



Micro-Faraday Cage within Low-Temperature Co-fired Ceramic Board: Fabrication and Measurement

IMAPS CICMT Conference & Exhibition

Roberto Quezada

Dr. Emmanuel Decrossas

Dr. Latarence Butts

Dr. Samir El-Ghazaly

Dr. Alan Mantooth



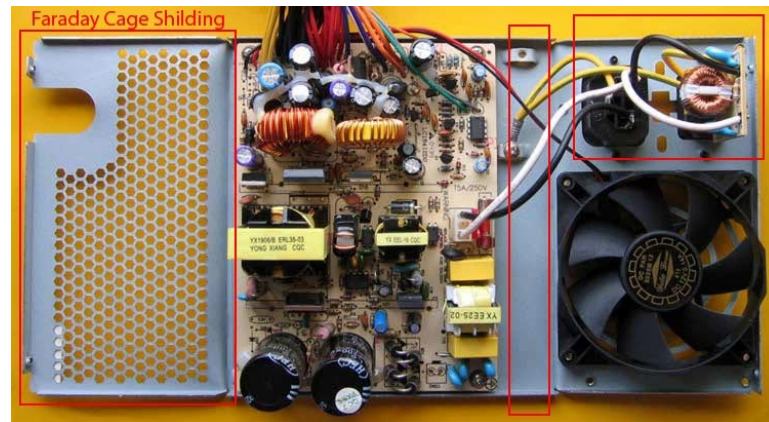


Overview

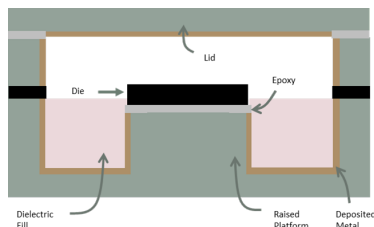
- Background and Motivation
- Project Goals and Design Considerations
- Project Life Cycle and Results
- Lessons Learned
- Future Work

Background and Motivation

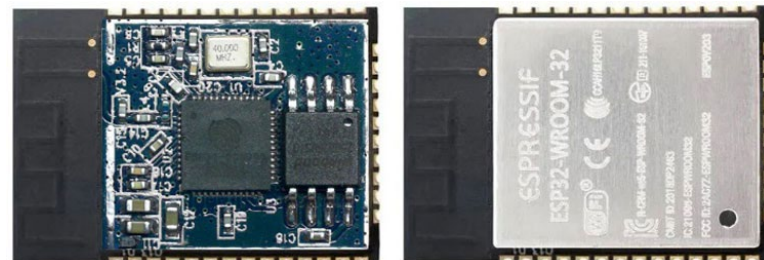
- Part of a collaborative radar consortium developing a switched-mode power supply (SMPS)
- SMPS components can emit EMI due to high-frequency switching
- Sensitive RF components require shielding to maintain signal integrity
- Goal: Embed micro-sized Faraday cage (MFC) for shielding directly within the LTCC structure
 - Evaluate shielding effectiveness through:
 - Structural design, Electromagnetic simulation, RF measurement



SMPS with EMI Shielding



Concept Model



WiFi and Bluetooth enabled module
with(L)/without(R) EMI shielding for reducing
interferences



Design Parameters

- DuPont 951
 - $\epsilon_r \approx 7.5$, $\tan \delta \approx 0.0060$
 - Excellent RF performance
- Via spacing ($d < \lambda/10$) for shielding
 - @25GHz: $\lambda_{951} = 4.38\text{mm} = 172.44\text{ mil}$
 - Distance between Via's is $5\text{ mil} < \lambda/10$ (17.2 mil)
 - Fabrication Limitations: Diameter of Via /2
 - Via Diameter = 10 mil
- Ground continuity
 - Ensure vertical vias connect top and bottom ground planes to enclose EM fields

DuPont 951 Datasheet



Technical Data Sheet

Product Description

DuPont™ GreenTape™ 951 is a low-temperature fired ceramic tape. Green Tape™ 951 system comprises a complete cofirable family of gold and silver metallizations, buried passives, and encapsulants. GreenTape™ 951 is available in multiple thicknesses and is designed for use as an insulating layer in:

- Multichip modules
- Single chip packages
- Ceramic printed wiring boards
- RF modules

The GreenTape™ 951C2, GreenTape™ 951PT, GreenTape™ 951P2 and GreenTape™ 951PX products are provided on a base film with improved punching characteristics.

Product Benefits

When used with compatible metallizations, GreenTape™ 951 offer the following benefits:

- Component integration – buried resistors, capacitors, and inductors
- Hermetic packaging
- Low temperature brazing
- Cavities
- High density interconnections
- Cofire processing and reflow stability

Processing Design

For detailed recommendations on use of GreenTape™ 951, see the GreenTape™ Design and Layout Guidelines (GreenTape™ 951 section). For compatible metallizations and their recommended use see the GreenTape™ 951 Product Selector Guide.

System Capability

The GreenTape™ 951 system is designed to deliver line and space resolution of 100 μm , via diameters of 100 μm , and maximum layer counts in excess of 100.

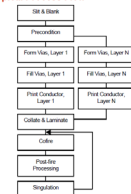
Printing

Following blanking and preconditioning of GreenTape™ 951 green sheets, print compatible compositions directly onto unfired GreenTape™ 951 using thick film printing methods and a vacuum stone or other support structure that uniformly distributes vacuum. Follow specific printing and drying recommendations described on individual composition product data sheets.

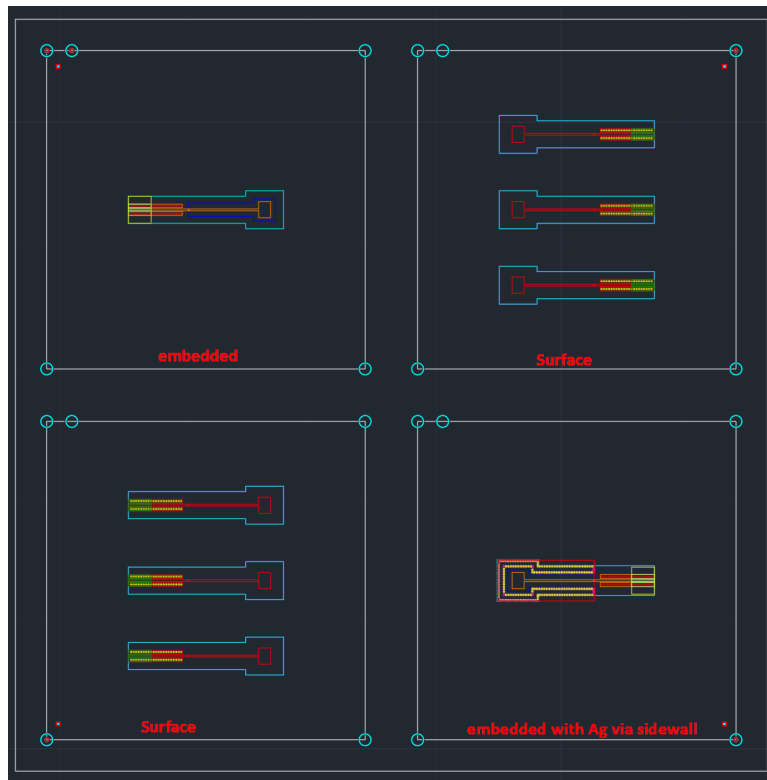
Inspection

Inspect via, conductor and other prints prior to collation and lamination.

Typical Process Flow

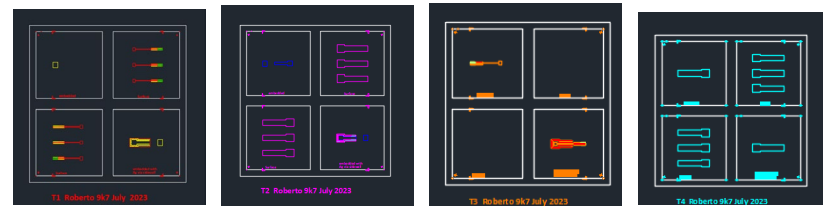


Micro-Faraday Cage (MFC) Board and Design

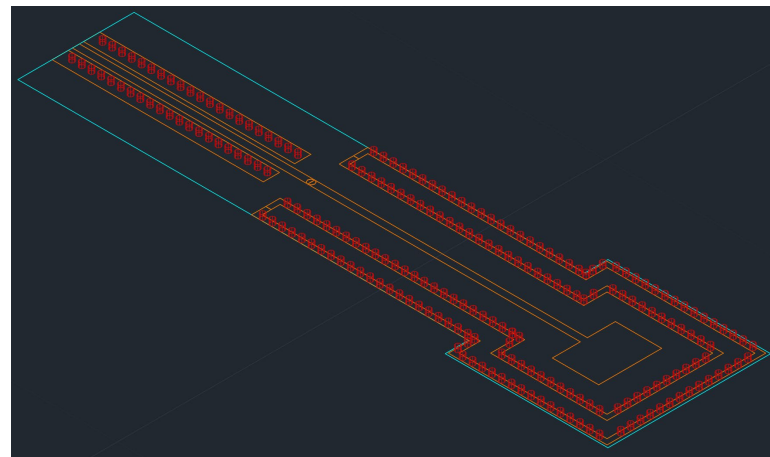


MFC Test Coupon – 4 Panel Layout

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Layer-by-layer View



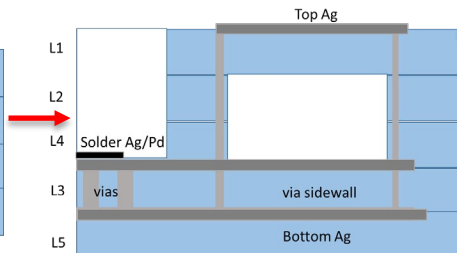
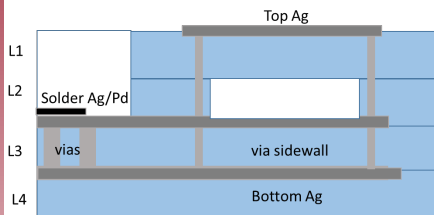
MFC 3D Close-Up – Embedded with Ag via Sidewall



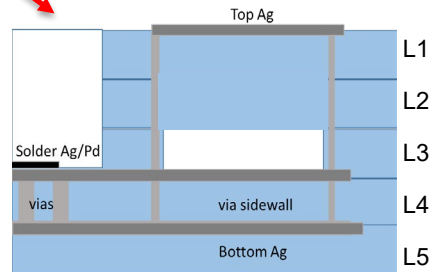
Design Life Cycle

Initial proof of concept began with 4 Layers. Bowing was noticeably present

The overall tape count was increased to 5 Layers to double the cavity height from 10 mils to 20 mils to reduce warping; however, bowing was still slightly present.

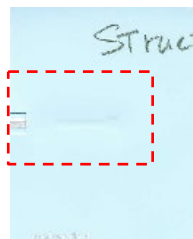


Board 2: No Cavity Cross Section

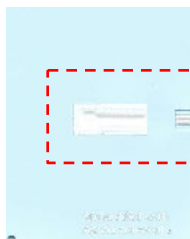


Board 1: Cavity Present
Cross Section

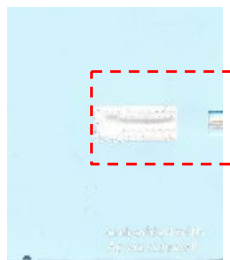
2 Versions were made. A 4-layer with no cavity and a 5-layer with a smaller cavity but more support Tape.



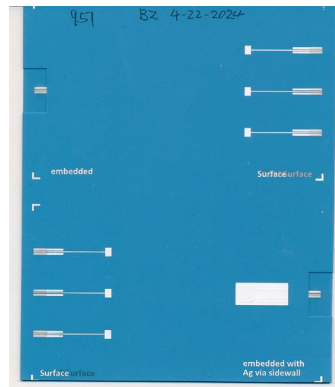
Port 2 (No Metallization)



Port 4 (Metallization)



5L - Port 4 (Metallization)



Board 2

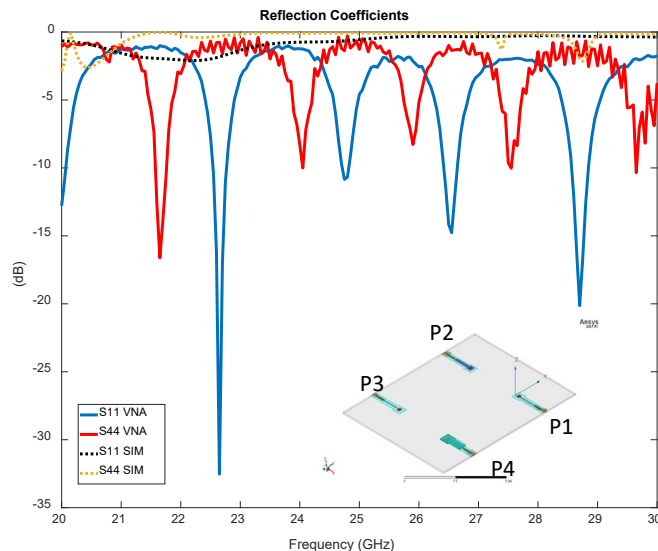


Board 1

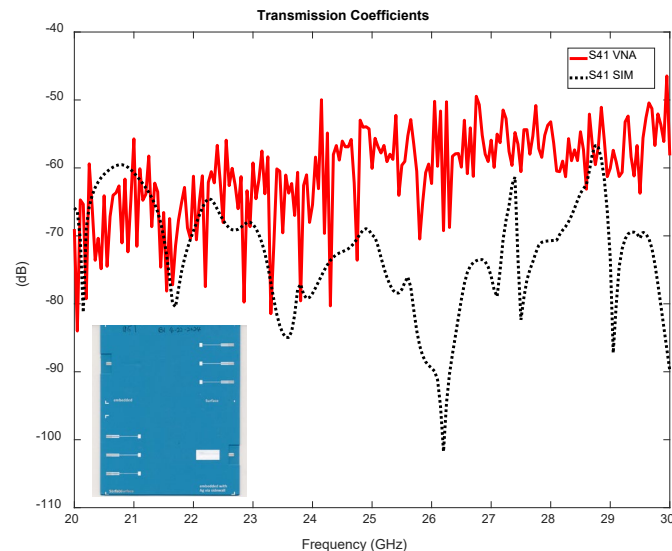


Board 1: Simulated vs Measured Results

- Board 1: Cavity Present (5 Layers)
- Reflection Coefficient (S11, S44)
- Transmission Coefficients (S41)



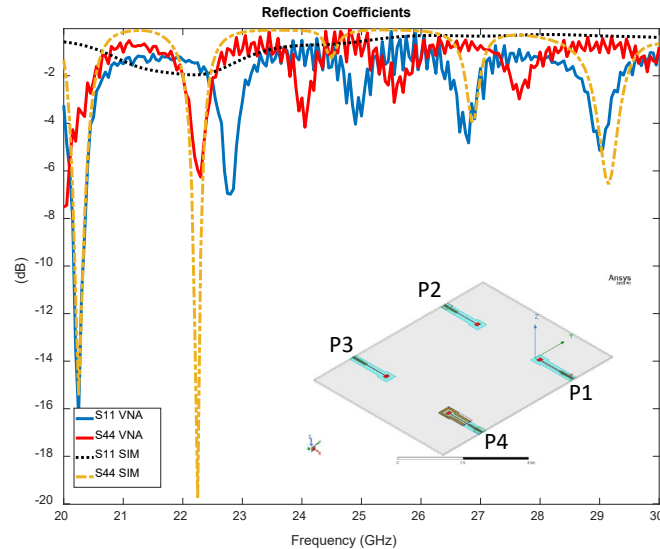
Board 1 – Reflection Coefficient Simulation vs VNA Measurement



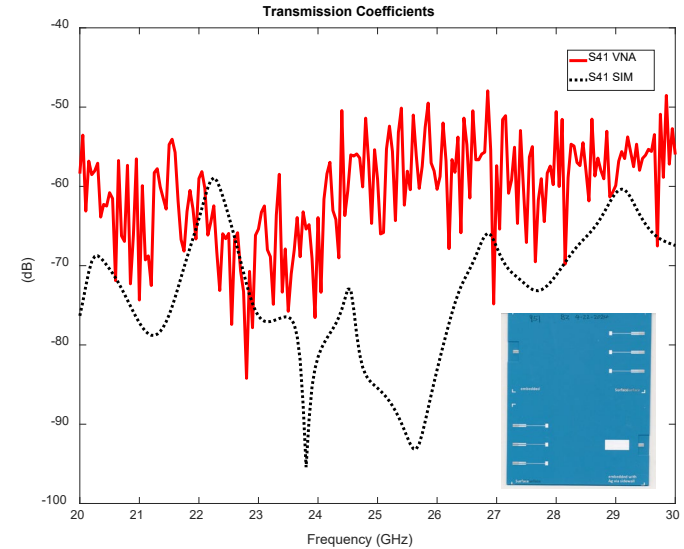
Board 1 – Transmission Coefficient Simulation vs VNA Measurement

Board 2: Simulated vs Measured Results

- Board 2: No Cavity (4 Layers)
- Reflection Coefficient (S11, S44)
- Transmission Coefficients (S41)



Board 2 – Reflection Coefficient Simulation vs VNA Measurement

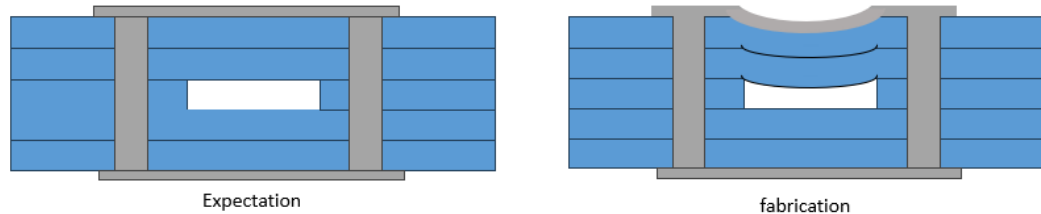


Board 2 – Transmission Coefficient Simulation vs VNA Measurement



LTCC Micro-Faraday Cage Assessment

- 5-layer board shows significant warping.
 - Approx. 8 mils bowing leaving a 2-mil gap between the Lower and Upper Layers
- Conclusion from the fabrication:
 - need to add extra layers for support.

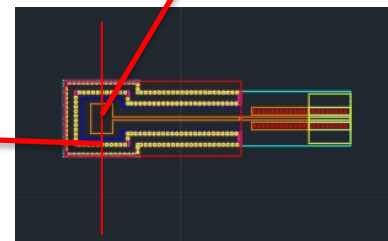
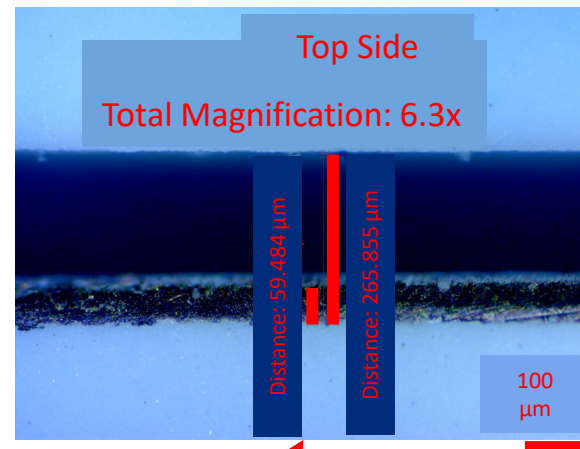
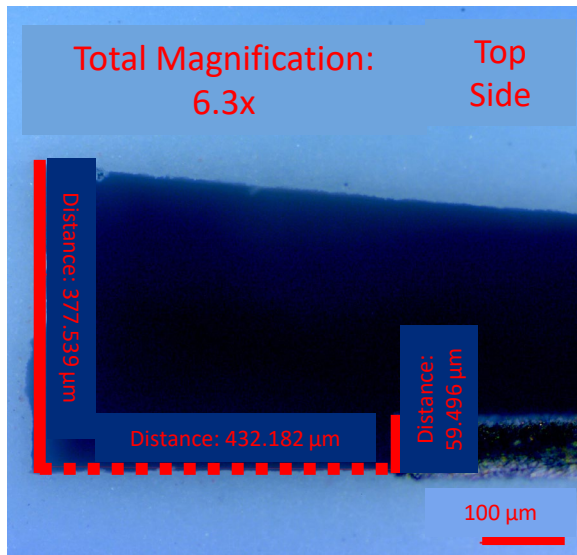


5-Layer Board Cross Section Simple Model
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LTCC Micro-Faraday Cage (8 Layers)

- (L) Left side of the cavity
- (R) Middle of the cavity

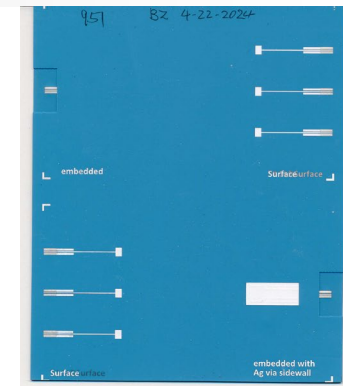


Cross Section Cut



Early Prototypes – Lessons Learned

- 4-Layer Structure
 - Single cavity cutout
 - The top layer collapsed during sintering
 - Insufficient support for cavity width
- 5-Layer Structure
 - 2 metallization support layers + 1 cavity cutout
 - 8 mil depression from the top layer
 - 2 mil air gap in cavity
 - Enhanced support, though overall rigidity remains limited
- 8-Layer Test Stack
 - 3 metallization support layers + 2 cavity cutouts
 - 4 mil cage depression
 - 6 mil air gap
 - Better cavity formation, but lid collapse still observed in wide configurations
- Key Finding
 - The Wide cavities consistently resulted in lid collapse during fabrication
 - More support layers are needed to distribute mechanical stress



Board 2

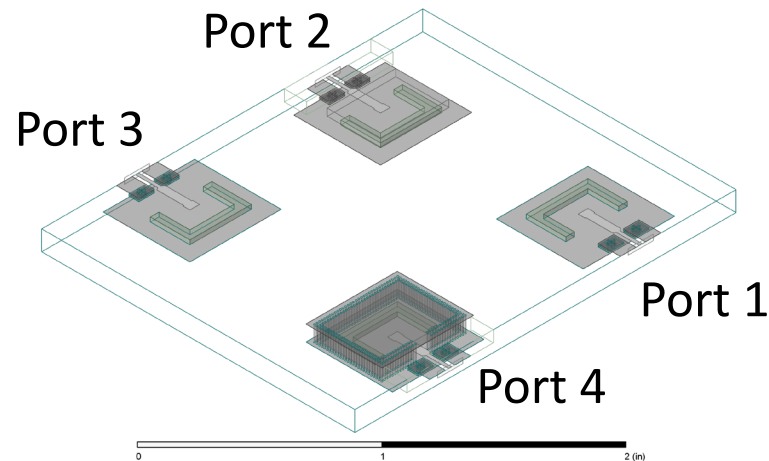


Board 1

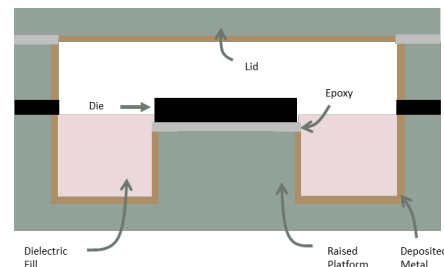


Future Work

- Dimensions: ~2.5 in x ~2.5 in
 - (2500 mils VS 5500 mils)
- 4 Patch Sensors (25 GHz)
 - 2 Surface
 - 2 Embedded (1 shielded/ 1 unshielded)
- 14 Layers Total vs 5-Layer:
 - Above Sensor
 - 3 Support Layers for Metallization
 - 5 Cavity cutouts Layers
- Double Via Wall (12 Layers)
 - 5 mil Spacing
- Ground Plane expanded for support on top and bottom ground plane
- Different connector type is used to ensure the same placement each time



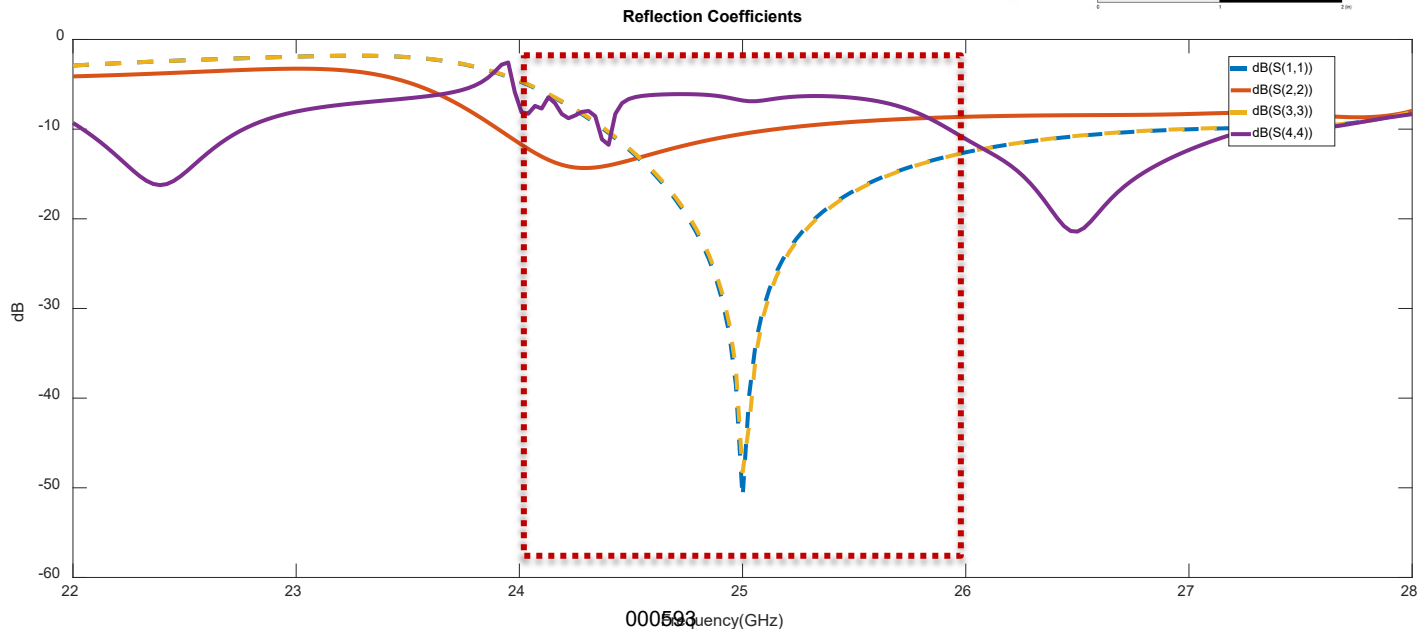
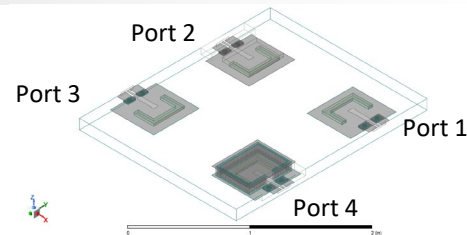
HFSS Simulation Model



Concept Model Cross Section

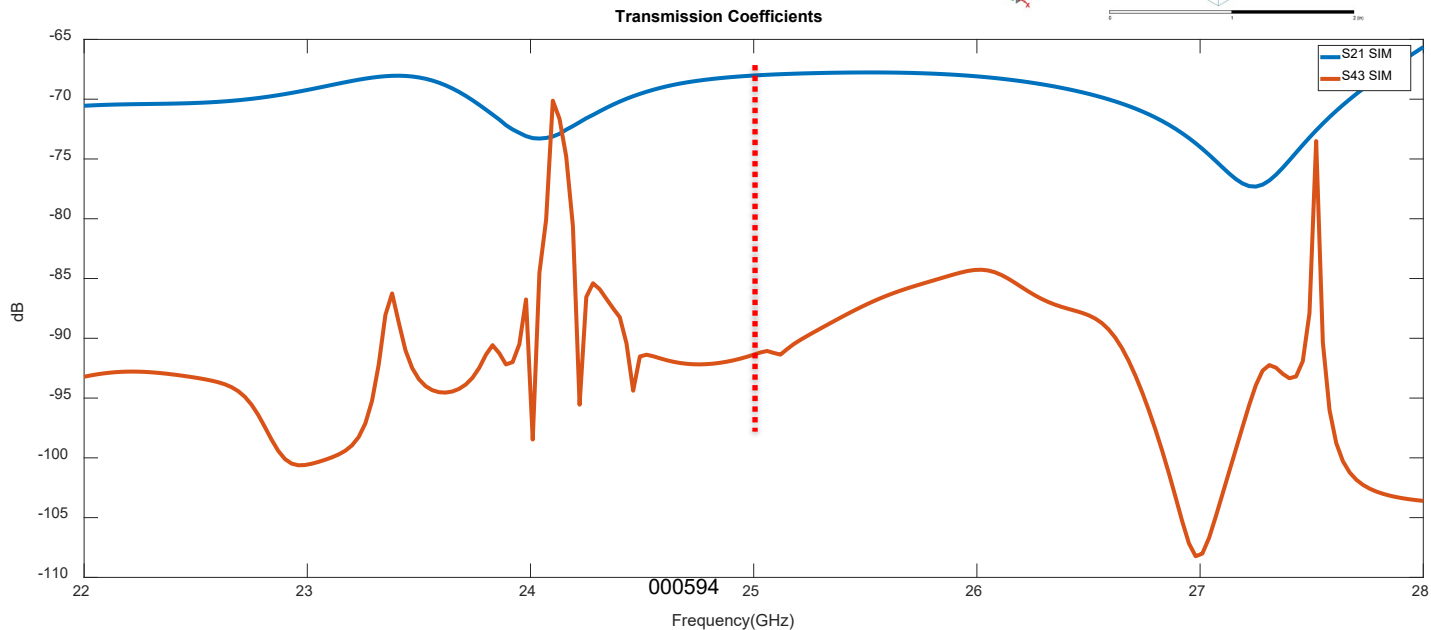
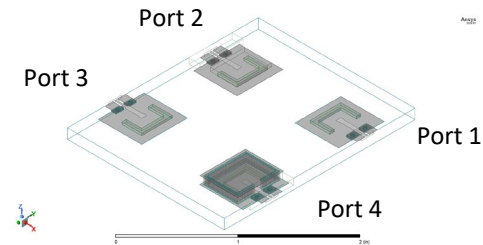
Simulation Results - Reflection Coefficients

- Port 1: S11 Blue Surface Sensor
- Port 2: S22 Orange Embedded (No Shield)
- Port 3: S33 Yellow Surface Sensor
- Port 4: S44 Purple Embedded (Shielded)



Simulation Results - Transmission Coefficients

- S21 Blue
 - Port 2 Embedded (No Shield)
- S43 Orange
 - Port 4 Embedded (Shielded)



Summary of Findings

- Micro-Faraday cages can be successfully embedded in LTCC structures.
 - Early iterations confirmed proof of concept
- Final Version simulations predict effective isolation
 - Expected greater than $\sim 20\text{dB}$ (Pending measurements)
- Fabrication is in work, waiting on screens to arrive



Thank you

Questions?

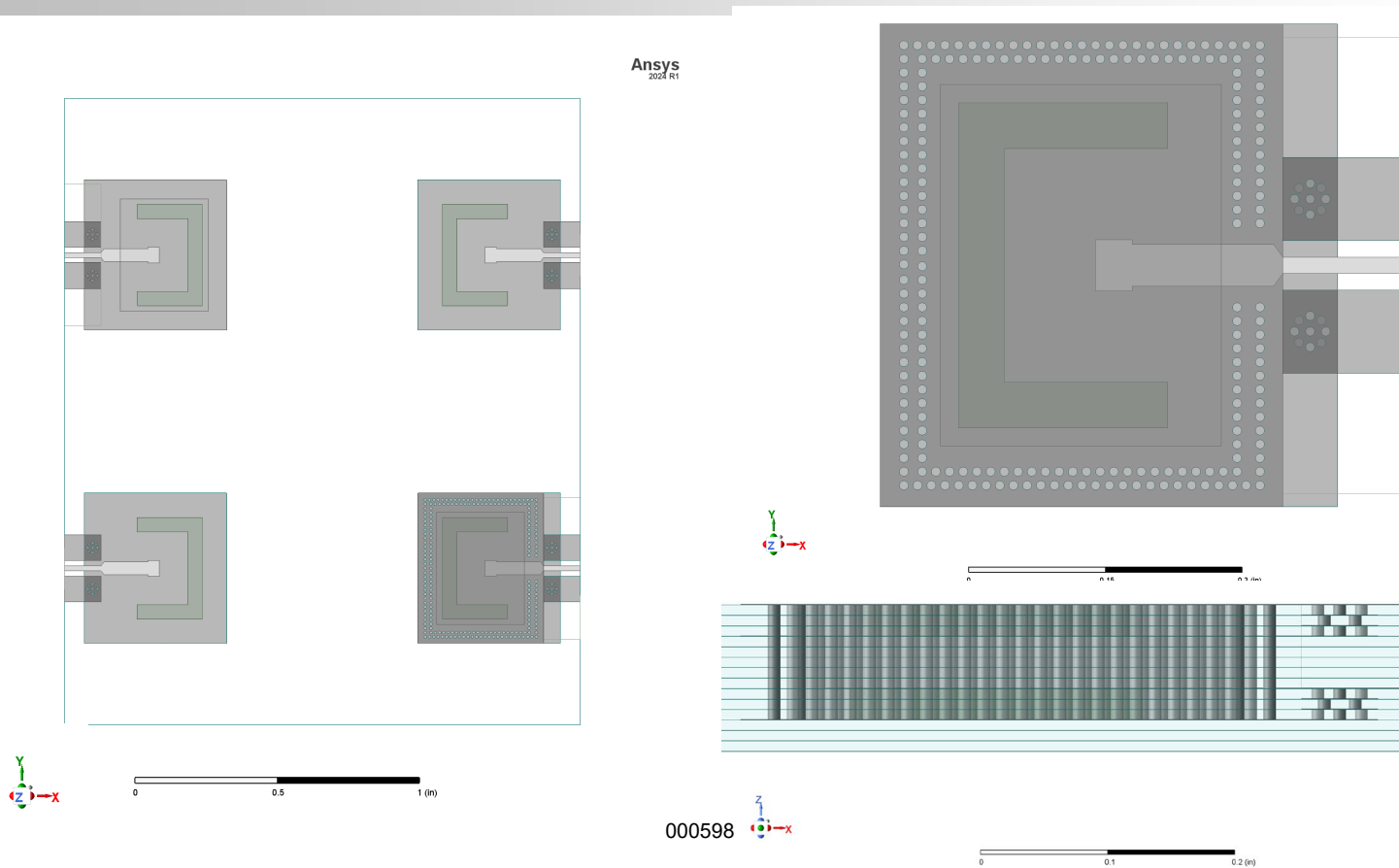


Extra Slides



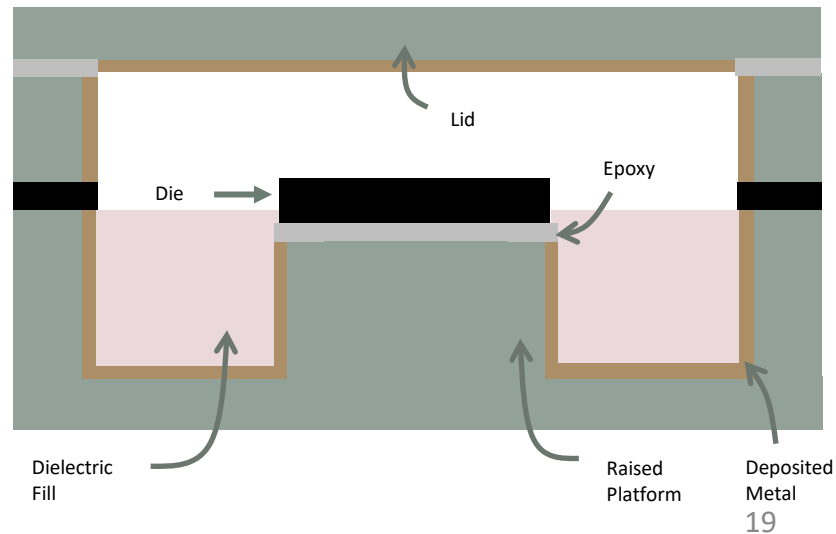
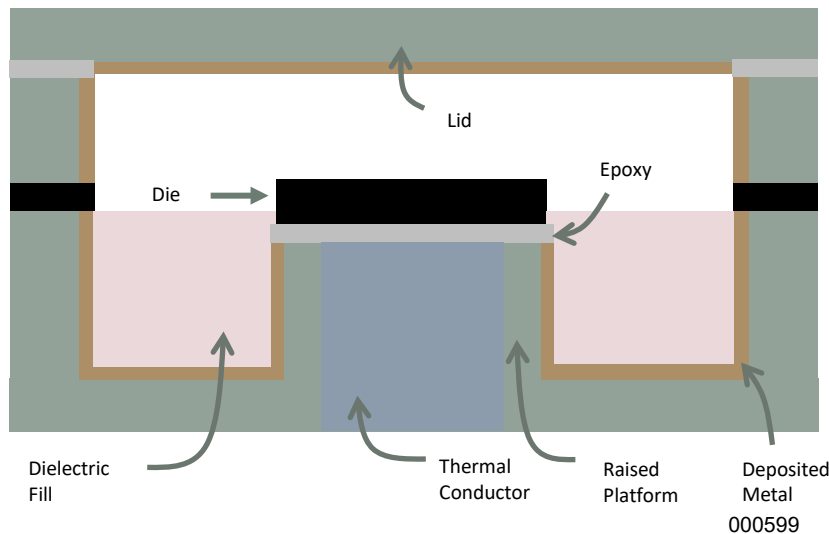
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Final Version



Concept Model

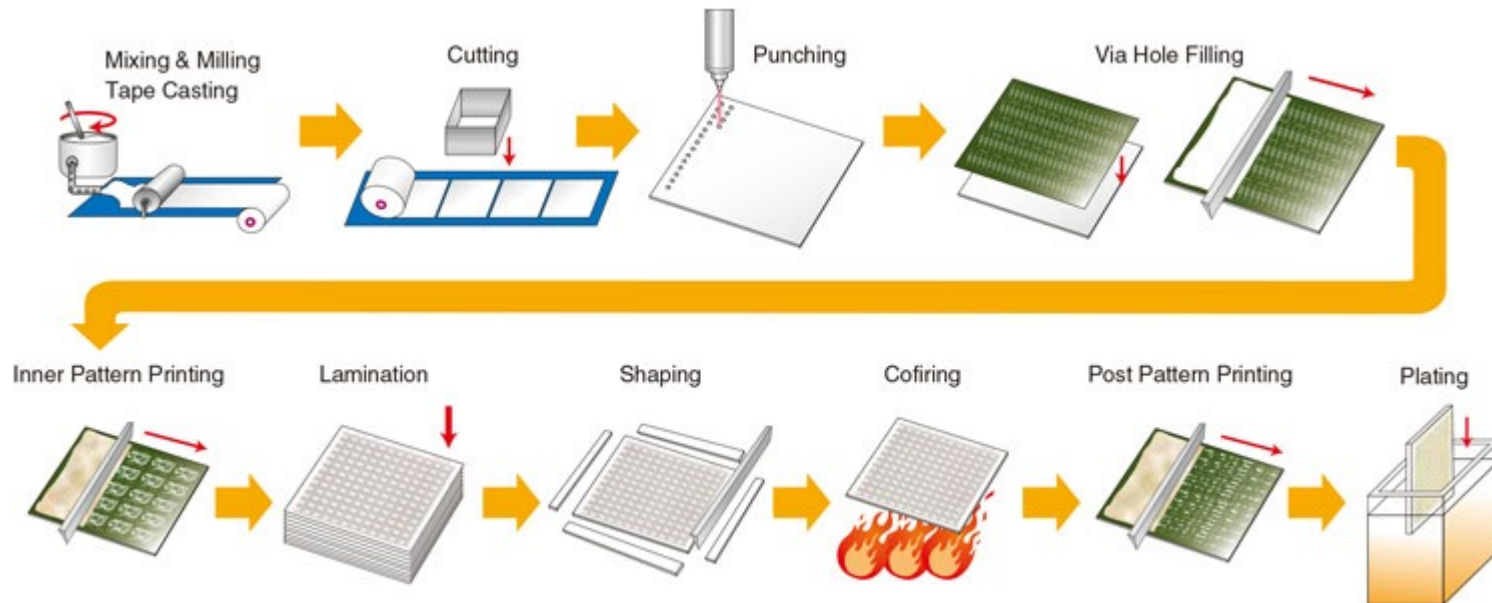
- (L) With Heatsink
- (R) Without Heatsink





Fabrication Process

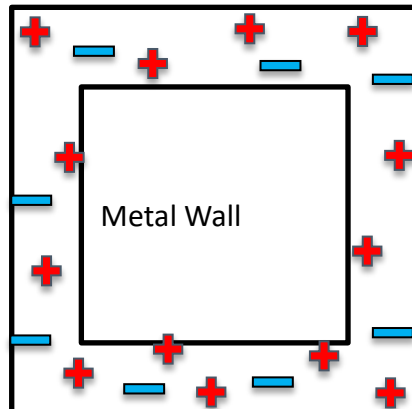
- Steps:
 - Green tape punching (cavity, vias)
 - Silver paste fill
 - Screen-printed traces
 - Lamination and sintering at 850°C
- LTCC 951 stack built in-house



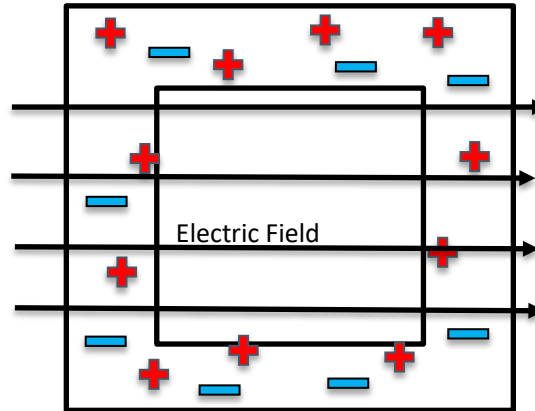


What is a Faraday Cage?

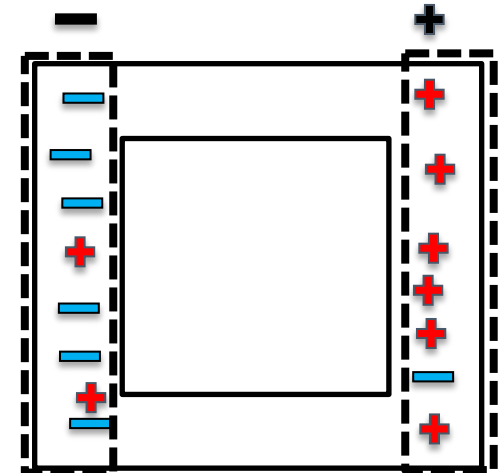
- A Faraday cage is a conductive enclosure embedded within a substrate
- Shields critical circuits from EMI
- Our Faraday Cage = micro-sized conductive enclosure with Via sidewalls and top/bottom ground (Silver Composite Materials)
 - Built directly into LTCC layer stack



Faraday Cage in the absence of an electric Field



The Charged Particles in the wall of the Faraday Cage respond to an applied electrical field



Electrical Fields generated inside the wall cancel out the applied field, neutralizing the interior of the cage.