Section A: Overview of the Research Project Proposal

1. Academic level of research project

Masters

2. Broad field of research

Engineering

3. Title of the research project

Numerical electromagnetic analysis for radio astronomy antennas

4. Research project abstract/summary

Wideband reflector feed and a variety of array antenna systems are currently being developed for future expansions to the SKA. Designing these complex antennas require extensive numerical modelling, to the extent that design spaces are restricted by the computational capabilities of commercial electromagnetic field solvers. This generally leads to sub-optimal designs. In radio astronomy, even a small improvement to antenna performance may be crucial.

Efficient analysis of these antennas require customized, integral equation based solvers. These involve solving for high numbers of unknown coefficients. Past groundwork at Stellenbosch University (SU) has been done towards reducing the numbers of unknown coefficients, by eliminating unnecessary unknowns through error estimation and by grouping unknowns together into "macro basis functions," by exploitation prior structural knowledge. The project objective is to take these existing, individually-developed methods and make them work together, for radio astronomy antennas of practical interest. This will involve incorporating past work into custom analysis tools being developed at SU. It will require a mix of theoretical refinements (e.g. reformulating the error estimation work for radiation analysis, rather than scattering), as well as code implementation work.

At SU there is significant, ongoing research on radio astronomy antennas. This involves classical design in combination with sophisticated optimization methods. The project advisors coordinate their efforts. This project is in crucial support of these activities, which rely heavily on solver technology. The student will join a team with a common goal of excellence in antenna technology.

Section B: Supervisor(s) Details

1. Primary supervisor's details

a. Title and full name

Prof. Matthys M. Botha

b. Name of South African university

Stellenbosch University

c. Email address and/or contact telephone

mmbotha@sun.ac.za
0218084318

d. Supervision of postgraduate students.

i. Doctoral Students:

Name of student	Nationality	Date started	Date completed	Title of Research Project / Thesis	Co-Supervisor (if relevant)
Dao P. Xiang	China	May 2013	Dec 2016	Fast Mesh-Based Physical Optics for Large-Scale Electromagnetic Analysis	N/A
Keshav Sewraj	Mauritius	Jan 2018	Dec 2020	Novel methods of fast numerical electromagnetic analysis for radio astronomy antennas	N/A
Matthews Chose	Botswana	Jan 2018	Dec 2020	Approximate inversion solvers for large-scale antenna array analysis	N/A

ii. Masters students:

Name of student	Nationality	Date started	Date completed	Title of Research Project / Thesis	Co-Supervisor (if relevant)
Renier G. Marchand	South Africa	Jan 2005	Mar 2007	Finite Element Tearing and Interconnecting for the Electromagnetic Vector Wave Equation in Two Dimensions	Prof. David B. Davidson
Willem J. Strydom	South Africa	Jan 2013	Mar 2015	Recovery Based Error Estimation for the Method of Moments	N/A
Keshav Sewraj	Mauritius	Jan 2016	Mar 2018	Extensions to the characteristic basis function method, for antenna array analysis	N/A
Michael P. Richardson	South Africa	Jan 2016	Mar 2018	Physical Optics Based Methods for Scattering Analysis	N/A
Ben A. P. Nel	South Africa	Jan 2017	Dec 2018	Accelerated electromagnetic analysis of superconducting circuit structures	N/A
Robey C. Beswick	South Africa	Jan 2018	Dec 2019	Method of Moments tools for array antenna analysis	N/A

Section C: Full Research Project Proposal

Maximum of three A4 pages, written for a professional who is not necessarily an expert in the relevant subfield

1. Scientific merit:

The analysis of large array antennas and wideband feed antennas remain challenging, not so much because a single analysis (i.e. fixed geometry, frequency of excitation and excitation configuration) of such antennas is unachievable, but because such a single analysis is expensive. This, coupled with the fact that designing such antennas require thousands of analyses, means that the analyses are a major bottleneck in the design process. The scientific merit of advancing solver technology for these challenging problems is thus very strong. This is especially so, considering the potential consequence of such work, for enabling the design of more thoroughly optimized radio astronomy antennas.

2. Feasibility:

This project is entirely feasible. Both in the research literature on error estimation for reduction of unknowns and on macro basis functions for reduction of unknowns, and through past work at SU, it is well established that these are technologies which lead to more efficient solutions. With this project these technologies will be tailored to the antenna applications of interest, in aid of faster design capabilities. The code implementation will not be from scratch, but rather will build upon existing code infrastructure at SU.

The milestones for Year 1 are to gain familiarity with existing code infrastructure and to extend the error estimation scheme to radiation modelling for antennas. The milestones for Year 2 are to implement the error estimation scheme and make it work together with macro basis functions, for radio astronomy antenna models. 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. SARAO research priority area:

Radio astronomy antennas and receivers. The project will contribute to this area through development of efficient modelling capabilities. See the project abstract for further details.

4. Qualifications, academic abilities, skills and/or experience required:

The successful candidate for this project needs a Bachelor's degree in engineering. Interests in mathematics, physics and computation are required.

Matthys M. Botha, 2018/08/29