A Single-Chip 4-Bit SiGe BiCMOS T/R Module for X-Band Phased-Array Radar Systems

Tushar K. Thrivikraman, Curtis M. Grens, Joel M. Andrews, Wei-Min Lance Kuo, Jonathan P. Comeau, Matt Morton, John D. Cressler, John Papapolymerou, and Mark Mitchell [1]

School of Electrical and Computer Engineering
Georgia Institute of Technology, 85 5th Street NW, Atlanta, GA 30308 USA
[1] Georgia Tech Research Institute, Atlanta, GA 30332 USA
email: tthrivi@ece.gatech.edu

We present a single-chip, 4-bit, T/R module for X-band phased-array radar applications using a commercially-available 130 nm silicon-germanium (SiGe) BiCMOS technology platform. This SiGe T/R module provides a 4-bit phase shifter with a *rms* phase error < 4 degrees across band. The receiver achieves a gain of over 15 dB, a noise figure less than 4 dB, and an input-referred, third-order intercept point (IIP3) of -10 dBm, while only dissipating 34 mW of power. The transmitter achieves 18 dB gain, 28% PAE, and dissipates 505 mW of power. The entire SiGe T/R module occupies a total of only 13.3 mm^2. With this demonstrated level of integration and circuit performance, SiGe BiCMOS technology is shown to be an excellent candidate for integrated X-band phased-array radar transmit/receive modules and offers significant benefits for both existing and emerging radar applications.

Silicon-Germanium (SiGe) heterojunction bipolar transistors (HBTs) offer high speed, low noise and low power dissipation, while maintaining compatibility with standard Si processing and best-of-breed CMOS, enabling high yield, low cost, and high levels of integration. Because of these advantages, SiGe HBT BiCMOS technologies can offer competitive monolithic solutions for these demanding applications. Several recent studies investigated highly integrated transmit/receive (T/R) modules for phased-array radar systems. These radar systems can incorporate thousands of T/R modules, making size and cost of the individual modules a crucial consideration. For this reason, an affordable, highly integrated solution is desirable, making a SiGe HBT BiCMOS technology an appealing platform to implement a single-chip T/R module.

Our work highlights the potential of SiGe HBT BiCMOS technology for low power density scalable phased arrays for next-generation X-band radar applications. Based on the reported performance, the presented T/R module may be suitable to replace the pre-amplifier and phase shifting components in conventional T/R modules for a reduction in chip count, cost, and power consumption, particularly with the addition of on-chip integrated digital logic and control circuits. In addition, this SiGe T/R module should be applicable to space-based and near-space radar applications, which require very low power consumption and radiation tolerance.

Our presentation will focus on the design and integration of these high-performance SiGe T/R modules for use in X-band phased array radar systems. We will highlight specific block and component level design, integration, optimization, and the final results. In addition, we will highlight design challenges and their mitigation as well as discuss trade-offs involved in the design process.

Acknowledgement

This work was sponsored by the US Army Space and Missile Defense Command under contract DASG0-99-C-0006. The authors are grateful for the support of Tracy Wallace and Mike Harris. We are also grateful to the members of the SiGe Devices and Circuits Group, the Microwave Circuit and Technology Group, and the Georgia Electronic Design Center at Georgia Tech.