Section A: Overview of the Research Project

1. *Title of the research project*
   Optimization of Single Element Radio Astronomy Antennas

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

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

4. *Abstract of research project*
   This project will develop full pipeline optimization algorithms for antennas of single element radio astronomy instruments. Physical parameters of the antenna will be tuned, while the resulting beams simulated through a pipeline that estimates the performance of the actual system on a real sky. Several simplifications and surrogate models must be developed to make the simulation time tractable. It is foreseen that such a full pipeline method can produce improved antenna systems over those designed by traditional methods where antenna beam patterns act as surrogates for the actual system performance.

5. *Primary supervisor's details:*
   a. *Full name of primary supervisor:* Dirk Izak Leon de Villiers

   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)*
   ddv@sun.ac.za

   c. *University where primary 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.*
   Design of radio astronomy antennas mostly relies on optimization of the antenna reflection coefficient and beam pattern so that they adhere to a set of constraints defined in terms of traditional antenna parameters (beamwidth, sidelobe level, etc). During design of MeerKAT and SKA, more advanced methods were employed where direct maximization of the receiving sensitivity was pursued, with no mind given to the final feed antenna pattern during the calculation of the optimization goal function. This proved a successful strategy, as better systems were produced than could have been done if only the feed pattern shape was optimized. In this project we will extend this idea to more sophisticated optimization goal functions – specifically focused on single element radio astronomy systems. Examples are the REACH and X-BASS experiments, which will both use only a single antenna to measure power spectra. Their total performance metric is not only a strong function of the antenna beam pattern, but also of how the pattern interacts with the radio sky. Normally performance prediction is done through computationally expensive astronomical observation simulation pipelines, which take as their input the antenna beam pattern. Here, we will attempt to develop simplified pipelines, specifically tailored to the experiments at hand, which can be tightly integrated with the antenna simulation and design software. As such, the optimization goal function becomes more closely aligned to the final goal of the experiment, and better antenna systems (which possibly performs worse according to traditional generic antenna pattern metrics) will likely result.

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.*
   Most of the work will be simulation driven, so physical infrastructure required is mainly computers and simulation software. It is foreseen that close collaboration with the REACH group (already established, since the supervisor is co-PI), as well as the C(X)-BASS development group (already in place, since the supervisor is supervising a PhD student developing the X-BASS system), will provide both required real-world data as well as expertise in radio sky modelling pipelines. A rough timeline can be the first year is used for background study and model development, the next 3 semesters for implementation of the models into optimization loops and design of actual antennas, and the final semester on dissertation write-up.

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).*

   (1) Antenna, receiver, (analogue and digital) signal processing, data analysis and data recording systems associated radio telescope and geodesy instruments supported and hosted by SARAO.

   This project is most suited to a student with interest in both mathematical modelling as well as antenna design. Experience in radio astronomy related projects would be helpful.