Section A: Overview of the Research Project

1. Title of the research project
Solver integration for large-scale radio astronomy antenna array analysis

2. Broad area of research (Engineering or Science)
Engineering

3. Academic level of research project (Masters or Doctoral)
Masters

4. Abstract of research project
Array antennas are an important component of the SKA, for the mid-frequency aperture array (MFAA) stations of SKA Phase 2, and for phased array feeds. The Stellenbosch University (SU) research group is part of the international MFAA consortium. Designing such arrays require extensive numerical modelling. The analysis of a single candidate geometry at a single frequency is very expensive with conventional methods. Thus, analysis is a major bottleneck in the design process. The implication is that design spaces are restricted by the computational capabilities of commercial field solvers, leading to sub-optimal designs. The objective of this work is to integrate the various new solver techniques being developed at Stellenbosch University for efficient array analysis. Approaches which are in development for disjoint array elements include fast macro basis function (MBF) methods, hp-adaptive analysis and global solutions based on collections of localized solutions. It is envisaged that the integrated solver should be suitable for execution on large-scale computing facilities. The final goal is to use this industrial-grade solver to analyse real-world array antennas of interest to the SKA.

5. Primary supervisor's details:
a. Full name of primary supervisor
Matthys M. Botha

b. Primary supervisor's email address (please note that if this project is approved, this email address will be made available to students to contact the primary supervisor)
mmbotha@sun.ac.za

c. University where primary supervisor is employed
Stellenbosch University

6. Co-supervisor/Research supervisor's details (if relevant)
a. Full name of co-supervisor/research supervisor
N/A

b. University where co-supervisor/research supervisor is employed
N/A

Section B: Details of Research Project

1. Scientific/Engineering merit: describe the objectives of the research project, placing them in the context of the current key questions and understanding of the field.
Array antennas are an important component of the SKA, for the mid-frequency aperture array (MFAA) stations of SKA Phase 2, and for phased array feeds. The Stellenbosch University (SU) research group is part of the international MFAA consortium. Designing such arrays require extensive numerical modelling. The analysis of a single candidate geometry at a single frequency is very expensive with conventional methods. Thus, analysis is a major bottleneck in the design process. The implication is that design spaces are restricted by the computational capabilities of commercial field solvers, leading to sub-optimal designs. Optimal

performance is crucial to the SKA, therefore the scientific merit is very strong for advancing solver technology for these challenging problems.
A number of PhD students and a postdoc are currently working on the development of new solver technologies. In contrast, this Masters project will be in support of the practical realisation of the algorithms, by integrating them into an industrial-grade implementation. The project advisors involved in radio astronomy antenna research at SU, coordinate their efforts and the student will join a team with a common goal of excellence in antenna technology.

2. Feasibility: outline the methods that will be used to achieve the objectives. Provide details on the availability of required data / access to required equipment / availability of research facilities and other resources required. Include any relevant expected intermediate milestones and associated timeframes towards attaining the overall objectives of the project.
This project is very feasible, as it is in support of ongoing, leading-edge research on array analysis algorithms at SU. At SU there is a sizable and highly capable computational electromagnetics research group, to support this work.
The milestones for Year 1 are to gain familiarity with the state-of-the-art in the noted solver technologies being developed, as well as with existing, experimental code infrastructure.
The milestones for Year 2 are to implement an industrial-grade, optimized solver for large arrays, based upon existing in-house code infrastructure. The work will slot into a coordinated CEM code development effort underway within the research group. It is envisaged that the solver should be made to execute on large-scale (parallel) computing platforms. It must be used to solve real-world radio astronomy array antennas and benchmarked against existing state-of-the-art solvers. Writing up the thesis and potentially a conference/journal paper is the final milestone.
The relevant commercial software and computer hardware infrastructure is in place for this project, as well as academic expertise and literature resources. SU has comprehensive journal subscriptions.

3. Link the proposed project to one or more of the SARAO research priority areas for 2021 (refer to Section 5 of the Application Guide), and explain in some detail how the proposed research will contribute to the priority area(s).
“Antenna and receiver systems associated with radio telescope instruments supported and hosted by SARAO.”
Tightly coupled array antennas are an important component of the SKA, for the mid-frequency aperture array (MFAA) of SKA Phase 2, and for phased array feeds. The Stellenbosch University (SU) research group is part of the international MFAA consortium. Development of leading-edge modelling capabilities for both these classes of SKA-related arrays would constitute a valuable contribution by South Africa to the international radio astronomy engineering community.

4. If relevant, describe any particular qualifications, academic abilities, skills and/or experience that a student should have in order to successfully deliver on the objectives of the research proposed.
The successful candidate for this project needs a Bachelor’s degree in engineering. Interests in mathematics, physics and computation are required.

Matthys M. Botha, 2021/02/24