An X-band Active Antenna System-in-Package Module
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INTRODUCTION
System-in-Package (SiP) is based on the concept of combining all the electronic requirements of a system into a single package. Along with providing cost and size benefits, SiP with an integrated antenna can help mitigate the feed network losses and phase errors in an antenna array based application. This work presents the development of a low cost, compact RF front end SiP solution for X-band. A printed antenna is integrated with a transmit/receive system in a multilayer ball grid array (BGA) package using low cost laminate substrates. This active antenna module can be further integrated into arrays and used for wireless as well as sensing applications.

RESEARCH OBJECTIVES
- Development of low cost multi beam radar.
- Mixed signal approach (digital baseband processing integrated with the SiP RF front end) will be used for creating digital beamforming radars.

DESIGN OVERVIEW
- A microstrip fed patch antenna integrated with RF front end in a multilayer package (X-band).
- The low cost, multilayer BGA packaging scheme uses currently available laminate substrates.
- Vias provide connection between the layers and help move package resonance up in the spectrum.
- Solder balls used for mounting the module on the motherboard.
- Commercially available GaAs ICs used for transmit/receive (T/R) ICs.

SYSTEM FEATURES
- Highly compact (15X15X1.5 mm³) and low cost (final cost target ~ couple of dollars per module)
- Limited bandwidth of patch antenna relaxes the requirements for image rejection filter.
- Good isolation between transmit and receive sections of the package.
- Mitigates feed network losses in an array environment.

SYSTEM PERFORMANCE
- Passive Patch
  - Resonance frequency: 10.2 GHz
  - Bandwidth: 3%
  - Measured Gain: 6.4 dB, Efficiency: 81.3%
- Active Module (Transmit Mode)
  - Measured Gain: 17.3 dB (expected gain: 17.3 dB)
- Active Module (Receive Mode)
  - Downconversion with IF = 300 MHz
  - Measured gain: 24 dB (expected gain: 25 dB)
  - Upper sideband image rejection (no filter): 12 dB

Gain Measurements for X-band module

Fabricated 1X4 T/R array module

Radiation Patterns for T/R active module