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S-Band Radar Transmitter and Receiver LTCC MCM Subassemblies

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Introduction
S-Band Transmitter / Receiver

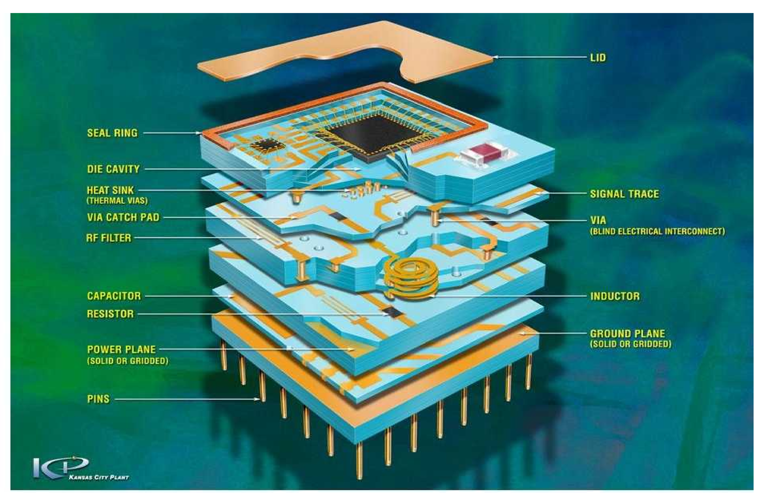
Technical Issues

- Reliability
- Cost
- New thermal challenges
  - -50 W peak power amplifier RFIC, dissipates 50 W
- Assembly
- RF isolation

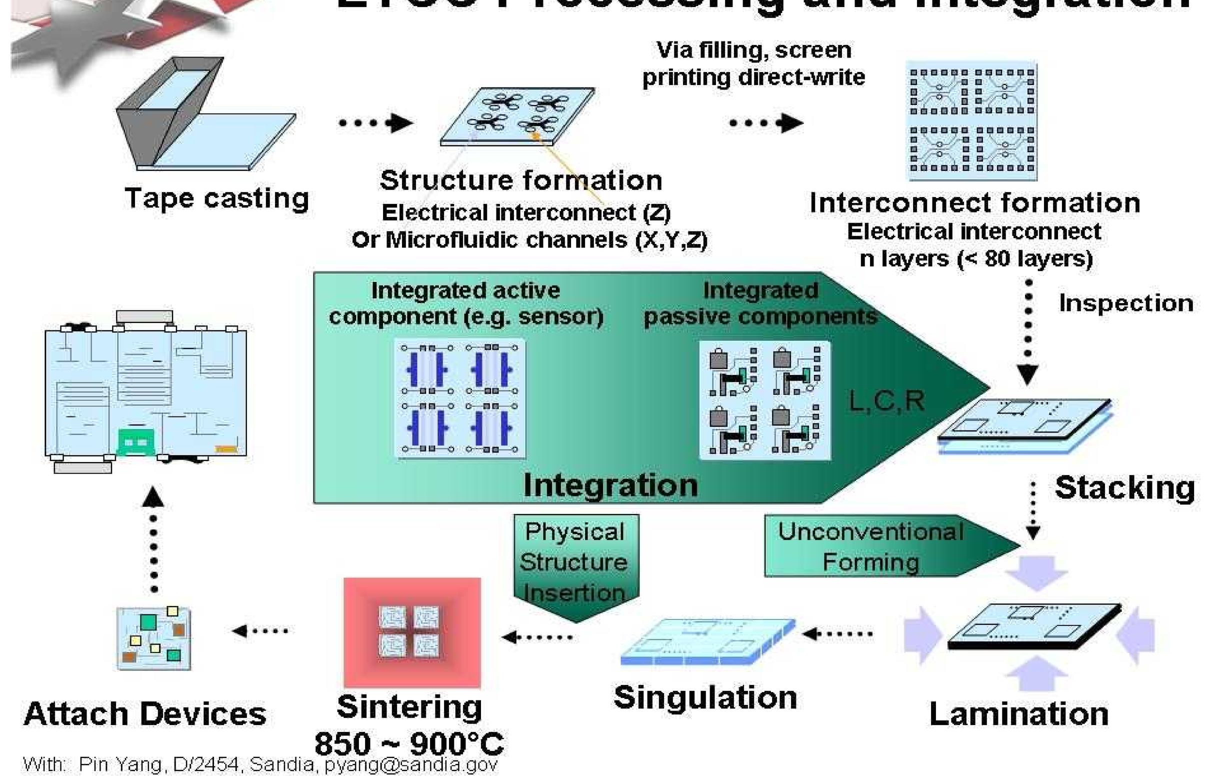
Technical Approach

- Stable technology
  - -Fewer parts / interconnections
- Direct integration
  - -LTCC/MCM RF circuit is a completed package
  - -Eliminate parts-- don't have to purchase, track, assemble
- High K heat spreader, heat sink, attachment materials
- Processing thermal hierarchy
  - -Au/Sn - Sn/Pb - polymer attach- reworkablility
- 150 dB cavity 1 to 4
  - -Via fences/ground planes & Full Tape Thickness Conductors (FTTC)

LTCC with Embedded Passives

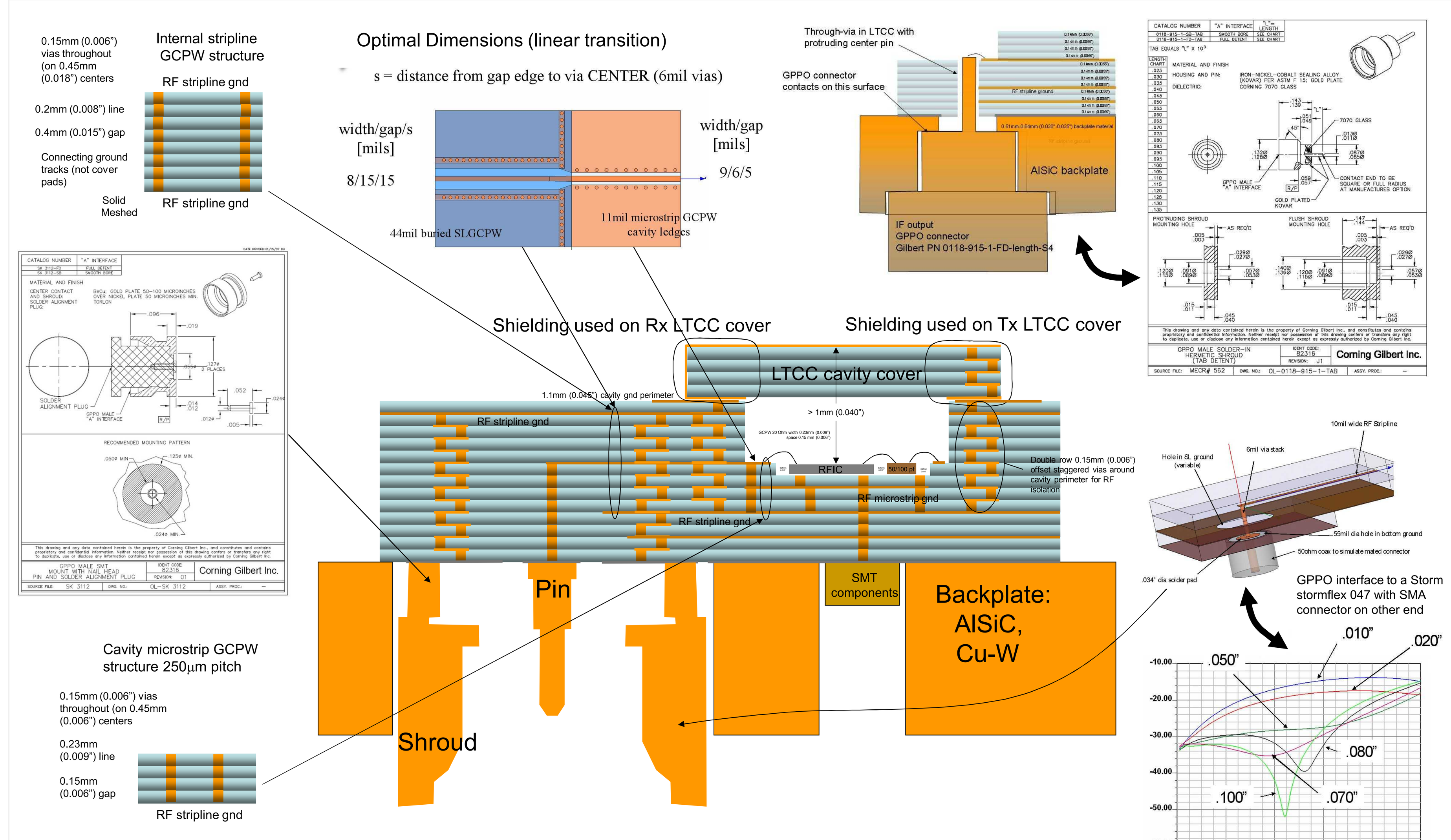


LTCC Processing and Integration



Additional Technical Details

- 'Post-up' of vias, goal: 5μm, demonstrated: 10-20μm
- Shrinkage, characterized, controlled (50 μm over 12.5 cm)
- Deep cavity definition, floor camber characterized and controlled to < 25μm
- Backplate to LTCC attachment, vacuum Sn/Pb soldering, 90-95 % void free (based on X-Ray using AlSiC)
  - Tx had AlSiC backplates
  - Rx has AlSiC & CuW backplates
- Wirebonding, monometallic Au wedge, low loop
- Die attach includes high thermal conductivity polymers



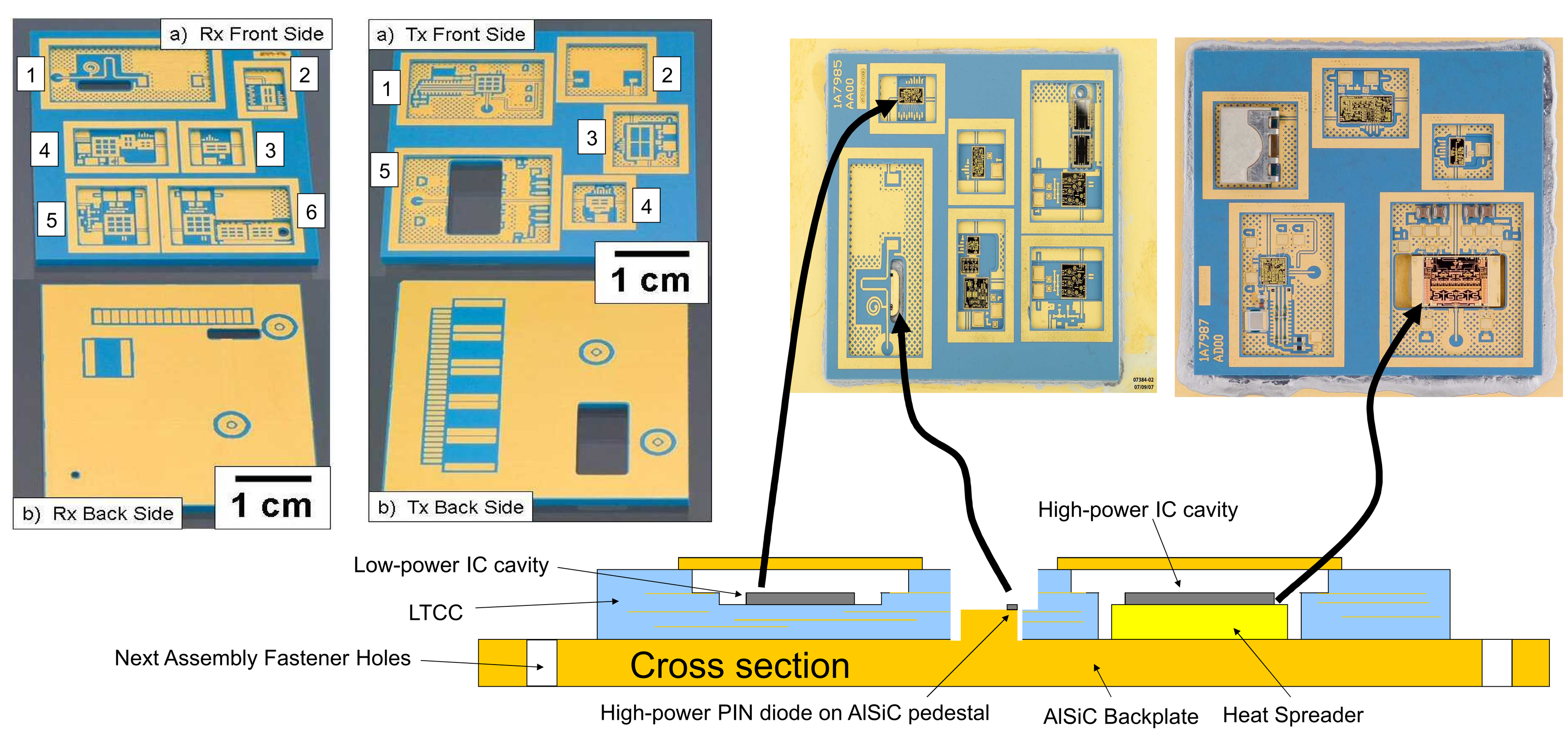
Conceptual LTCC Cross Section

Construction Details

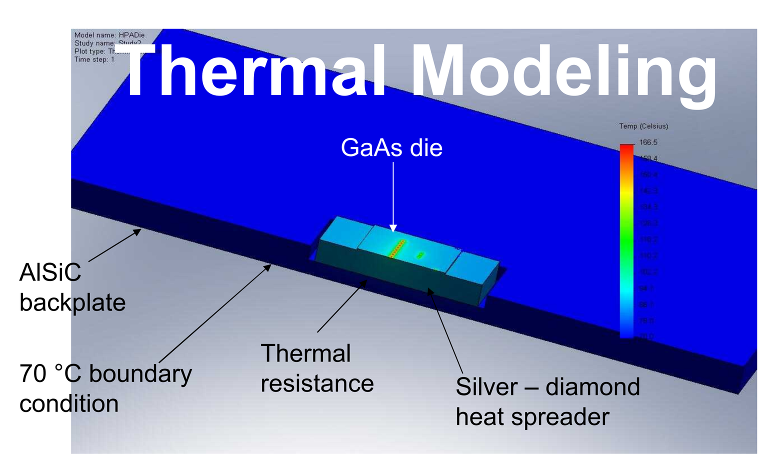
- 13 layers of 140μm (0.055") fired DuPont 951
- Au-based DuPont thick film inks
- RF connectors – GPPO, surface mount & hermetic
- Embedded vertical coaxial feed
- Embedded stripline from cavity to cavity
  - 4 tape layers between signal-ground
- Microstrip in-cavity launch
- AlSiC back plate/heat sink (integrated pedestal)
- RFIC power amp soldered to heat spreader
- Faraday cavity & covers
- Thin film outer layer capability demonstrated

Receiver and Transmitter Layout

Cavity	Receiver (Rx)	Transmitter (Tx)
1	Limiter & bandpass filter	LO, IF oscillator, and mixer
2	Switched attenuators	Bandpass filter
3	LNA & switch	Phase & pulse modulator
4	Switch & image reject mixer	Pulse modulator and driver amp
5	IF amplifier	Power amplifier
6	IF amp & matched radar filter	



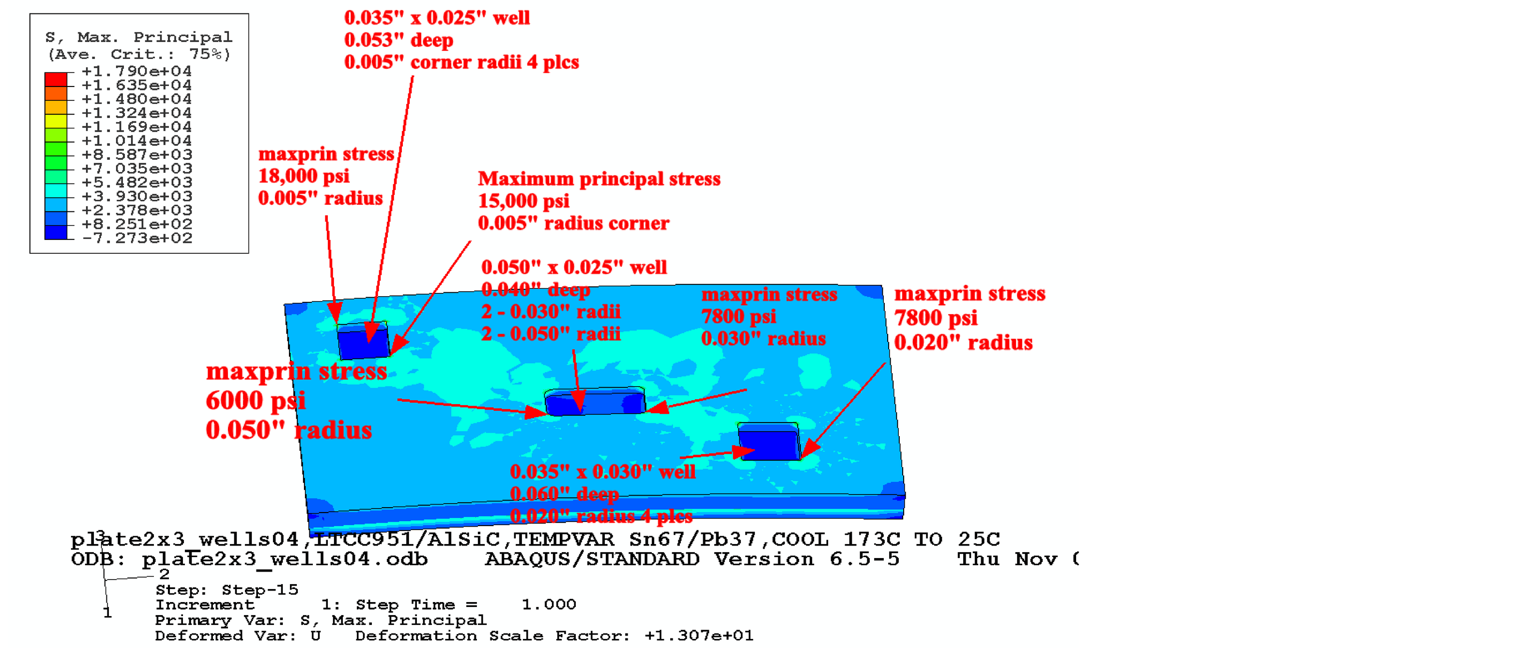
Thermal Modeling



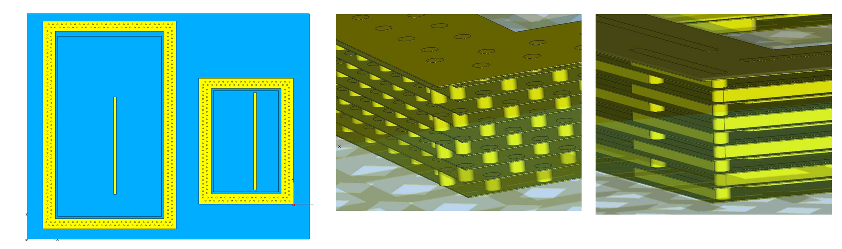
Thermal Spreader Properties

Heat Spreader 2 mm thick 15 mm wide 6.5 mm across	Thermal Conductivity W/mK @ 23°C	Maximum Junction Temperature @ 70°C maximum backplate temperature
Cu-Diamond	550	153 °C
Cu-W 15-85	210	174 °C
AlSiC-9	180	178 °C

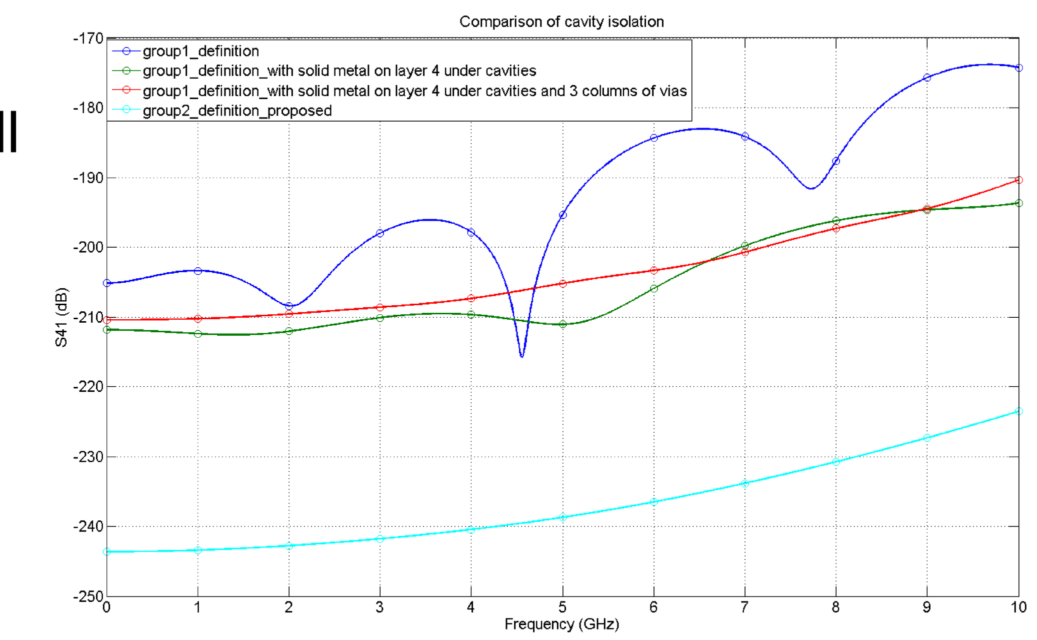
Mechanical Stress in LTCC as a result of cooling from 179 to 25 °C



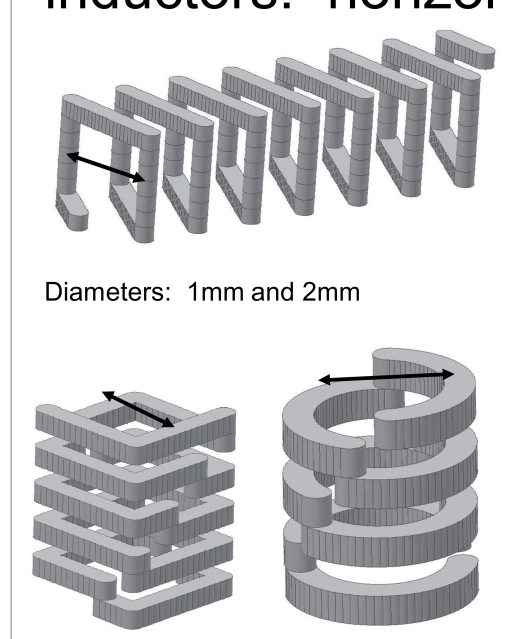
3D-EM faraday cavity isolation, traditional via fence & novel Full Tape Thickness Conductor (FTTC) staggered fence



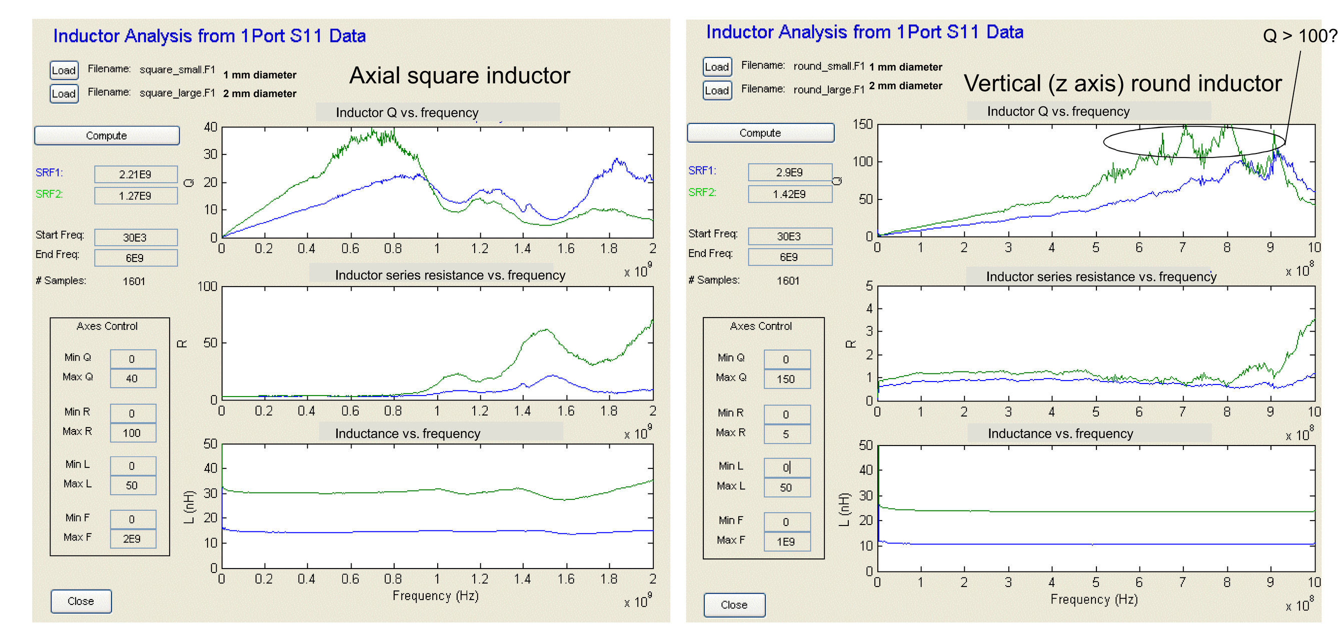
3D-EM simulator antenna radiator & receiver



Full Tape Thickness Conductor (FTTC) high Q inductors: horizontal & vertical implementations



Diameters: 1mm and 2mm



Measurements performed by Prof. Bill Kuhn at Kansas State

Summary

- Developed custom HBT & pHEMT GaAs RFICs using TriQuint Oregon foundry
- Used all-commercial tapes, inks, and standard industry practices
  - Sequential lamination used for cavity integrity
  - Via planarization
- Rx & Tx MCMs functional
  - Demonstrated Rx MCM functionality in radar
    - 120 dB on/off receiver isolation (goal > 150 dB)
    - Tested to 100 cycles -55 to +125° C (going to 1000 cycles)
  - Demonstrated Tx MCM 50 W peak power @ 33% duty factor
    - Developed processes for high K heat spreaders, sinks, adhesives, and solders
- Demonstrated Faraday cavity and lid construction
- Demonstrated FTTC structures
  - Low resistance lines
  - High Q inductors
  - Faraday isolation structures
- Demonstrated Ti/Ni/Au in Rx and Ti/Pt/Au on test structures
- Future work will improve soldering practices on connectors, Au-Sn die attach for large die, embedded resistors, via post-up, via coverage by thin films, embedded capacitors, and high Q FTTC inductors

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