Section A: Overview of the Research Project Proposal

1. Academic level (Masters or PhD): Doctorate - PhD (Physics)

2. Broad field of research: Research on an Engineering aspect of the Telescope

3. Title of research project
Coherent Frequency Reference and Data Signals over Optical Fibre Networks for the SKA

4. Full names of Supervisor
Professor Tim Gibbon
Email: Tim.Gibbon@mandela.ac.za

5. University where postgraduate student will be registered
Nelson Mandela University (Port Elizabeth, South Africa)

Section B: Research Project Proposal

1. Scientific merit

Optical fibre networks form the hidden backbone of the MeerKAT and SKA Radio Telescopes. Tremendous volumes of of data need to be aggregated from the individual dish elements to the central Correlator. The dishes of the SKA and aperture arrays will produce 110 times the current global Internet traffic. Furthermore, phase stable timing and frequency reference (TFR) signals need to be sent from a central hydrogen maser ensemble to dishes located at distances from tens to hundreds of kilometers away. Optical communication systems to achieve this down to the picosecond stability required are not yet commercially available. The objectives of this project are to develop techniques for creating, transmitting and receiving signals based on coherent optical techniques. Coherent generation allows creation of high frequency reference tones via all-optical techniques (frequency combs, heterodyning, gain switching etc.), while coherent detection allows phase recovery and correction through digital signal processing (DSP) and/or all-optical hardware actuators. Recent developments in coherent communication have revolutionized the telecommunication industry through high receiver sensitivity, extended reach and DSP dispersion mitigation. This research project is novel and high value in its approach to further develop and harness coherent technologies, with custom application to next generation radio telescopes. Nelson Mandela University has the best equipped optical fibre research lab in the country. Our students have the opportunity to travel and present at overseas conferences, as well as spend time on research visits abroad.

2. Feasibility

The Nelson Mandela University has an extremely well equipped laboratory with cutting edge optical fibre research equipment. The equipment and expertise have been assembled over a period of seventeen years, with a proud history of producing MSc and PhD graduates. We collaborate closely with both local and international universities, as well as key industry partners such as Telkom. CISCO is a notable world leader and research partner in the area of flexible spectrum research. We also work closely with the SKA-SA Engineering team on the MeerKAT project in developing technologies implemented in the MeerKAT Telescope. Our graduates are in high demand, with former students employed by SARAO. Our group has an excellent publication record, validating the scientific merit and quality of our research. https://broadband.mandela.ac.za/Publications With the campus situated in Port Elizabeth beside the ocean on a nature reserve, Nelson Mandela University is a great opportunity for pursuing postgraduate studies.

Milestones and timeframes:

Year 1

1) Background study on theory and operation of network components (coherent receivers, wavelength selective switches, single frequency fibre lasers, optical transceivers etc.) and modulation formats (QPSK, DPQPSK, TFR signals etc.).
2) Background study on optical fibre network architectures, specifically relating to coherent signal generation, transmission and detection. This includes experimental work to gain expertise with equipment in the Nelson Mandela University lab.
3) Full review of coherent signal generation and signal correction methods: frequency combs, heterodyning, gain switching, DSP dispersion correction, optical phase actuators, VCSEL correction, etc.
4) Publish novel and innovative work at relevant conferences and journals (SAICSIT, SATNAC, SAIP etc.).

Year 2

5) Clear formulation of the data and TFR requirements as relating to future networks, MeerKAT and SKA.
6) Identify and improve the best technologies from 1) and 3) above most suited to the problem. This features proposing novel and hybrid solutions.
7) Design and build an experimental lab testbed reflecting a full coherent signal generation, transmission, detection and correction
8) Publish novel and innovative work at relevant conferences and journals (SAICSIT, SATNAC, SAIP etc.).

Year 3

9) Using the experimental lab testbed developed, implemented the relevant coherent data and TFR generation and phase correction technologies. Fully evaluates their performance and success.
10) Publish novel and innovative work at relevant conferences and journals (SAICSIT, SATNAC, SAIP etc.).
11) Write-up and submit.

3. Link to SARAO research priority areas for 2020

The research relates to " Radio astronomy antennas and receiver systems (including digitisation) associated with supported and hosted instruments." – Timing and frequency reference (TFR) signals need to be sent from a central hydrogen maser ensemble to vial optical fibre to all dishes and antennae elements. Without optical communication systems of the type researched in this project, the digitisers would not function and the antennae would not be able to conduct critical pointing, steering and basic tasks. The research further develops technologies to transport signals between individual telescope subsystems, making data available to Astronomers and telescope end users. Optical networks to meet these requirements demand rely on complex technologies and networks, with thousands of individual network components (transceivers, routers, wavelength selected reconfigurable add-drop multiplexers, optical amplifiers, etc.) distributed within optical networks spanning thousands of kilometers.

4. Qualifications, academic abilities and skills required for this project

The successful applicant should already have a Masters in Physics, Engineering or similar.