Section A: Overview of the Research Project

1. Low-loss, broadband, cooled Dicke switches
2. Engineering
3. Masters
4. A common technique in calibrating radio astronomy receivers is rapidly switching between separate antennas, or between the antenna and a reference load. This switch, called a Dicke switch, needs to feature both high isolation and extremely low loss. With the trend in radio astronomy receivers toward wider bandwidths, suitable wideband, low-loss switches are required; preferably with integrated low-noise gain (though this needs to be extremely stable, else it would negate the purpose of the switch). This project will investigate the state-of-the-art in solid-state, low-noise, full-band waveguide switching, and produce suitable prototype devices.
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Section B: Research Project Proposal

1. Scientific merit:

A commonly used technique to calibrate atmospheric variation from radio astronomy receivers is to switch rapidly between two closely aligned beams (that overlap in the atmosphere), or between the antenna and a reference load. These techniques rely on a front-end switch, called a Dicke switch, that selectively routes the appropriate source to the front-end amplifier. Because the switch is placed before the low-noise amplifier, its insertion loss is a determining factor in the receiver's sensitivity.

A number of these switches (including the ones currently used on the 26m dish at the SARAO station in Hartebeesthoek) use ferrites embedded in waveguide. Although reasonably low loss and quite reliable, the bandwidth of operation of the switch is quite narrow, limiting the bandwidth of the subsequent receiver.

There are, however, several broadband approaches to high-frequency switching available in recent literature, which may be exploited to replace the narrowband ferrite switches. One way of mimicking this switching action is with a balanced LNA with binary phase shift elements at the output, though this approach might not lend itself well to broadband operation either. A more attractive option is a cascade of parallel switched low-noise amplification stages, where the parallel low-noise paths are selectively powered to select the amplification path. This does, however, introduce the risk of unequal gain variation in the parallel stages, negating the purpose of the switch; methods to explicitly equalize the gain have not been developed, nor has macro-electronic implementation or the effect of cooling have.

2. Feasibility:

There have been numerous studies published on solid-state broadband switching, dual-path amplification, and selective path amplifier design in literature; the application of any of these approaches would, therefore, feasibly lead to the development of a working prototype.

The M4 lab at the University of Pretoria has significant experience in macro-electronic and MMIC design. The lab is further equipped with all the necessary laboratory facilities for measurement (including wafer-probed microelectronic measurements), as well as software for circuit and system modelling. Semiconductor prototyping is also in place, with access to various suitable foundries and processes. Cryo-cooling and RF measurement facilities are available both at UP and at HartRAO, about an hour's drive from campus.

Potential objectives for this project would be:

Y1: Literature review. Macro-electronic design and prototyping of diode switch. Prototyping and measurement (both at room temperature and cryo-cooled).

Y2: Switched-path LNA design. Macro-electronic design, prototyping and testing (both at room temperature and cryo-cooled). Produce a concept microelectronic design.

3. The project relates to Priority Area 1. If successful, it will improve the sensitivity and / or bandwidth of an existing receiver at a SARAO site.

4. The preferred candidate would have a firm undergraduate background in high frequency electronics and / or electromagnetics, having completed a related final year B.Eng project. Prior knowledge of microelectronic design would will be beneficial.