Section A: Overview of the Research Project

1. Title of the research project
Higher-order basis modelling for fast analysis and optimisation of ridged horn feeds

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

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

4. Abstract of research project
Ridged horn feed antennas are important to the SKA, forming a crucial part of the reflector antenna array. The Stellenbosch University (SU) research group is part of the international single pixel feed consortium. Such antennas are designed through optimisation. This entails exploring large parameter spaces, which relies on full-wave analysis of candidate designs in combination with surrogate-based modelling. Reduction of the full-wave analysis cost is directly proportional to reduction of the design optimisation cost. This project will entail the development of novel higher-order basis functions and macro basis functions for constructing full-wave solutions with the fewest possible unknown coefficients to solve for, and hence, reduce the cost of such solutions. The developed solver technology must further be integrated into the latest optimisation schemes for ridged horn feeds, which are currently under development within the SU research group. Such leading-edge analysis and optimisation capabilities for ridged horn antennas would constitute a valuable contribution by South Africa to the international radio astronomy engineering community.

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
Dirk I. L. de Villiers

b. University where co-supervisor/research supervisor is employed
Stellenbosch University

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.
Ridged horn feed antennas are important to the SKA, forming a crucial part of the reflector antenna array. The Stellenbosch University (SU) research group is part of the international single pixel feed consortium. Such antennas are designed through optimisation. This entails expensive exploration of large parameter spaces, which relies on full-wave analysis of candidate designs in combination with surrogate-based modelling. The implication of high computational cost is limited design space exploration and hence sub-optimal designs. Reduction of the full-wave analysis cost is directly proportional to reduction of the design optimisation cost. This project will entail the development of novel higher-order basis functions and macro basis functions for constructing full-wave solutions with the fewest possible unknown coefficients to solve for, and hence,

reduce the cost of such solutions. Optimal antenna performance is crucial to the SKA, therefore the scientific merit is very strong.
This work will be at the international research forefront. This project is in support of ongoing research on radio astronomy antennas at SU, where the project advisors coordinate their efforts. 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 challenging but feasible. It will build on very strong existing expertise at SU on higher-order basis functions and MBF techniques, as well as leading expertise at SU on the design of ridged horn feed antennas. Solutions will require physical insight and creativity.
The milestones for Year 1 are to gain familiarity with the state-of-the-art in higher-order basis functions and MBFs. Also, in-depth familiarity with the characteristics of ridged horn feed antennas will have to be established.
The milestones for Year 2 are to develop and implement custom basis functions for representing the solution fields/currents on ridged horn feed antennas with as few as possible degrees of freedom. Any positive results should be immediately written up and submitted for journal publication (possibly a fast-track, letter-format journal). Work should also be presented at conferences.
The milestones for Year 3 are to further develop and refine the methods and also get the full-wave solver up and running. The final task is to combine it with the design optimiser. This must be documented for publication in the top international journal in the antenna field. Work should also be presented at conferences and the thesis must be written up.
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.”
Ridged horn feed antennas are important to the SKA, forming a crucial part of the reflector antenna array. The Stellenbosch University (SU) research group is part of the international single pixel feed consortium. Development of leading-edge optimisation capabilities for faster design over larger parameter spaces than currently considered, 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 Master’s degree in engineering. Interests in mathematics, physics and computation are required.

Matthys M. Botha, 2021/02/24