Section A: Overview of the Research Project Proposal

1. Doctoral
2. Engineering
3. Built-in self-testing and calibration of radio astronomy receiver components and sensors
4. Electronic systems in radio astronomy (like all other electronic systems) are subject to degradation and failure over time. This creates a need for periodic system testing and, where necessary, predictive maintenance. This project will analyse the failure modes of electronic components up and down a typical radio astronomy receiver chain, and propose areas where self-testing (even built-in self-testing) may be applied for testing. It will, further, apply machine learning techniques to not only detect faults, but to diagnose them, and extend on these diagnoses to apply self-maintenance or self-healing where possible. Self-testing techniques that may be applied to this study are oscillation-based testing, surrogate component testing, one-shot calibration, and others.

Section B: Supervisor(s) Details

1. Primary supervisor's details

a. Dr Tinus Stander
b. University of Pretoria
c. tinus.stander@up.ac.za
d. Supervision of postgraduate students
i. Doctoral Students:

Name of student	**Nationality**	**Date started Doctoral Degree (Month and Year)**	**Date completed / will complete Doctoral Degree (Month and Year)**	**Title of Research Project / Thesis**	**Co-Supervisor (if relevant)**
Piotr Osuch (Also supervised for M.Eng)	RSA	01/2016	07/2018	Synthesis and monolithic integration of in-system analogue data pre-processing networks	
Flavien Sagouo Minko	Cameroon	01/2014	12/2018 (part-time)	Broadband, radiation hardened mm-wave components for space-based Sun observation instruments	
Brilliant Habeenzu	Zambia	02/2015	12/2018 (part-time)	Radiation degradation characterization and modelling in mm-Wave microelectronics	
Titus Oyedokun	Nigeria	01/2014	08/2018	Planar Groove Gap Waveguide	Prof. RH Geschke (primary, UCT)
Hannes Venter (Also supervised for M.Eng)	RSA	06/2018	12/2020	Dispersive and multi-band phase shifters	

ii. Masters Students

Name of student	**Nationality**	**Date started Doctoral Degree (Month and Year)**	**Date completed / will complete Doctoral Degree (Month and Year)**	**Title of Research Project / Thesis**	**Co-Supervisor (if relevant)**

Nishant Singh	India	01/2015	05/2017	Active Q-Enhanced Tunable High-Q On-Chip E-band Resonators and Pseudo-Combline Coupled Resonator Filters in 130nm SiGe BiCMOS	
Vishal Bhana	RSA	01/2013	11/2017 (part-time)	A Slow-Wave CMOS Delay Line Filter for mm-Wave Applications	Prof. S. Sinha (UP)
Shaunel Walker	RSA	01/2016	12/2018	Low cost RF PCB integrated front-ends for mm-wave water vapour radiometry	Mr AC de Villiers (TUT)
Edward Hunter	RSA	01/2017	12/2018	Radially distributed mm-wave array antennas	Prof. DIL de Villers (SU)
Anthony Gaskell	RSA	01/2016	12/2018 (part-time)	Resonant tunnelling diode based analogue to digital converters	Prof. WE Meyer (UP)
James Smith	RSA	01/2014	12/2018 (part-time)	A substrate integrated waveguide amplifier matching scheme	

2. Co-supervisor / Research Supervisor's details (if relevant): N/A

Section C: Full Research Project Proposal

1. Scientific merit:

Electronic systems in radio astronomy (like all other electronic systems) are subject to variation, degradation, and failure over time. Even under normal operating conditions, these receivers need to be calibrated due to environmental variation.

A fairly conventional approach to testing RF systems is to apply a test stimulus (i.e. an RF signal) and to measure the response of the circuit at the output using some form of sensor. This may not always be possible, as both driving source and detection circuitry need to be available.

There are plethora of minimally invasive techniques for testing systems and circuits without test equipment (generators or detectors). These built-in self-testing techniques are not only useful where test equipment is not readily available, but may be necessary where test nodes are inaccessible. This is often the case inside integrated circuits, but may apply equally to test nodes that are inaccessible because of remote locations or EMI/RFI shielding encasement.

From reviewed literature, it would appear as if such a formalised approach has not yet been taken to radio astronomy receiver calibration, self-testing, or self-correction. This raises questions as to their applicability to this field, given that many of them have drawbacks that may be exacerbated due to the unique nature of the systems under test.

2. Feasibility:

There have been numerous published studies on the application of various self-testing / built-in self-testing methods for a variety of digital, mixed signal, and RF components. Though the application of some of these methods to radio astronomy receivers may be novel (given the unique nature of the receivers) there is a firm basis in published literature to work from. These include (but are not limited to) oscillation-based testing, surrogate component measurement, one-shot calibration, and thermal monitoring.

The M4 lab at the University of Pretoria has significant experience in especially oscillation-based testing of mixed signal and RF circuits. The lab is further equipped with all the necessary laboratory facilities for measurement (including cryo-cooled measurements), as well as software for circuit and system modelling.

Potential objectives for this project would be:

Y1: Literature review. Identify the critical degradation / failure points along the RF path of the receiver, as well as typical failure modes. Formulate self-testing / built-in self-testing approaches for each identified node, based on the variety of techniques

Y2: Implement selected BIST circuits. Establish links between test results and failure modes.

Y3: Investigate and apply machine learning approaches for fault diagnosis. Investigate and apply self-healing based on diagnostic data.

3. This proposal links to Research Priority Area 12: Predictive maintenance and scheduling using sensor data analytics, machine learning and system modelling. This project aims to introduce novel, minimally intrusive sensors and self-testing techniques into radio astronomy receivers, for the express purpose of estimating system performance and aiding preventative maintenance.

4. The preferred candidate would have, if not a postgraduate, than at least a firm undergraduate background in high frequency electronics and / or electromagnetics. This would include knowledge of basic RF components (transmission lines, filters, couplers, mixers) as well as RF simulation software. Knowledge of machine learning techniques and systems engineering principles would also be beneficial

Section D: Signatures

1. Signed: T. Stander ______________________ Date: 31 August 2018