Development of Silicon-Germanium Circuits for High-Frequency Small Satellite-Based Integrated Radiometers

Christopher T. Coen*, A. Çağrı Ulusoy, Robert L. Schmid, and John D. Cressler
School of Electrical and Computer Engineering
Georgia Institute of Technology, 85 5th Street NW, Atlanta, GA 30308 USA
Email: chris.coen@gatech.edu

Invited Paper

Small satellites are increasingly attractive platforms for performing high-quality Earth science radiometric observations. Traditional scientific satellites and instruments are extremely expensive, one-of-a-kind designs with long design cycles. In order to maintain long-term uninterrupted science data collection, re-designing new large satellites and instruments for each application every few decades may not be practical. Small satellites, however, are relatively economical and can be deployed in large constellations to collect global data with high spatial and temporal resolution. These satellites can potentially be manufactured to scale and periodically replaced, enabling practical long-term data collection. Radiometers for these platforms need to be highly integrated and suitable for scale production, assembly, and testing. This necessitates a unique instrument design.

A potential instrument for these platforms is an integrated radiometer utilizing silicon-germanium (SiGe) heterojunction bipolar transistor (HBT) BiCMOS technology. Multiple emerging 4th generation SiGe technologies offer HBTs with f_T/f_{MAX} above 250/300 GHz, enabling high-frequency receivers with noise figures comparable to the best InP and GaAs receivers. SiGe technologies offer all-purpose SiGe HBTs along with digital CMOS to enable system-on-chip integration. Fabricated SiGe wafers are high-yielding with low performance variation, and fabrication costs significantly drop with scaled production. Furthermore, SiGe HBTs offer numerous advantages specifically beneficial for radiometers and small satellites—they have the lowest 1/f noise of all high-frequency semiconductor technologies, are tolerant as-fabricated to multi-Mrad doses of total-dose radiation, and are well-suited for low-power thermal control and monitoring.

This presentation will demonstrate the potential of SiGe technologies for high-frequency radiometers by showcasing the measured performance of numerous low-noise SiGe circuits developed at Georgia Tech. A Ku-band common-emitter LNA with a mean NF of 1.14 dB, more than 8.3 dB of gain, and only 5 mW of power consumption from a 1V supply will be presented. In addition, a cascode LNA with 13.6 dB of gain and an NF of less than 1.5 dB at 18.7 GHz will be presented. To our knowledge, these are the lowest achieved room-temperature noise figures in SiGe at these frequencies, and these values are competitive with the best reported GaAs and InP results. We will also present the measured performance of a W-band Dicke radiometer which does not require a lossy Dicke switch. Finally, the measured results for a G-band SiGe LNA with simulated gain of more than 22 dB and simulated NF of less than 8 dB at 183 GHz will be shown.

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