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

Multi-Ridge Horns as Wideband Reflector Antenna Feeds for SKA

4. Full Names of Supervisor and Co-Supervisor

Dirk Izak Leon de Villiers

5. University where postgraduate student would be registered

Stellenbosch University

Section B: Research Project Proposal

1. Scientific merit:

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 band corrugated feed horns. However, the quad-ridge flared horn (QRFH) antennas currently being developed do seem like promising candidates, with performance continually improving. The performance improvement is largely due to advanced CEM and optimisation tools enabling designers to investigate ever increasing design spaces. Standard techniques for the design of these horns, mainly used by researchers at Chalmers University and Onsala observatory, have become the use of spline profiles for the ridges and horns, which are optimised through some global population based meta-heuristic. The design spaces are typically extremely large – to the point where full design space exploration becomes intractable given the required simulation time to estimate the system performance. Even in this situation, several good geometries have been found for bandwidths in the order of 3:1 or 4:1. In contrast to the spline profile technique, a wide variety of analytic profiles have been investigated by workers at Caltech – yielding several feeds with good performance over similar bandwidths. However, several other options remain, with substantial room for improvement in performance. We have recently shown that QRFHs typically achieve in the order of 85% of the theoretical sensitivity limit, while octave band corrugated horns can achieve up to 98 % of the sensitivity limit.

This project will investigate a range of fundamentally different techniques to improve the performance of ridged horn antennas for use as feeds for the SKA dishes at frequencies above the current band 2 feeds. Promising work has recently been published on several such variations including adding corrugations and dielectrics, tapering the ridge cross-sectional profile, and using only three ridges instead of four. The tri-ridge concept is especially promising, since the broken symmetry allows much wider bandwidth single mode operation of the structure. Initial results are promising, but still requires refinement in terms of the profile optimisation as well as feed polarisation descrambling. However, most of these designs have not been optimised properly and for the SKA reflectors, and it is foreseen that substantial improvements to the performance of wideband feeds can be obtained.

The work will be performed within the mandate of the Advanced Single Pixel Feeds and Receiver (ASPFR) consortium – a group of academic and industrial institutions working towards developing next generation single pixel feed systems for the SKA. Close collaboration with this group allows regular updates of the current requirements as well as state-of-the-art performance.

2. Feasibility:

Recent developments of an optimisation methodology by a PhD student at Stellenbosch University has significantly simplified and sped up the process of formally optimising wideband feeds for the SKA reflector system. Also, 3D metal printing is becoming a more mature technology, allowing a much wider range of possible shapes to be accurately manufactured than with traditional subtractive manufacturing technology. This brings together two critical parts of the process to develop improved feeds – formal and specific optimisation and the ability to manufacture the resulting prototype. All

the required expertise in microwave and antenna system design is available in the department from the supervisor and various members of the academic staff and post-graduate students, while a full suite of testing and measurement equipment is also available in house (antenna measurement chamber, network and spectrum analysers, digital oscilloscopes, etc.). Furthermore, software required for the design, including a range of CEM tools, are all available in the department. As stated above, access to the ASPFR working group allows the project to have the most recent information on the requirements and trade-off implications of any wideband feed to be developed for the SKA.
The timeline of the project can be broken up into three yearlong blocks. The first year will be spent doing a thorough literature study and familiarising the candidate with the optimisation and simulation codes. A research proposal must also be developed and submitted by the end of year 1. The second year will then be used for initial and detailed design of the most promising feed types, while the final year will broadly spent on manufacturing and qualifying prototypes and writing the dissertation. Intermediate results will be reported at international conferences, while significant results will be reported in leading peer reviewed journals.
I don't foresee any difficulty in hosting the project, and expect a high probability of success.

3. SARAO research priority area:

- Radio astronomy antennas and receiver systems (including digitisation) associated with supported and hosted instruments.

This project could yield a design which can directly contribute to future expansions of the SKA telescope.

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

The successful candidate for this project needs a Masters (or equivalent) degree in electronic engineering, with experience in designing broadband antennas. Proficiency in CEM tools such as CST is a requirement, while experience in designing reflector feeds using GRASP will be a big advantage. Furthermore, knowledge of modern optimisation and modelling techniques will be very helpful.