Section A: Overview of the Research Project

1. A phase interferometer for atmospheric measurements
2. Engineering
3. Masters

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. While water vapour radiometers for site surveying is ongoing, phase interferometry has also proven to produce valuable results. This project will develop and deploy a phase interferometer using a suitable geostationary satellite. While most systems use retrofitted off-the-shelf LNBs, this project will develop a custom downconverter, giving it greater flexibility in source selection.

5a. Prof Tinus Stander
5b. tinus.stander@up.ac.za
5c. University of Pretoria

Section B: Details of Research Project

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. One way to estimate path delay is to use a passive radiometer to measure the emission of tropospheric water vapour at 22 or 183 GHz. While this method is popular, there are several shortcomings. For one, emissions from the 22 GHz line is quite weak in comparison to the 183 GHz line, and heavily influenced broadband emissions of liquid water (clouds) in the field of view. On the other hand, the 183 GHz line saturates at lower concentrations than 22 GHz, whilst also necessitating far more expensive RF electronics.

An alternative approach is to measure tropospheric path delay using phase interferometers, whereby two (or more) receivers are pointed at the same satellite beacon and the detected signals correlated to find small differences in the phase path. This variation in relative path delay may then be related to water vapour concentrations, when considering other parameters such as ground temperature, relative humidity, and atmospheric pressure.

Many interferometers use retrofitted off-the-shelf low-noise block downconverters for satellite TV networks. While this approach is both valid and effective, it limits the choice of satellite beacon. A more flexible system would use a custom LNB which could be used for a variety of beacons, or even combine data from multiple bands. A further dimension of this study would be to investigate the relative value of $N > 2$ receivers.

This project will aim to develop a phase interferometer suited to site surveying in Southern Africa, with emphasis on low-cost build and integration, as well as ease of deployment at remote sites.

2. Feasibility:

This project will build on previous student projects which studied tropospheric water vapour estimation through a variety of methods (including water vapour radiometry).

The M4 lab at the University of Pretoria has experience in radiometer design, mm-wave design, hybrid integration, and 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. The lab further has access to in-house prototyping facilities for building RF PCB systems, as well as 3D printing feed horns and dishes.

Potential objectives for this project would be:

Y1: Literature review. Architecture design. Detailed LNB design and testing.

Y2: Full system integration. Test deployment and data processing. Site survey deployment. Final dissemination.

3. This proposal relates to "Hardware, software and data analytic systems associated with the control and monitoring of radio telescopes". The prototype developed in this study may be deployed both for surveying potential new mm-wave radio astronomy sites in Southern Africa, and to provide monitoring data at existing centimetric observation sites.

4. A firm undergraduate background in high frequency electronics and / or electromagnetics is advisable for this project. This would include knowledge of basic RF components (transmission lines, filters, couplers, mixers, amplifiers) as well as RF simulation software.

Section C: CV of primary supervisor

Prof Tinus Stander, *Pr.Eng, PhD(Eng)(SU), SMIEEE*

Education

- **PhD, Electronic Engineering**
  Stellenbosch University, South Africa, 2009.
- **B.Eng, Electrical and Electronic Engineering with Computer Science**
  Stellenbosch University, South Africa, 2005

Awards, Distinctions and Fellowships

- Coimbra Staff Exchange Fellowship (2014)
- Erasmus Mundus EUROSA III scholarship (2013)
- Awarded NRF C-rating (2020)
- Awarded SANRAL B-category researcher rating (2020)
- IEEE MTTSAT Challenge Phase 2 participant (2020)

Leadership positions

- Vice-Chair: SA IEEE APS/MTTS/EMC Chapter (2019 – 2021)
- Project Leader, SANRAL Research Project 1.2a, “Sensors”.
- Co-PI, SA-Mexico Bilateral Programme on Water Vapour Radiometry (2018 – 2021)
- Advisor to VIP team, “Reliable Systems”

Professional Activities

- Registered as Professional Engineer with the Engineering Council of South Africa
- Consultant to South African National Roads Agency (SANRAL), leader of Project 1.2s: “Sensors”
- Scientific advisor to Multifractal Semiconductors (Pty) Ltd.
- Senior member of the IEEE (2005 – present)

Employment History

- **Associate Professor**
  Department of Electrical, Electronic and Computer Engineering, University of Pretoria, South Africa, January 2020 – present.
- **Senior Lecturer**
  Department of Electrical, Electronic and Computer Engineering, University of Pretoria, South Africa, January 2013 – December 2019.
- **Radio frequency and microwave engineer**, Denel Dynamics, Centurion, South Africa, 2010 – 2012

Teaching Activities

- Postgraduate Communications Electronics EMK732, UP, 2017 – current.
- Electronic engineering design ELO320, UP, 2014-current.
- Advanced Electronics ENE410, UP, 2014-current.
- Digital Electronics ERS 220, UP, 2013.
- Postgraduate Analogue Electronic Design EME 732, UP, 2013-2014.
- Analogue Electronics ENE310, UP, 2013.
- Microwave Filters for RADAR, UCT, 2013.
- Microwave Engineering EMW040, CPUT, 2008.

Research Interests

- mm-Wave microelectronics for terrestrial communications.
- Built-in self-testing of RF and mm-wave electronics
- mm-Wave radiometry for radio astronomy
- mm-Wave remote sensing for transportation applications
- Additive manufacturing for microwave and mm-wave components and packaging.

Research Activities

Completed Postgraduate Supervision

- M.Eng (Electronic and Microelectronic Engineering): 9
- PhD (Electronic Engineering): 6

Current Student Supervision

Supervisor or co-supervisor to 6 postgraduate students (M.Eng and PhD)

Current Research Grants

- NRF Competitive Support for Rated Researchers (2022 – 2024)
- Eskom Tertiary Education Support Programme on mm-Wave terrestrial communications (2014 – current)

Current Facilities Management

- mm-Wave coaxial and waveguide lab
- mm-Wave microelectronic wafer probe lab
- mm-Wave anechoic chamber
- Class 6 cleanroom

Publication Metrics

- Total journal papers: 25
- Total international conference papers: 57
- Total patents: 3
- Total citations in Scopus: 207
- h-index in Scopus: 7

Top Publications

1. J. J. P. Venter, T. Stander and P. Ferrari, “X-band Reflection-Type Phase Shifters Using Coupled Line Couplers on Single Layer RF PCB”, IEEE Microwave and Wireless Components, Vol. 28, no. 9, pp. 807 – 809, 2018.
2. P. J. Osuch, T. Stander, “A Millimeter-Wave Second-Order All-Pass Delay Network in BiCMOS”, IEEE Microwave and Wireless Components Letters, Vol. 28, no. 10, pp. 912 – 914, 2018.
3. J. B. Cloete, T. Stander, D. N. Wilke, “Parametric Circuit Fault Diagnosis Through Oscillation-Based Testing in Analogue Circuits: Statistical and Deep Learning Approaches”, IEEE Acccess, Vol. 10, pp. 15671 - 15680
4. N. Singh, T. Stander, “E-band Active Q-enhanced pseudo-combline E-band resonator 130nm SiGe BiCMOS”, Journal of Infrared, Millimeter, and Terahertz Waves, Vol. 39, No. 10, pp 949–953, 2018.
5. F. Sagouo Minko, T. Stander, “Effect of TID Electron Radiation on SiGe BiCMOS LNAs at V-band”, Microelectronics Reliability, Vol. 112, e113750, 2020.
6. J. J. P. Venter, T. Stander, “Phase Shifters with Multiple Independently Controllable Bands Utilizing Frequency-Selective Variable Gain Networks”, IET Microwaves, Antennas and Propagation, Vol. 15, no. 2, pp. 143-153, 2021.
7. H. P. Nel, T. Stander, F. C. Dualibe, “Built-In Oscillation-Based Self-Testing of a 2.4 GHz LNA in 0.35μm CMOS”, Proc. IEEE ICECS 2018, pp. 837 – 840.
8. P. J. Osuch, T. Stander, “High-Q second-order all-pass delay network in CMOS”, IET Circuits, Devices and Systems, Vol. 13, no. 2, pp. 153 – 162, 2019.
9. J. J. P. Venter, R. Maharaj, T. Stander, “Additive Manufacturing of Interdigital Filters with Arbitrary Line Cross Section”, IEEE Transactions on Components, Packaging and Manufacturing Technology, Vol. 10, no. 4, pp. 686–693, 2020.
10. F. Sagouo Minko, T. Stander, “A comparison of three-dimensional electromagnetic and RC parasitic extraction analysis of mm-wave on-chip passives in SiGe BiCMOS low-noise amplifiers”, International Journal of RF and Microwave Computer-Aided Engineering, vol. 30, no. 2, e22019, 2020.