Section A: Overview of the Research Project Proposal

1. Academic level of research project
Doctoral

2. Broad field of research
Engineering

3. Title of the research project
Fast, custom electromagnetic field solver for wide-band reflector antenna feeds

4. Research project abstract/summary
High fidelity wideband reflector feeds for the SKA remain an elusive problem, with current best effort feeds not achieving similar levels of sensitivity and beam purity as the narrower corrugated feed horns. However, the quad-ridge flared horn (QRFH) antennas currently being developed do seem like promising candidates, with performance continually improving. One of the main difficulties in the designs is the combination of a high dimensional input geometry description, coupled with slow simulation times due to the wide bandwidth required. Most design strategies rely on global optimization schemes, which require a very large number of full wave simulations of the antenna. To make this tractable, the design space dimensionality is typically reduced – causing non-optimal designs.
This project will build on a number of previous projects which focussed on development of fast tailored optimization strategies for radio telescope reflector feed antennas. Here the focus will be on the development of a fast computational code for the rapid and accurate simulation of the QRFH antenna. Given the specific geometry of a QRFH antenna, there are a number of options to implement custom solvers instead of general solvers to solve the currents on the structure. It is foreseen that a speed-up of several orders of magnitude can be expected. This will allow a much wider variety of geometrical configurations to be investigated during the optimizations, and thus improving the ultimate radio astronomical performance of the antennas

Section B: Supervisor(s) Details
1. Primary supervisor's details
a. Title and full name
Prof. Dirk de Villiers

b. Name of South African university
Stellenbosch University

c. Email address and/or contact telephone
ddv@sun.ac.za
0218084011

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)
Ryno Beyers	South African	Jan 2013	Dec 2015	Circuit Model Design of Conical Transmission Line Power Combiners and Isolation of Reactive Combiners	N/A
Ngoy Mutonkole	DRC	Jan 2014	Dec 2016	Modelling of Antenna Responses	N/A
Brandt Klopper	South African	Jan 2016	Dec 2018	Antenna elements for sparse-regular aperture arrays	N/A
Fahmi Mokhupuki	Botswana	Jan 2017	Dec 2019	Surrogate-based Design and Optimisation of Wideband Feeds for the SKA	N/A

ii. Masters students:

Name of student	Nationality	Date started	Date completed	Title of Research Project / Thesis	Co-Supervisor (if relevant)
Sunelle Otto	South African	Jan 2009	Dec 2010	A study of radio astronomy principles and SKA pathfinder system designs with pulsar science	Prof. Petrie Meyer
Karla Schoeman	South African	Jan 2009	Dec 2010	Waveguide Antenna Feed for the Square Kilometre Array	Prof. Petrie Meyer
Phillip Terblanche	South African	Jan 2010	Dec 2011	Electronically Adjustable Bandpass Filter	Prof. Petrie Meyer
David VdM. Prinsloo	South African	Jan 2010	Dec 2011	Characterisation of L-band Differential Low Noise Amplifiers	Prof. Petrie Meyer
Shamim O. Nassar	Kenya	Jan 2010	Dec 2011	An Investigation of the Equivalence Between Combline and Evanescent-Mode Waveguide Filters & of Aspects Related to Reduction of Manufacturing Costs for Combline Filters	Prof. Petrie Meyer
Stephanie Alphonse	Madagascan	Jan 2010	Mar 2012	Fast Analysis of a Compound Large Reflector Antenna	Prof. Keith Palmer
Alex Ibbotson	South African	Jan 2011	Dec 2012	The Design and Analysis of a Rotman Lens with Reduced Conjugate Port Coupling	Prof. Keith Palmer
Dewald Schoeman	South African	Jan 2011	Mar 2013	Full Scale Low-Cost Ultra Wide Band Antenna for SKA Low Frequency Array	N/A
Ngoy Mutonkole	DRC	Jan 2012	Dec 2013	Study of a Wideband Sinuous Feed for Reflector Antenna Applications	N/A
Lukas M. van Vuuren	South African	Jan 2013	Dec 2014	Design of a Receiver System for Use in Radio Astronomy'	N/A

Brandt Klopper	South African	Jan 2014	Dec 2015	Fast Design and Optimisation of One-Dimensional Microstrip Patch Antenna Arrays	N/A
Alex A. Vermeulen	South African	Jan 2014	Dec 2015	The design of a dual reflector feed using surrogate modeling techniques	N/A
Nicol Steenkamp	South African	Jan 2015	Dec 2017	Design of a Wideband Sinuous Antenna for Radio Telescope Applications	N/A
Malan A.X. Ruppert	South African	Jan 2016	Dec 2017	A Study on Phased Array Feeds for Paraboloidal Reflector Antennas	Dr. Ryno Beyers
Ridalise Louw	South African	Jan 2016	Dec 2017	Surrogate Modelling of Performance Metrics of a Wideband Feed for the SKA Reflector Antenna	N/A
Clifford Sibanda	Zimbabwe	Jan 2016	Mar 2018	Design and Optimization of Gap Waveguide Components through Space Mapping	N/A
David Wolsky	South African	Jan 2015	Dec 2018 (Part time student)	A space Mapping Code for Microwave Optimization	N/A
Jako du Toit	South African	Jan 2016	Dec 2018	Partially Filled Radial Power Combiner	Dr. Ryno Beyers
Chanel Hannah	South African	Jan 2016	Dec 2018	Antenna Noise Temperature Measurements and Modelling	N/A
William J. Cerfonteyn	South African	Jan 2017	Dec 2018	A Multi-beam Reflector Antenna for Water Vapour Radiometry	N/A
Shane Moyce	South African	Jan 2017	Dec 2018	Practical Implementation Issues of Null-steering Anti-jamming GPS Arrays	N/A
Hein Swart	South African	Jan 2017	Dec 2019 (Part time student)	A Short-step Axially Symmetric Power Combiner	N/A
Michael Johnston	South African	Jan 2017	Dec 2018	Wideband Marchend Baluns for Radio Astronomy Antennas	Dr. Carlo van Niekerk
Scott Kriel	South African	Jan 2018	Dec 2019	Antenna Array Calibration using a UAV	N/A
Zain de Toit	South African	Jan 2018	Dec 2019	Manufacturing wideband sinuous antenna reflector feeds	Dr. Carlo van Niekerk
Jackline Koech	Kenya	Jan 2018	Dec 2019	Hyperband directional EMC antenna design	`Dr. Gideon Wiid
Ben van der Merwe	South African	Jun 2018	Dec 2020 (Part time student)	H1 Galactic Drift Scan Using a 4.5m Reflector	N/A

1. Co-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

1. Scientific merit:

Developing truly high fidelity wideband feeds for the SKA remains an elusive problem. Given the success of the quad-ridge flared horn (QRFH) within this context, it is worthwhile investigating further variations along the same theme. These antennas are very difficult to properly optimize due to the slow simulation times when general computational electromagnetic (CEM) solvers are used, coupled with the large number of parameters required to fully describe the geometry. Current methods use significantly reduced design spaces to make the global optimization problem tractable.

This project aims to develop a fast, custom CEM solver specifically tailored to quickly solve the currents on QRFH antennas. It is foreseen that such a technique can speed up the simulation of the structure by a few orders of magnitude, which will allow much larger parameter spaces to be investigated during the optimization. This allows the proper investigation of a variety of new ideas to improve the performance of these types of feeds. Among these are the use of corrugations to improve the low frequency performance of the antenna, dielectric lenses to improve the high frequency performance, and cross sectional profiled ridges to improve the loss. All these modifications lead to improved performance in some sense, but add a few dimensions to the design space – making full global optimizations all but intractable when using general CEM solvers.

2. Feasibility:

The basic idea, solving the internal waveguide problem with mode matching techniques while solving the external part of the structure with a boundary value integral, is feasible – as it is widely used for simpler antenna structures. The extension required here is the numerical mode matching implementation to handle the ridged structure where analytical modal solutions aren't available. The first milestone is thus the development of a numerical mode matching code for tapered quad-ridge waveguide structures of arbitrary cross section. This can be easily tested against full wave general CEM solver solutions for accuracy, and should be completed within the first year of the project. The next step is the implementation of the boundary value integral formulation to solve the outside of the structure. This should be completed before the end of the third semester of the project, to allow time for integration and code optimization during the rest of the second year. The final year will be used for development of actual designs and integration into optimization schemes. By this time the most recent requirements of SKA-2 should be considered, and included in the design goals. Writing up of results in journal papers as well as the dissertation will be completed in the third year, while conference presentations will be used to present the intermediate results throughout the project.

The host department has access to a variety of high performance computing machines, as well as all required commercial CEM code licenses (CST, FEKO, and GRASP).

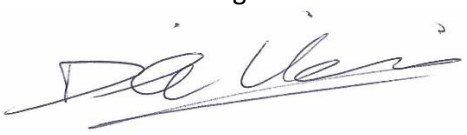
Supervision roles will be split between Profs De Villiers and Botha. Prof De Villiers has extensive experience in design of reflector antenna systems as well as modern optimization strategies and methods, while Prof Botha is a CEM expert.

3. SARAO research priority area:

Radio astronomy antennas and receivers.

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

The successful candidate for this project needs a Masters (or equivalent) degree in microwave or antenna engineering – preferably with some experience in computational electromagnetics or numerical modelling of microwave structures.



Dirk de Villiers, 2018/08/26

Matthys Botha, 2018/08/26