Attachment 1: Research Project Proposal

Section A: Overview of the Research Project Proposal

1. Academic level (Masters or PhD): Masters

2. Broad field of research: Engineering

3. Title of the research project: Array failure analysis for large aperture arrays using Machine Learning and Domain Decomposition

4. Research project abstract:

The goal of this research is to apply machine learning (ML) approaches to array failure analysis in the context of the SKA antennas. Investigating various test-cases (required for ML algorithms) is typcically done using a large number of software simulations. This can be computationally expensive for large arrays, such as those planned for the MFAA and LFAA. The goal here is to incorporate domain decomposition based approaches to allow for fast and efficient test-data generation for the ML training step.

Section B: Supervisor's Details

1. (a) Supervisor's title and full name: Dr. Danie J. Ludick

(b) Name of the South African or SKA Partner Country university at which the primary supervisor is a permanent academic staff member: Stellenbosch University

(c) E-mail address and/or contact telephone number: dludick@sun.ac.za | 084 524 5994

(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	
Ntombi Mtetho	South African	January, 2018	December, 2019	Developing a fully functional Aperture Synthesis Array Radio Telescope	

Section C: Full Research Project Proposal

1. Scientific merit:

Detecting failed elements in large antenna arrays using machine learning algorithms, such as the k-nearest neighbour algorithm, feed forward neural networks or support vector machines, will be partricularly useful for large, distributed arrays. The accuracy of the algorithm is reliant on the availability of reliable test-data, which in this context can be generated using software simulations.

A major drawback however is that simulating electrically large (and sometimes aperiodic) antenna arrays can become computationally costly in terms of memory and runtime. The goal of this project is to incorporate domain decomposition strategies, such as macro basis function (MBF) approaches, to aid in this process.

2. Feasibility:

Stellenbosch University offers access to a state of the art High Performance Computing (HPC) facility, various commercial CEM codes such as FEKO, as well in-house solvers that can be used for this study. We also have a small aperture array radio telescope setup that can be used for validating results (when applied to small test cases).

Initially, the student will work on gaining an understanding of fundamental computational electromagnetic (CEM) methods, such as the Method-of-Moments (MoM), which is offered during the first semester of the MEng as part of a comprehensive set of postgraduate courses. Other coursework include a revision of electromagnetics and antennas. A postgraduate course on High Performance Computing (HPC) is also planned for 2019.

In the first year, a detailed literature study and revision of current machine learning approaches is expected. The student will also investigate conventional domain decomposition strategies, such as macro basis function methods and the domain green's function method. The goal of this first phase, would be to generate test-data for large array layouts (i.e. various element failure scenarios) and to assess different ML algorithms.

The goal of the 2^{nd} year is to focus on a specific ML algorithm, selecting on the basis of year 1's findings and to incorporate a suitable domain decomposition approach to accelerate test data generation.

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

The skills that are acquired by the candidate will not only allow the student to become acquainted with CEM solving methods – something that is useful when simulating antenna structures in the context of the SKA - but also to Machine Learning algorithms, such as the k-nearest neighbour algorithm, feed forward neural networks and support vector machines. This skill is transferable to other sectors, e.g. system modeling, which is relevant in the context of the SKA research objectives, as laid out in Annexure 1 of the Application Guide (see Point 12: Predictive maintenance and scheduling using sensor data analytics, machine learning and system modeling).

4. Students with an interest in programming, electromagnetics as well as computing will be ideal for this project.

Section D: Signatures

1. Signature of primary supervisor and date of proposal submission:

Dr. Danie J. Ludick - 2018-08-31