New Technologies Driving Decade-Bandwidth Radio Astronomy:

Quad-Ridged Flared Horn & Compound-Semiconductor LNAs

Thesis by

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Abstract

Among the branches of astronomy, radio astronomy is unique in that it spans the largest portion of the electromagnetic spectrum, e.g., from about 10 MHz to 300 GHz. On the other hand, due to scientific priorities as well as technological limitations, radio astronomy receivers have traditionally covered only about an octave bandwidth. This approach of "one specialized receiver for one primary science goal" is, however, not only becoming too expensive for next-generation radio telescopes comprising thousands of small antennas, but also is inadequate to answer some of the scientific questions of today which require simultaneous coverage of very large bandwidths.

This thesis presents significant improvements on the state of the art of two key receiver components in pursuit of decade-bandwidth radio astronomy: 1) reflector feed antennas; 2) low-noise amplifiers on compound-semiconductor technologies.

The first part of this thesis introduces the quadruple-ridged flared horn, a flexible, dual linear-polarization reflector feed antenna that achieves 5:1–7:1 frequency bandwidths while maintaining near-constant beamwidth. The horn is unique in that it is the only wideband feed antenna suitable for radio astronomy that: 1) can be designed to have nominal 10 dB beamwidth between 30 and 150 degrees; 2) requires one single-ended 50 Ω low-noise amplifier per polarization. Design, analysis, and measurements of several quad-ridged horns are presented to demonstrate its feasibility and flexibility.

The second part of the thesis focuses on modeling and measurements of discrete high-electron mobility transistors (HEMTs) and their applications in wideband, extremely low-noise amplifiers. The transistors and microwave monolithic integrated circuit low-noise amplifiers described herein have been fabricated on two state-of-the-art HEMT processes: 1) 35 nm indium phosphide; 2) 70 nm gallium arsenide. DC and microwave performance of transistors from both processes at room and cryogenic temperatures are included, as well as first-reported measurements of detailed noise characterization of the sub-micron HEMTs at both temperatures. Design and measurements of two low-noise amplifiers covering 1–20 and 8–50 GHz fabricated on both processes are also provided, which show that the 1–20 GHz amplifier improves the state of the art in cryogenic noise and bandwidth, while the 8–50 GHz amplifier achieves noise performance only slightly worse than the best published results but does so with nearly a decade bandwidth.

Contents

List of Figures

List of Tables