Filtering Low-Noise Amplifiers for Radio Astronomy
proposed for a Doctoral degree study in Engineering

supervised by

Prof Tinus Stander, University of Pretoria
tinus.stander@up.ac.za

Abstract

The loss and gain at the very front of a radiofrequency receiver chain dominates the noise performance of the receiver in its entirety. For this reason, great care is taken to design and implement first-stage amplifiers with very low noise figures, known as low-noise amplifiers (LNAs). However, with increasing adoption of more (and higher) frequency bands for telecommunications and industrial radar applications, there is an increased need to shield sensitive receivers from out-of-band interferers by using front-end filters, at the expense of insertion loss and decreased system sensitivity. What would be ideal, is to have a single component that performs both filtering and amplification functions: rejecting out-of-band interference without incurring the loss associated with cascading a filter and an LNA. While singular examples of such devices exist in literature, these are usually narrowband examples, and are mostly achieved by performance optimization rather than explicit fundamental synthesis.

This project will different theoretical synthesis approaches to designing a filtering low-noise amplifier.

Details of Research Project

Scientific merit

The front-end of a radio astronomy receiver should provide extremely low-noise amplification as a primary function. Rejection of out-of-band interference is a secondary consideration, but one growing in importance due to the proliferation of terrestrial and extraterrestrial RFI sources. Filters introduce insertion loss, which means they are usually (with notable exception of superconducting filters [1]) placed after the first-stage LNA where their loss is mitigated, but where they serve no purpose in protecting the LNA from saturation due to out-of-band RFI. Filtennas (feed antennas with filtering properties) is a mitigating approach with growing interest [2], but frequency selectivity is often a trade-off with other critical antenna properties such as the desired beam pattern over bandwidth. The ideal solution would be a co-designed component with a prescribed frequency selective transmission response (such as a filter) but with low-noise amplification (such as found in an LNA).

Two approaches are possible: introduction of low-noise amplification in the synthesis of filters, or introduction of frequency selectivity in the synthesis of LNAs. The latter has been pursued for some time [3], with reasonable results achieved by engineering frequency selectivity into the impedance matching networks of the LNA. This approach is, however, limited in that greater selectivity requires higher order networks, which incur more loss and lead to higher noise levels and lower gain in the LNA. The second, more interesting approach, is incorporating optimal driving-point impedance into the synthesis of coupled resonator filters with active elements [4]; however, this limits the synthesis bandwidth of front-end amplifiers to that achievable with the coupled resonator approximation, negating the possibility of e.g. enhancement of interdigital filter elements [5] with low-noise active enhancement [6]. One possible avenue might be to re-investigate the classical theories of active filters, such as transversal or recursive synthesis [7], but with emphasis on low-noise amplification.

By following both approaches, this project will seek to answer three key research questions:

1) What is the maximum feasible band selectivity achievable by incorporating frequency selectivity into low-noise amplification impedance matching synthesis?
2) Can low-noise gain elements be included into the synthesis of broadband (coupled line or interdigital) filters?
3) Can low-noise gain elements be used in the synthesis of classical active filters?

References:

[1] 10.1109/RFIT.2018.8524121
[2] 10.1109/InCAP52216.2021.9726195
[3] 10.1109/TCSI.2022.3224439
[4] 10.1109/TMTT.2024.3449135
[5] 10.1109/TCPMT.2020.2967807
[6] 10.1007/s10762-018-0524-0
[7] 10.1109/TMTT.1985.1133225

Feasibility

This project will build on both substantial underlying theory and institutional know-how in filter and broadband LNA synthesis. It is anticipated that each of the three key questions will produce some publishable answer, though of course none of them are guaranteed to produce a solution that outperforms the separate cascade of filter and LNA.

Availability of resources

The University of Pretoria has all the requisite institutional know-how, software, manufacturing, and measurement equipment to complete this study successfully. This project may be completed either by discrete component prototyping or by microelectronic design, both of which are available.

Milestones

Y1: Literature review. Broadband LNA synthesis. Frequency selectivity modification investigation, prototyping, testing.
Y2: Broadband filter synthesis, active enhancement integration, prototyping, testing.
Y3: Active low-noise element selection and testing, adaptation of active filter synthesis for low-noise driving impedances, prototyping, testing.

Profile of the successful applicant

A master's degree 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. A background in microelectronics design would be advantageous, but not required.

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
- **M.Eng (Engineering Management)**
  University of Pretoria, South Africa, 2024 (current)

Short Courses and Certifications

- **Programme in Project Management**
  University of Pretoria, South Africa, 2023.

Awards, Distinctions and Fellowships

- 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)
- Oppenheimer Memorial Trust Sabbatical Funding (2024)

Leadership positions

- Vice-Chair: SAIEEE APS/MTTS/EMC Chapter (2019 – 2022)
- Project Leader, SANRAL Research Project 1.2a, "Sensors".
- Co-PI, SA-Mexico Bilateral Programme on Water Vapour Radiometry (2018 – 2021)

Professional Activities

- Registered as Professional Engineer with the Engineering Council of South Africa
- Scientific advisor to Multifractal Semiconductors (Pty) Ltd.
- Senior member of the IEEE (2005 – present)
- Journal Reviewer: IEEE T-MTT, IET MAP, IET CDS, IEEE MWTL,

Employment History

- **Professor**
  Department of Electrical, Electronic and Computer Engineering, University of Pretoria, South Africa, January 2023 – present.
  Responsible for conducting and supervising novel academic research, and supporting research activities by securing research grants, as well as establishing and maintaining relevant research facilities.
  Responsible for undergraduate and postgraduate teaching, including curriculum development and assessment.
  Responsible for community engagement through professional society volunteering and consultation to industry.
    - Previously Senior Lecturer (2013 – 2019) and Associate Professor (2020 – 2022).

- **Radio frequency and microwave engineer**,
  Denel Dynamics, Centurion, South Africa, 2010 – 2012
  Responsible for RF component designs: requirements analysis, conceptualization, implementation, testing and reporting. Designs included communication systems, filters, and EMC measurement equipment.

Teaching Activities

- Postgraduate Wireless Electronics EMK732, UP, 2017 – current.
- Electronic engineering design EPR320, 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

- 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): 11
- PhD (Electronic Engineering): 7

Current Student Supervision

Supervisor or co-supervisor to 17 postgraduate students (M.Eng and PhD) and 1 postdoctoral fellow

Current Research Grants

- NRF National Equipment Programme (2023-2028) "sub-THz Measurement Facility" (R15,000,000)
- NRF National Equipment Programme (2022-2027) "Advanced microfabrication and integration facility" (R12,428,000)
- SARAO Research Group Grant "Wide-Band, High-Frequency Receivers and Data Recording Systems" (R3,800,000)
- Member of AtLAST2 consortium

Current Facilities Management Responsibilities

- mm-Wave microelectronic wafer probe lab
- mm-Wave anechoic chamber
- Class 6 cleanroom
- Microelectronics packaging line
- PCB patterning and assembly line

Active Research Collaborations

- TU Eindhoven, Fraunhofer FHR, IMT Atlantique, Kutleng Engineering Technologies
  "Materials characterization and design paradigms for 3D printed dielectric parts"
- National Autonomous University of Mexico, INAOE Mexico, Radboud University, University of Namibia
  "Radio astronomy site characterization through water vapour radiometry"
- Saab South Africa
  "Resilience and built-in self-testing of wideband GaN LNAs"
- SARAO, University of Groningen, Radboud University
  "Multi-band receivers for the African Millimeter Telescope (AMT)"
- University of Sao Paulo, Brazil
  "Hybrid packaging of mm-wave circuits on nanowire substrates"

Publication Metrics

- Total journal papers: 30
- Total international conference papers: 61
- Total patents: 3
- Total citations in Scopus: 293
- h-index in Scopus: 8

26 February 2026

CONFIRMATION OF RESOURCES FOR SARAO-FUNDED M AND PHD STUDIES

We hereby confirm the confirmation of the following software, equipment, and data at the Carl and Emily Fuchs Institute for Microelectronics, in support of our proposed M.Eng and PhD topics:

<u>Software:</u>
EM simulation software (CST Microwave Studio, Ansys HFSS, Altair FEKO)
Circuit and system simulation software (Cadence AWR, Cadence IC design suite)
AMD VivadoTM Design Suite: Enterprise Edition

<u>Digital hardware and development boards:</u>
Xilinx ZYNQ Ultrascale+ RFSoC FPGA development board
RealDigital RFSoc 4x2 Xilinx Ultrascale+ FPGA development board
Digilent Eclypse Z7 Xilinx FPGA development board

<u>Manufacturing and assembly equipment:</u>
3D printers (FormLabs Form3, Intamsys Funmat HT, Creality Halot Mage S)
PCB / planar substrate patterning (LPKF ProtoLaser U4, ProtoMat S64, MultiPress S4, Contac S4 copper plating bath)
F&S BondTec 53XX semi-automatic wirebonder
Tresky T-5100 manual die bonder

<u>RF metrology equipment:</u>
Anritsu ME7838G VNA (220 GHz)
Harmonic mixers and noise sources up to 220 GHz
Anritsu ME7828A VNA (110 GHz)
R&S FSW50 signal analyser (with noise figure and phase noise measurement)
Cascade Microtech PM300 wafer probe station, with probes and positioners
Compact antenna test range (CATR), for antenna measurements up to 40 GHz
Millimetre-wave anechoic chamber for antenna measurements > 50 GHz

Cryogenic testing will be conducted at the Department of Physics, UP, and at the SARAO engineering facilities in Cape Town.

Kind regards

Tinus Stander
Professor

Johan Schoeman
Senior Lecturer

Heinrich Laue
Senior Lecturer

Carl and Emily Fuchs Institute for Microelectronics
Dept. EEC Engineering
University of Pretoria
Private Bag X20
Hatfield, 0028