been adopted from the outset. We describe our group's contribution to this evolving effort. We consider the RFI beginning from the 100 km powerlines, through to the site base equipment and continue right up to the KAT-7 telescopes. A site survey was conducted with systems initially deactivated and then individually switched on to determine signature characteristics. More detailed studies include analysis of telescope pedestal shielding interfaces and cable transfer impedance.

1. Introduction

The South African Square Kilometre Array (SKA) demonstrator currently consists of seven centre-fed radio telescopes known as Karoo Array Telescope Seven (KAT-7). The next phase of the demonstrator will be a 64-telescope array, dubbed MeerKAT. At the last URSI session, we reported [1] some of our first experimental KAT work. This led to early radio frequency interference (RFI) mitigation recommendations. RFI-mitigation has been a constant component of the developing infrastructure. Figure 1 pinpoints the remote, low-RFI, low lightning flash density Karoo site, with a zoomed topographical view of the MeerKAT core. Small flat-topped hills have been exploited in the layout of the powerlines and buildings. We present an overview of our group's recent research.



(a) (b)

Figure 1: KAT-7 and MeerKAT positioning in the Northern Cape of South Africa with lightning flash density shown in (a) and a zoomed topographical depiction of the site location shown in (b).

2. Site Interference Integrity

South Africa has placed considerable emphasis on the RFI quietness of the site. This effort includes the government proclamation of the Astronomy Geographic Advantage Act of 2007 [2].

2.1 Powerline Sparking and Associated Signal Propagation

The first possible RFI source is the powerline. Corona is not of concern as its spectral density is predominantly below 30 MHz and it will not be generated on the existing 22/33 kV lines. We have found that sparking noise, which can originate from the line hardware, produces energy up to several GHz. The frequency and time domain properties of this type of interference have been investigated through measurements using an artificial

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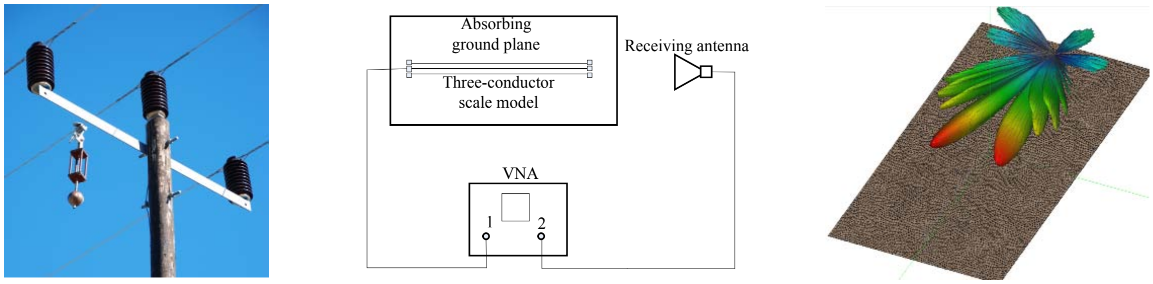
spark-gap device, seen Figure 2 (a). The noise propagation associated with the powerline generates a discernable lateral, longitudinal and height profile.



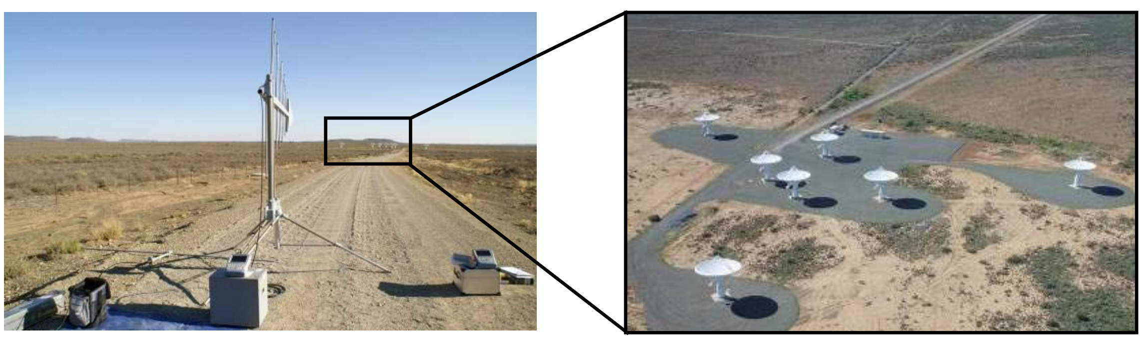
(a) (b) (c)

Figure 2: (a) Measurement using an artificial spark-gap generator; (b) Schematic indicating the measurement setup of the powerline scale model. (c) Typical computationally-generated radiation pattern of powerline.

The radiation pattern of the sparking noise has also been examined using computational analysis and a physical scale model. A schematic of the measurement setup is shown in Figure 2 (b). The physical scale model was constructed using three horizontal wires above a block of lossy-coated polystyrene beads. The radiation pattern was measured inside an anechoic chamber. The Method-of-Moment-based, frequency domain, electromagnetic code, FEKO was used to model various powerline configurations. A typical radiation pattern is shown in Figure 2 (c).

2.2 Infrastructure and Ancillaries

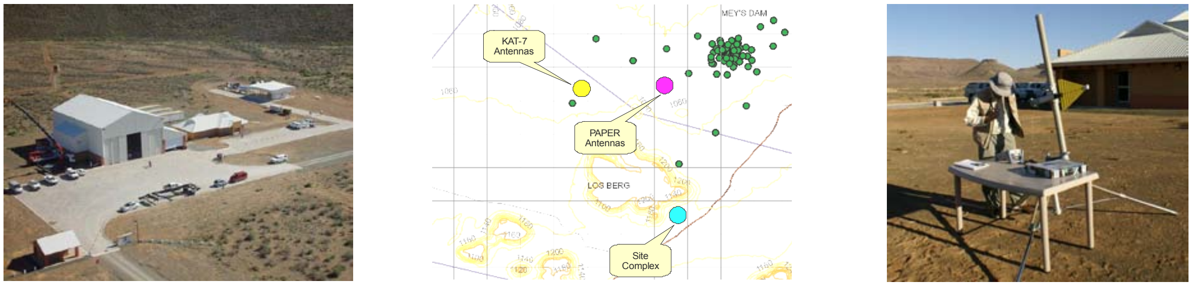
Having recommended powerline orientation and hardware policies which prevents propagating interference such as wideband sparking noise, we focused on the site self-generated RFI. We interacted at all stages with the civil works, mechanical, and electrical teams to suggest cabling and layout practices. Then, to investigate the site radio quietness, a sequence of RFI measurements was made starting with all systems off. This yielded the background RFI down to levels specified by our equipment's sensitivity. Next, individual items including the telescope systems, antenna services chamber, antenna control unit and chiller-plant were switched on in a controlled sequence to isolate their noise spectrum. Measurements were made at various locations in proximity of the KAT-7 dishes (Figure 3 (a)).



(a) (b)

Figure 3: (a) Background measurements of the KAT-7 site using various antennas and receivers. (b) Aerial view of the KAT-7 site showing all seven dishes [3]. Power to specific components of the KAT-7 site was sequentially switched on while the background RFI was monitored continuously.

RFI from the ancillaries at the support base was also quantified. This went down to the detail of a microwave oven, a television, and lights, especially those located in the assembly shed (Figure 4 (a)). These lights were chosen specifically for their low-noise characteristics as determined during separate laboratory measurements. They were evaluated in switch-on, quiescent, and switch-off stages of operation. This potentially allows the site manager to administer electrical equipment operation during telescope surveys. The power cables to lights in the assembly shed were designed to eliminate galvanic loops. The site complex is nestled behind Losberg (Figure 4 (b)) to exploit the RFI shielding provided by the hill. This shielding effect was investigated through propagation measurements at various frequencies from the support-base to the KAT-7 site (Figure 4 (c)).



(a) (b) (c)

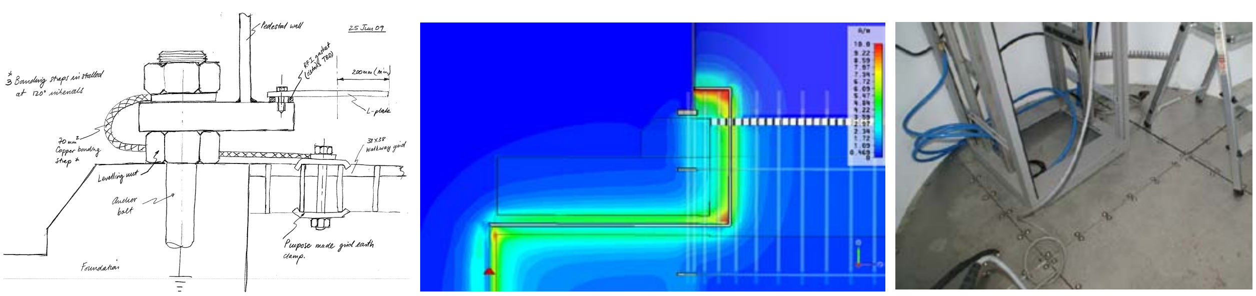
Figure 4: (a) KAT site complex including an assembly shed, accommodation, and other facilities; (b) Topographical map showing infrastructure evaluated; (c) Noise propagation studies over Losberg.

3. System RFI Mitigation

We have examined telescope lightning protection and soil properties leading to earth foundation strategies. The lightning down conductor work is reported elsewhere [4]. Testing has been done on scale models and a KAT-7 telescope [5]. Investigations also include pedestal RFI hardening through shielding, cabling and interface definitions.

3.2 Shielding

Because of the sensitivity of each KAT-7 telescope, simple methods of RFI mitigation may not be sufficient. A particular focus was shielding of the dish and feed control electronics in the lower section of the telescope pedestal. Cables entering the lower pedestal could, through unwanted CM current, introduce interference into this environment. Preventative measures were evaluated using Computer Simulation Technology's Microwave Studio (CST MWS) to analyse possible shielding interfaces. These were discussed with the mechanical engineering team for viability. To prevent corrosion, every surface of the pedestal was painted during construction. We had not anticipated the painting which compromised the galvanic connections. These had to be re-established after construction and the bonding strap in Figure 5 (a) was proposed. The strap connects the telescope pedestal and grid floor inside, to a common earth reference. Considering the grid size of the initial floor, and the connection of the power cable outer conductor to it, CST MWS showed that CM currents would still penetrate the floor, Figure 5 (b).



(a) (b) (c)

Figure 5: (a) Illustration of additional bonding straps for earthing connection through foundation bolts to telescope pedestal; (b) Computational analysis of CM currents on power cable; (c) Installed floor of pedestal.

The end result was that in one of the seven telescopes a solid but sectioned metallic floor (Figure 5 (c)) and roof were installed. All cables enter the pedestal through these two interfaces, and the outer conductor or sleeving of each cable, make contact with the interface. Between 1 MHz and 200 MHz, the results from computational analysis and measurements show a reduction in CM current on cables entering the pedestal of 45 dB to 20dB, respectively.

3.3 Transfer Impedance

A large percentage of electromagnetic compatibility problems are caused by inadequate layout and earth termination of a cabling system [6]. A practical example is incorrect cable screening as shown in Figure 6 (a). We investigated the transfer impedance of principal coaxial cables used with KAT-7 over a frequency range of 300 kHz to 1.3 GHz. A current injection clamp was used together with a current probe and a vector network analyser (VNA) in a controlled environment (Figure 6 (b)), to measure cable transfer impedance. A reverberation chamber (Figure 6 (c)) is used at higher frequency to measure the shielding effectiveness as the total power escaping from the cable braid, from which the transfer impedance can be calculated. Cable RFI mitigation and cost can then be identified.

(a) (b) (c)

Figure 6: (a) Incomplete cable sleeving leads to a 10 dB difference in CM currents; (b) Transfer impedance measurements using a VNA and EM injection clamp; (c) Reverberation chamber to measure transfer impedance.

4. Conclusion

We have presented our group's evolving RFI mitigation investigations for the South African SKA demonstrator. Powerline sparking characterisation, site interference testing and some examples of specific system RFI mitigation have been highlighted. We show how practical measurements and computational analysis are used as complementary investigative tools.

5. Acknowledgments

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6. References

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