Attachment 1: Research Project Proposal

Section A: Overview of the Research Project Proposal

1. Title of the research project: Radio Frequency Interference (RFI) detection for aperture array antennas
2. Broad field of research: Engineering
3. Academic level (Masters or PhD): Masters

4. Research project abstract:

The goal of this research project is use real-time data obtained from an aperture array radio telescope to detect, monitor and possibly locate potential radio frequency interference (RFI) sources. The telescope that will be used for the study is the transient array radio telescope (TART) that is a 24-element open source project initiated by Otago University in New Zealand. Real-time data is available (both raw digitised channel data, as well as visibilities) via an application program interface (API) and web interface. This data has to be stored (in an efficient manner using a suitable time-series database) that can be analysed and processed to identify potential RFI sources.

5. Supervisor's details

(a) Full name of primary supervisor: Dr Danie J. Ludick
(b) Primary supervisor e-mail address: dludick@sun.ac.za
(c) University where the primary supervisor is employed: Stellenbosch University
(d) Supervision of postgraduate students:

Name of Student	Nationality	Date started Master's degree	Date completed / will complete degree	Title of thesis	Co-Supervisor
Tristan Steele	South African	January, 2016	December, 2017	Coupled Structural and Electromagnetic Analysis of a Radio Telescope	Prof. David Davidson, Dr. Martin Venter
Lydia de Lange	South African	January, 2018	December, 2019	Array failure detection using Machine Learning	Dr Trienko Grobler
Ntombi Mtetho	South African	January, 2018	December, 2020	Analysis of an Aperture Synthesis Array Radio Telescope	-
Tameez Ebrahim	South Africa	January 2019	December 2020	Development of an object orientated C/C++ Computational Electromagnetic Solver	-
Caleb Mnisi	South Africa	January 2019	December 2020	Accelerating computational electromagnetic solvers with FPGA hardware	Mr Arno Barnard

6. Co-supervisor's details

(a) Full name of co-supervisor: Dr Trienko L. Grobler

(b) University where the co-supervisor is employed: Stellenbosch University

Name of Student	Nationality	Date started Master's degree	Date completed / will complete degree	Title of thesis	Co-Supervisor
Lydia de Lange	South African	Jan 2018	Dec 2019	Array failure detection using Machine Learning	D.J. Ludick (main supervisor)
Ulrich Armel Mbou Sob	Cameroonian	Jan 2015	Dec 2016	Calibration and imaging with variable radio sources	S.K. Sirothia (main supervisor)
Chuneeta Nunhokee	Mauritian	Jan 2013	Dec 2014	Link between ghost artefacts, source suppression and incomplete calibration sky models	O.M. Smirnov (main supervisor)

Section B: Details of Research Project

1. Scientific/Engineering merit:

RFI poses a significant problem for radio astronomy telescopes, such as aperture arrays. The underlying goal and merit of this project would be to use the channel data that is generated by each of the antennas, such as visibilities, to detect whether RFI is present and if so, the location of the source. This will benefit the remainder of the radio astronomy pipeline by discarding datasets that are polluted with RFI. Additionally, if the position of the RFI source is determined, operational personnel can potentially take additional steps to remove or mitigate the effect of this. A central aspect of this project would also be the storage and analysis of real-time data. This in itself can also be used to monitor the overall system health of the instrument.

The 24-element transient array radio telescope (TART), operating at Stellenbosch University will primarily be used to conduct the study. Collaborative efforts can also be formed with Otago University and the Netherlands Institute of Radio Astronomy (ASTRON), to apply the methods to their radio telescopes (such as LOFAR), where possible.

2. Feasibility:

Stellenbosch University offers access to state of the art antenna and RF measurement equipment, a High Performance Computing (HPC) facility and various commercial CEM codes such as FEKO, that can be used for this study. We also have a 24-element aperture array radio telescope (TART) setup that can be used for validating results (when applied to small test cases). The TART system is shown in Figure 1.

Figure 1 – The 24-element transient array radio telescope at Stellenbosch University

Initially, the student will work on gaining an understanding of radio interferometry, receiver systems, electromagnetics and antennas. This is primarily done via a comprehensive set of postgraduate courses offered in the first semester of the MEng project.

Also in the first year (second semester), the student will become familiar with our 24-element radio telescope testbed (TART) and develop an efficient real-time monitoring application that can store the data associated with the individual antennas (including the raw data, as well as visibility data). Once completed, the student will spend time working on the automatic identification of anomalies in the time-series representation for specific outliers, and if detected, attempt to locate the source of these. In the second year, the student will continue the data analysis component of this project and apply it (if time and resources permit) to other instruments such as LOFAR.

3. Relevance of the research proposed to the SARAO priority areas:

This project is relevant to the following SARAO priority areas,

- *Antenna, receiver, (analogue and digital) signal processing,* ***data analysis and data recording*** *systems associated radio telescope and geodesy instruments supported and hosted by SARAO.*

- *Hardware and data analysis systems for* ***detecting, monitoring and locating source of Radio Frequency Interference (RFI)****, including the use of telescope data (e.g. using MeerKAT or HERA visibilities to locate RFI sources).*

A central aspect of this project is to develop an efficient data recording system, as well as a data analysis software utility that can be used for monitoring and identifying potential RFI in the recorded data. By having access to a local instrument that can supply real-time data via an API, various tests can easily be done to verify the toolset.

- *Hardware, software and data analytic systems associated with the control and* ***monitoring of radio telescopes****.*

Additionally, the system health of the telescope can be monitored using the software tools that will be developed. Quantities such as power spectra of individual antennas can be monitored to identify potential faults (such as a broken antenna, loose connection, faulty radio receiver).

4. Ability or skills:

Students with an interest in radio astronomy, programming and mathematics as well as software design will be ideal for this project.

Dr Danie J. Ludick - 2020-02-06