Attachment 1: Research Project Proposal

Section A: Overview of the Research Project Proposal

1. Academic level (Masters or PhD): PhD
2. Broad field of research: Engineering
3. Title of the research project: Intelligent monitoring and failure analysis for large aperture array antennas

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. The focus will be to use quantities such as power spectra associated with individual receivers to detect component failures, as well as the nature of the failures. Central to the aforementioned is a proper understanding of the receiver pipeline, as well a comprehensive model thereof. In addition, the use of other quantities such as visibilities, to detect array failures will also be investigated.

Section C: Full Research Project Proposal

1. Scientific merit:
Detecting antenna array failures in large arrays (especially partial failures, e.g. a malfunctioning antenna / receiver) will be a challenge for large configurations, such as that planned for the mid frequency aperture array (MFAA). The purpose of this project is to expand on previous MEng research that was undertaken to detect array failures using far field data. This research will be focussed on using digitised data for a particular channel and to investigate how the corresponding power spectra will vary, given particular failure scenarios (e.g. a broken, or partially broken antenna, receiver, amplifier, etc.). Machine learning will be incorporated to identify failure scenarios.

The scientific merit in this project is that the candidate will have to gain a solid understanding of the digital signal processes associated with the receiver chains, which includes modelling, simulation and measurements. Hands-on experience can be gained with a 24-element transient array radio telescope (TART), operating at Stellenbosch University that provides access to the desired quantities (i.e. raw channel data). Collaborative efforts will also be formed with 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 a state of the art antenna and RF measurement equipment, a 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 receiver systems and computational electromagnetic (CEM) methods. In addition, the student will become familiar with our small radio telescope testbed (TART). 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, the student will focus on modelling and understanding the receiver system (including digitisation). Faults can be simulated and compared to actual scenarios, using the small radio telescope testbed available at Stellenbosch University. In addition, the student will then apply machine learning processes to see whether failure scenarios presents itself in the power spectra.

In the second year and third years, the student will focus on applying the failure detection algorithms to data acquired from larger telescopes, such as that offered by ASTRON. The use of quantities derived from the raw data, such as visibilities, will also be explored.

3. Relevance of the research proposed to the SARAO priority areas:
The skills that are acquired in this project will allow the student to become acquainted with radio astronomy antennas and receiver systems (that includes digitisation), as well as interferometry. The failure detection software can also be integrated as part of the control and monitoring of radio telescopes.

4. Students with an interest in digital signal processing, 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 - 2019-09-23