Section A: Overview of the Research Project Proposal

1. Doctoral
2. Engineering
3. Novel approaches to multi-wavelength water vapour radiometry
4. Accurate estimation of tropospheric water vapour is imperative to site surveys, observation management, and path length correction in mm-wave radio astronomy. Water vapour radiometer systems are commercially available, but are large and expensive and require several moving parts. A major challenge in future radiometer research is, therefore, to find low-cost, solid-state (monolithic or hybrid) integrated solutions, with specific attention to novel switchless architectures. Another key development area is in calibration methods, specifically to determine feasible ways of calibrating out phased array antenna efficiency parameters (which current methods do not).

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:

Accurate estimation of tropospheric water vapour is imperative to site surveys, observation management, and path length correction in mm-wave radio astronomy. This may be estimated at 183 or 225 GHz, or with dual-band methods at 22 and 31 GHz. A real-time comparison of these observations would, however, be an in interesting experiment, for which an appropriate instrument needs to be developed.

Water vapour radiometer systems are commercially available, but are large and expensive and require several moving parts. One option would be to draw on knowledge from communications receivers in implementing phased array beamsteering, eliminating the moving antenna reflectors. This creates a new challenge, however, in system calibration, as the effect of amplitude and phase control elements are outside the calibration loop established with conventional architectures. This necessitates research in either novel receiver architectures, or at least, novel approaches to calibration (perhaps relying on oscillation-based testing and self-calibration).

Monolithic (integrated circuit) or hybrid integration of these radiometers is also only a partially addressed problem in literature. There exists significant unanswered research questions in the hybrid on-chip / off-chip integration at 183 / 225 GHz (interconnecting, integration media, hybrid co-design, appropriate semiconductor processes), which may lead to faster and more flexible system design if properly addressed.

2. Feasibility:

There are numerous published studies on both large and single-chip radiometers, demonstrating that that, at the two integration extremes, exist feasible solutions. Similarly, there are many compact communications transceivers in the relevant bands, which further substantiate the feasibility of the inquiry.

The M4 lab at the University of Pretoria has experience in radiometer design, mm-wave design, hybrid integration, and oscillation-based testing of mixed signal and RF circuits. The lab is further equipped with all the necessary laboratory facilities for measurement (including anechoic measurements), as well as software for circuit and system modelling.

Potential objectives for this project would be:

Y1: Literature review. Microelectronics design training. Formulate and qualify a hybrid integration simulation approach. Adapt and validate the system simulation approach.

Y2: Detailed monolithic and hybrid co-design, using conventional architectures. First iteration detail design, simulation, prototyping, and qualification.

Y3: System architecture revision, with emphasis on calibration methods. Second iteration detail design, simulation, prototyping, qualification.

3. This proposal relates to Research Priority Areas 3 (Radio Astronomy antennas and receivers), 5 (Instrumentation and systems for Radio Frequency Interference (RFI) detection and data analysis/archival/interrogation/visualization), and 8 (Interferometric Data Processing and Analysis, including calibration and imaging). The receiver techniques developed in this study may be applied in future receiver (for radio astronomy, or for RFI detection) design, while the data generated from

accurate WVR measurements could be used for correction in data processing in observations (potentially).

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 microelectronic design is preferred, but not necessary.

Section D: Signatures

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