10-TP1
Using Full Wave Solvers for Practical Analysis of Capacitor Mounting Structures

Scott McMorrow, Teraspeed Consulting Group LLC
Steve Weir, Teraspeed Consulting Group LLC
Fabrizio Zanella, CST of America

CST

TERASPEED
CONSULTING
GROUP

Outline

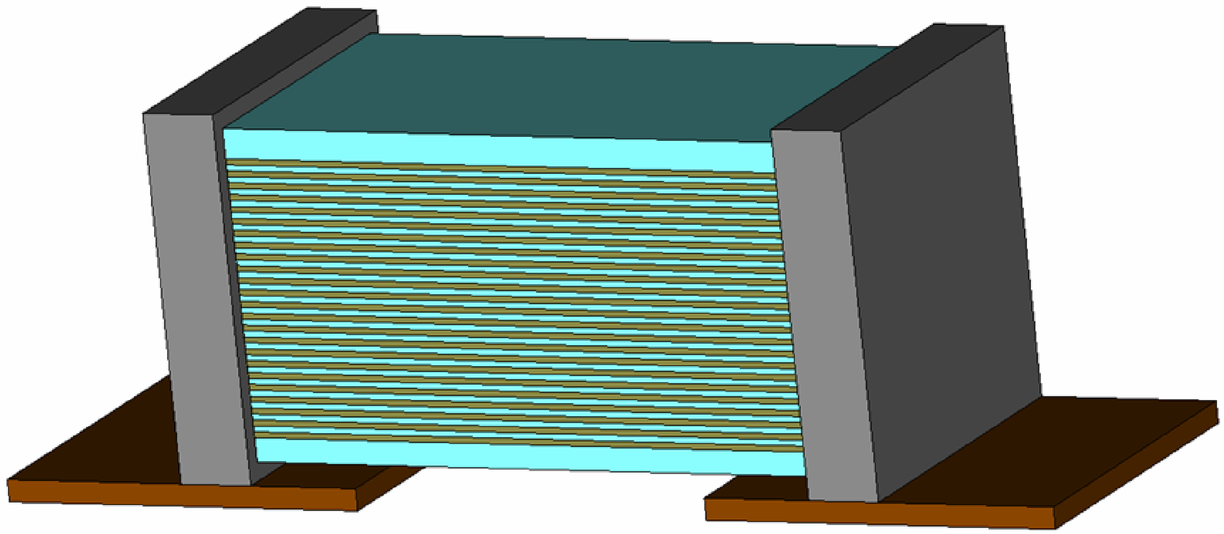
- MLCC Basics
- MLCC Full Wave Modeling
- Measurements of Capacitor Test Fixture
- Correlation between Modeling and Measurements
- Conclusion

TERASPEED CONSULTING GROUP

MLCC Capacitor Advantages

- Larger capacitance values
- Lower ESR, ESL, and Z than conventional capacitor designs
- Cost effective designs

MLCC Capacitor Design



MLCC capacitor with fully populated plates

CST

TERASPEED
CONSULTING
GROUP

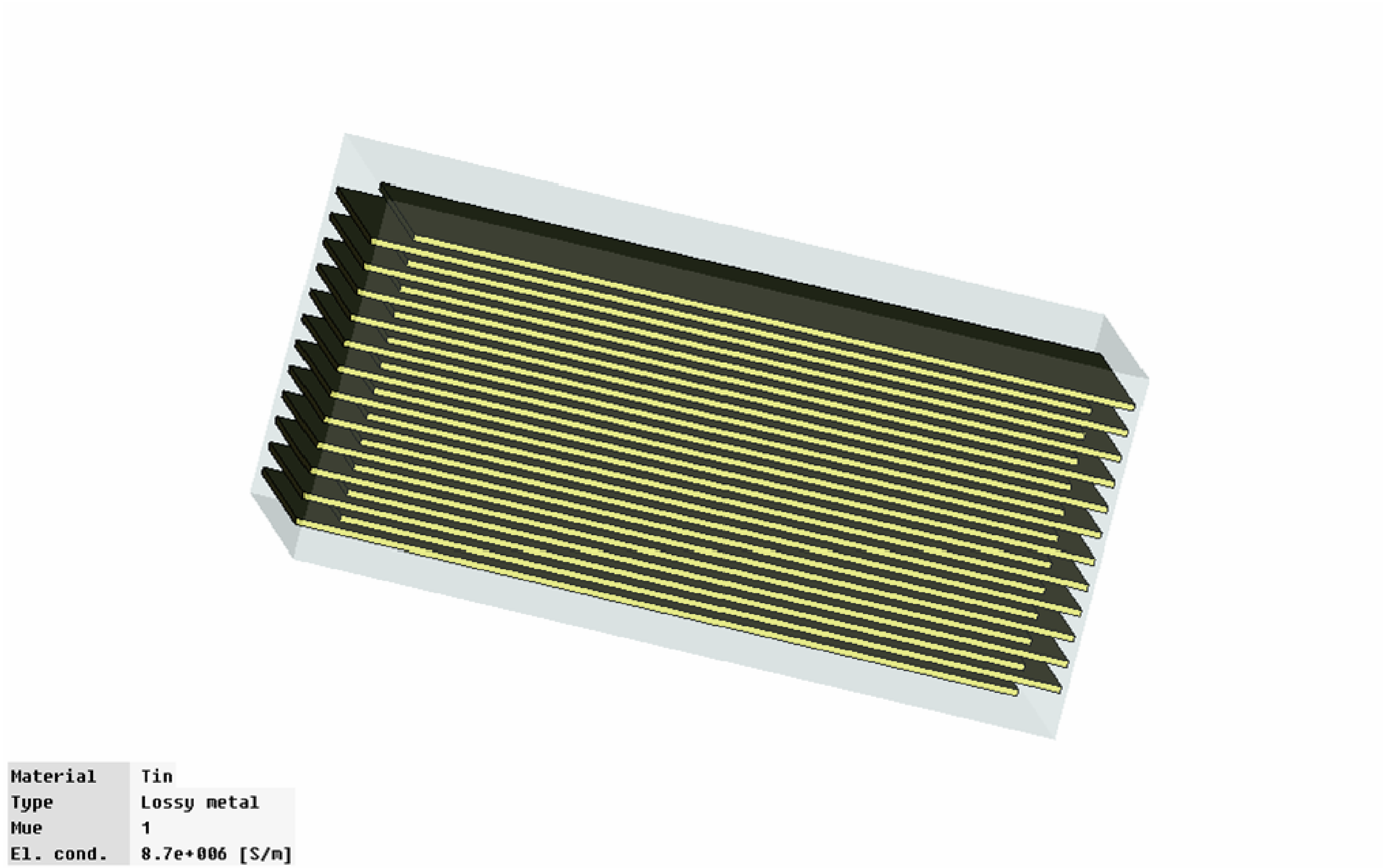
MLCC Capacitor Basics

MLCC capacitor: 2 sets of inter-leaved electrodes

$$C = \frac{(K)\,(n)\,(A)}{(d)}$$

C = capacitance value
K = dielectric constant
n = number of layers (n + 1 electrodes)
A = area of electrode overlap (figure 2)
d = dielectric thickness (between layers)

MLCC Capacitor Design

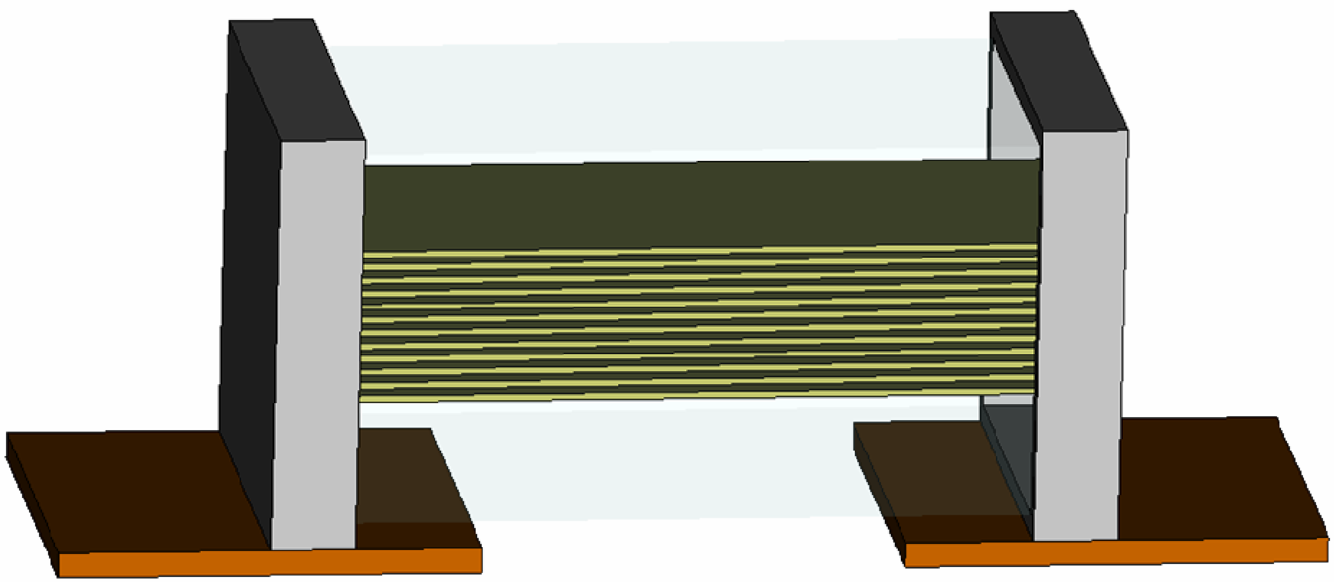


MLCC electrodes, showing plate overlap

CST

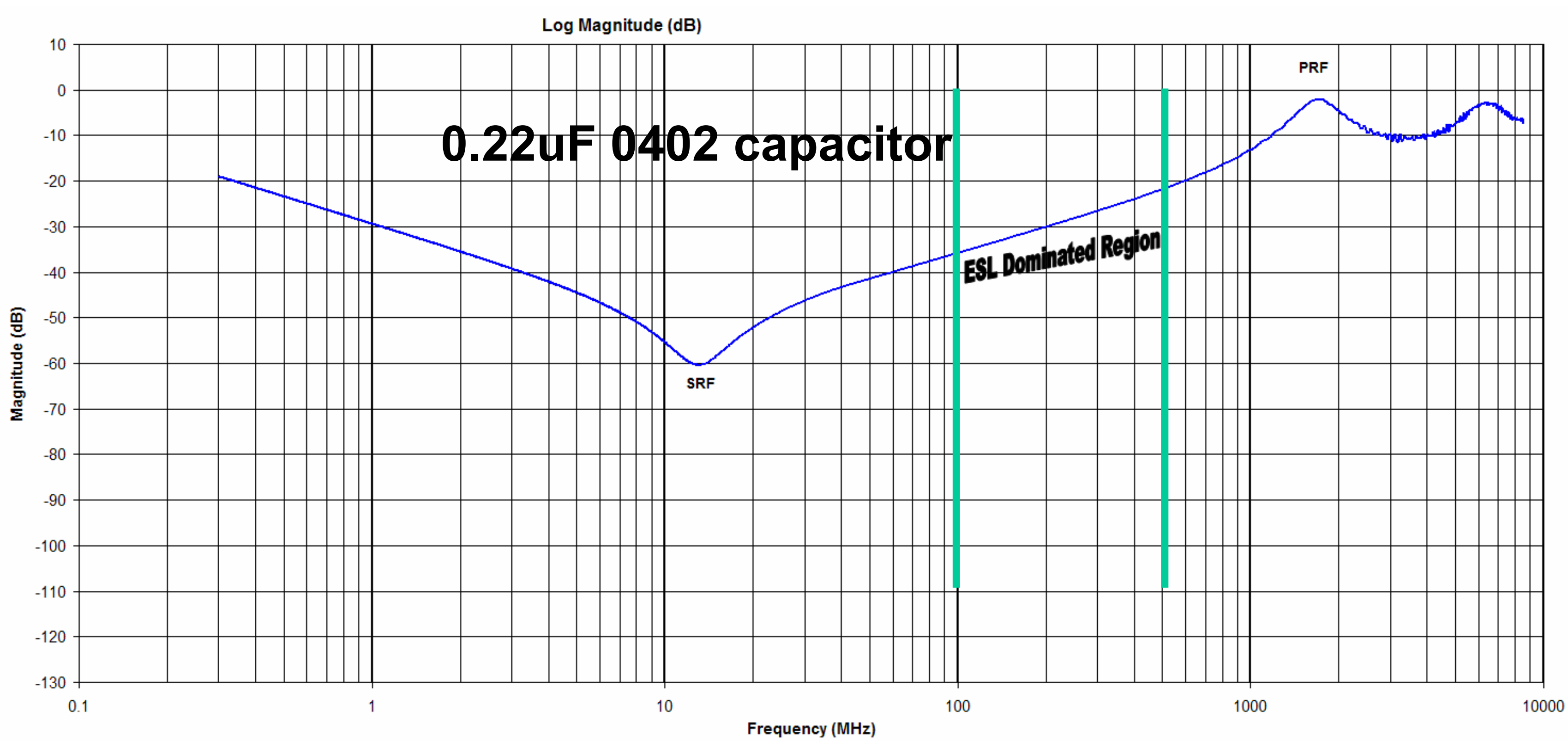
TERASPEED CONSULTING GROUP

MLCC Capacitor Design



Only part of capacitor body used, larger capacitance value possible by increasing number of plates

Capacitor Transfer Impedance Measurement



$$Z_{ESL} = j\omega ESL$$

$$Z_{ESL} = 2\pi f \times ESL$$

$$ESL = Z_{ESL} / 2\pi f$$

$$ESL = (25 * S21(mag) / (1 - S21(mag)))/2\pi f$$

CST

TERASPEED CONSULTING GROUP

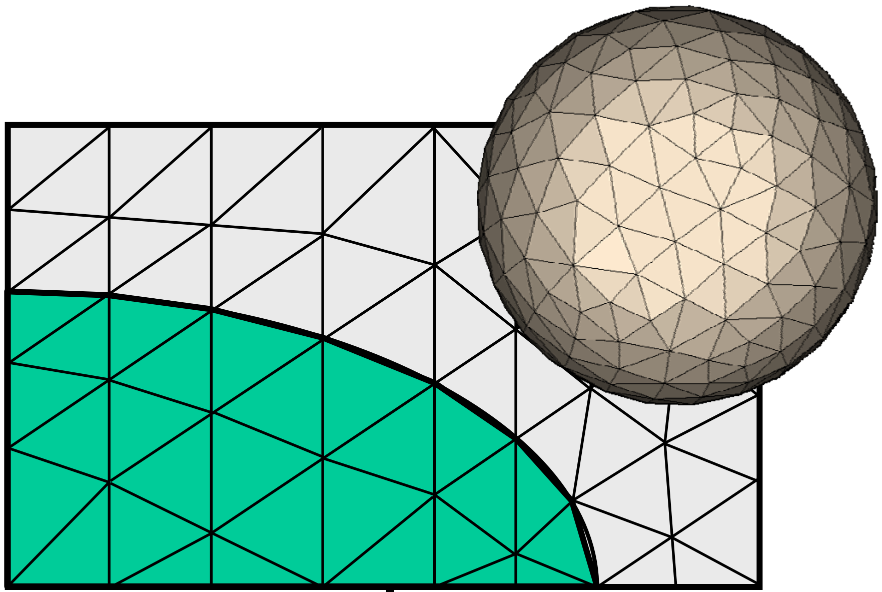
Capacitor Inductance Measurement

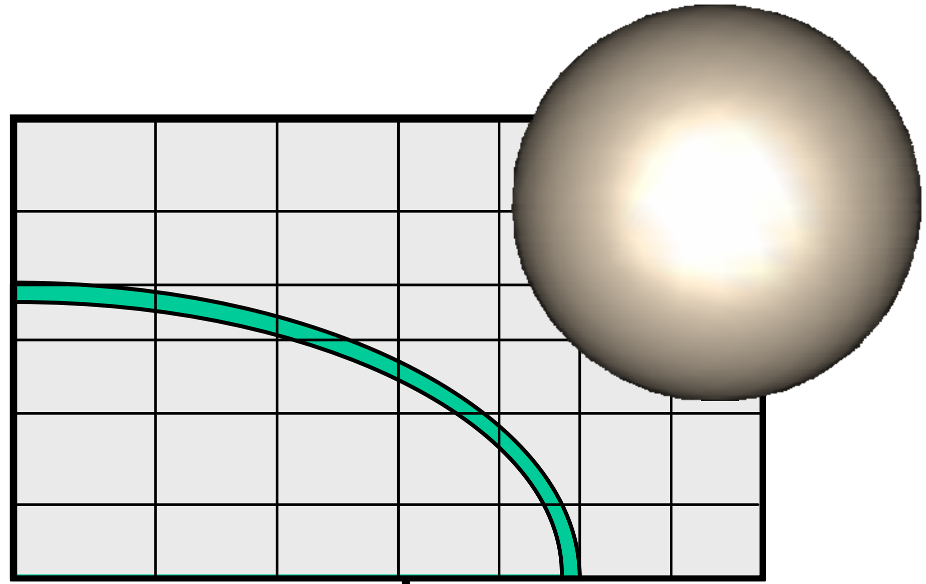
MLCC capacitor: 2 sets of inter-leaved electrodes

$$C = \frac{(K)(n)(A)}{(d)}$$

C = capacitance value
K = dielectric constant
n = number of layers (n + 1 electrodes)
A = area of electrode overlap (figure 2)
d = dielectric thickness (between layers)

3D Full Wave Modeling





TET-Mesh in Freq. Domain

- ☺ Push Button Solution
- ☺ Electrically small structures
- ☺ Arbitrary material dispersion

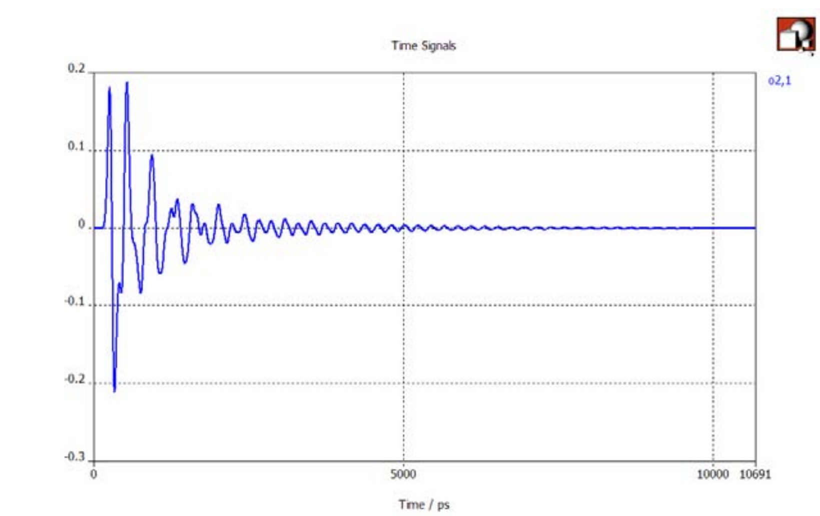
PBA-Mesh in Time Domain

- ☺ Electrically large structures
- ☺ Low memory
- ☺ Broadband Solution

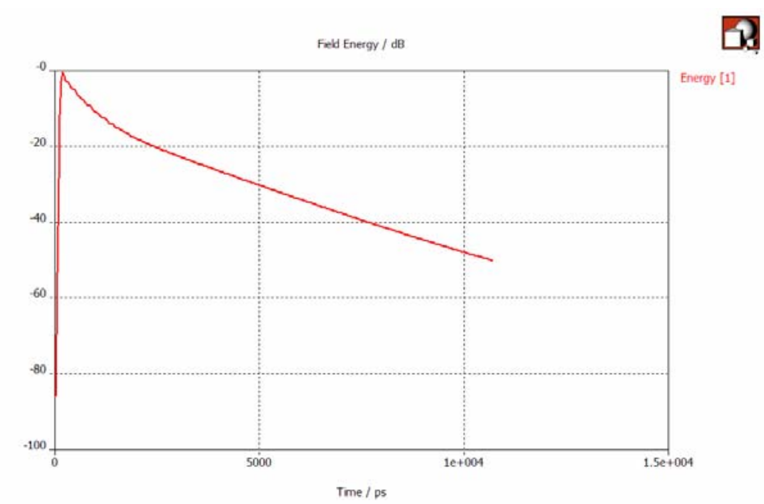
CST

TERASPEED CONSULTING GROUP

Transient Solver



Transient Response Port 1 to Port 2



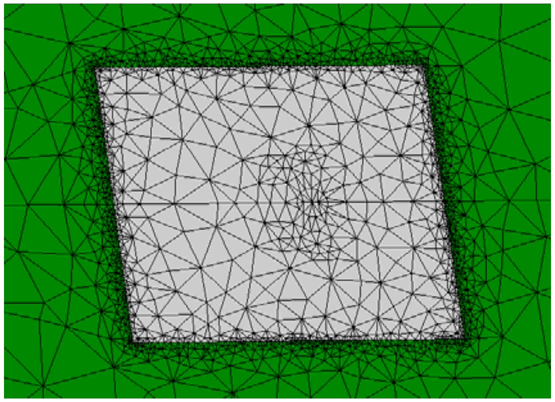
Solver Energy

- Begin with no energy inside calculation domain
- Inject energy and step through time
- Hexahedral meshing
- When energy decays “far enough,” the simulation stops

CST

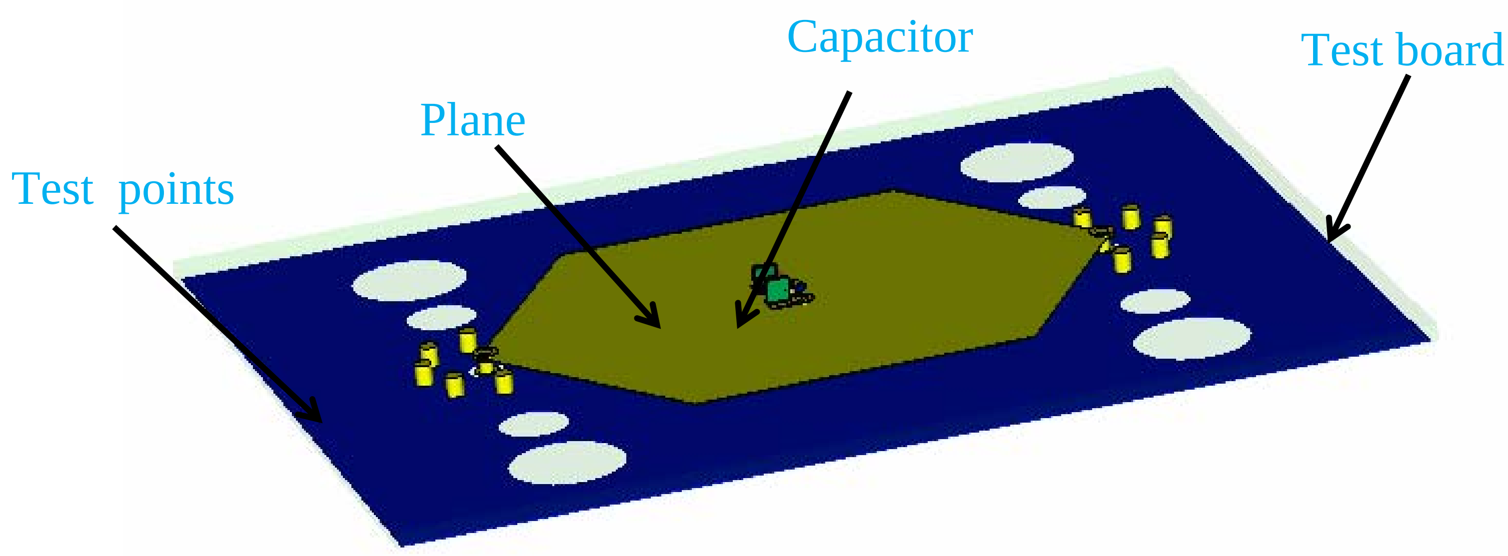
TERASPEED CONSULTING GROUP

Frequency Domain Solver



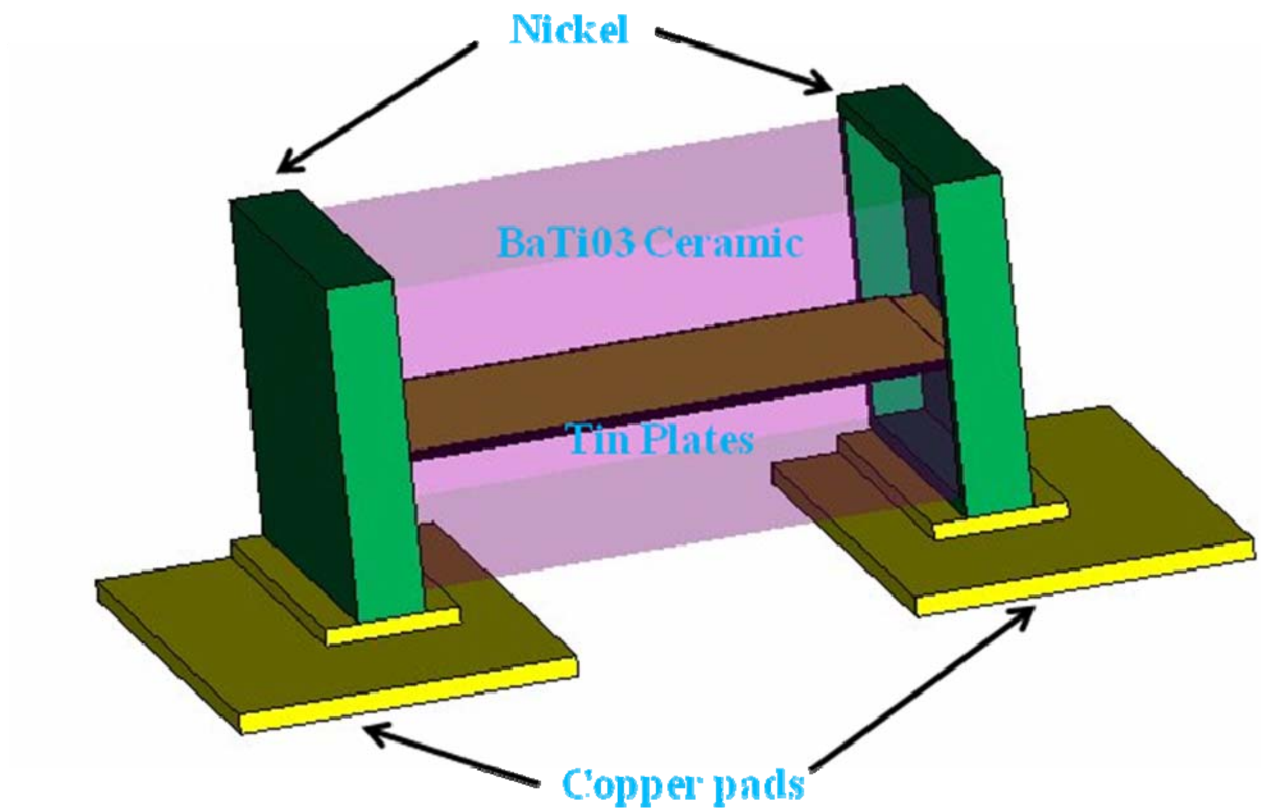
- Simulation performed at single frequencies
- Broadband Frequency Sweep to achieve accurate S-Parameters
- Well suited applications: Narrowband, electrically small structures

Capacitor Test Fixture Model



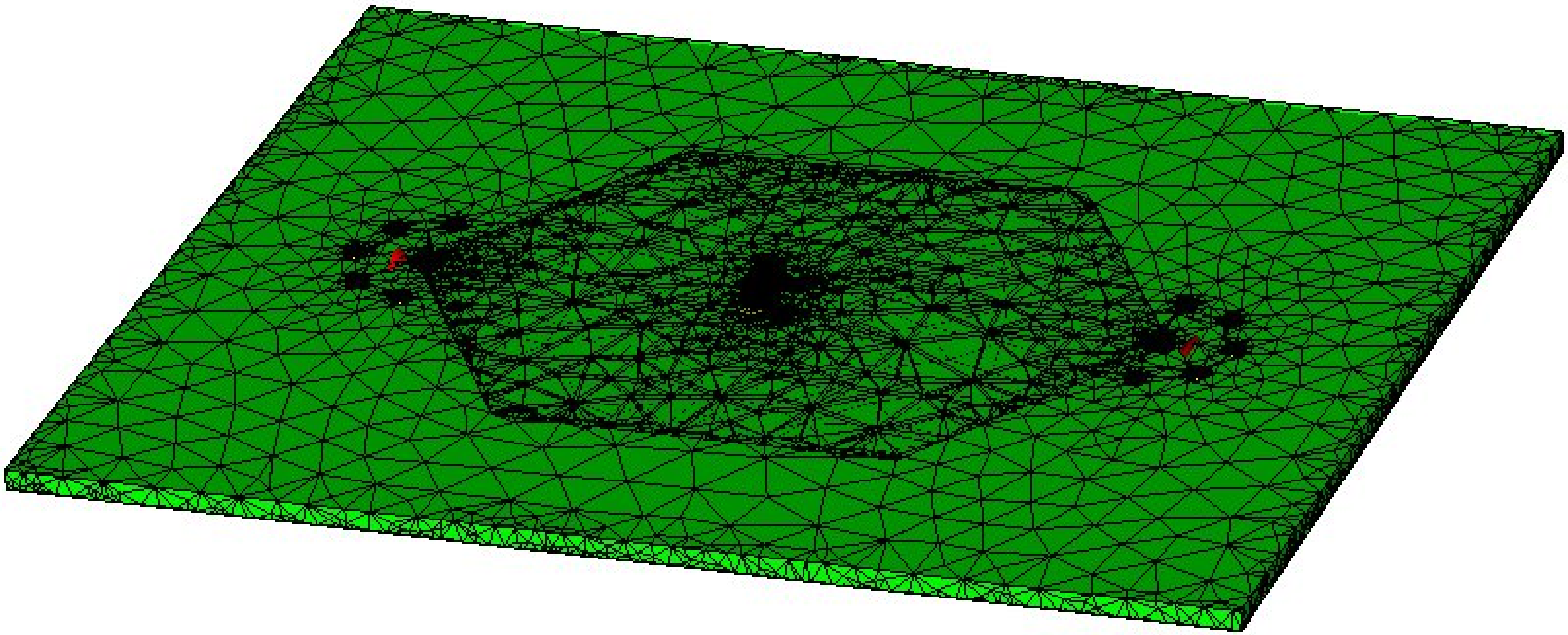
TERASPEED
CONSULTING
GROUP

MLCC Capacitor Full Wave Model



TERASPEED CONSULTING GROUP

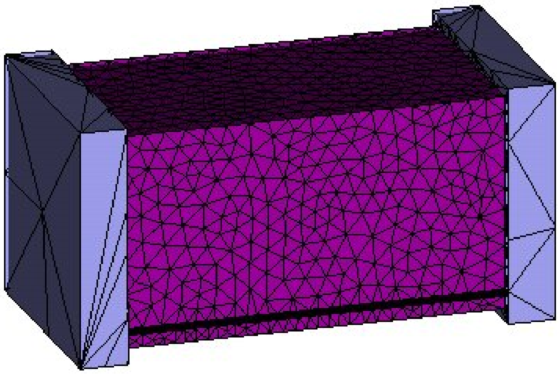
Test Fixture Model

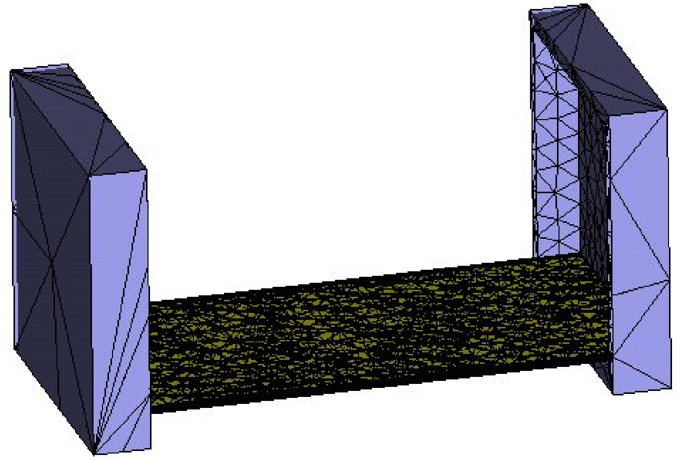


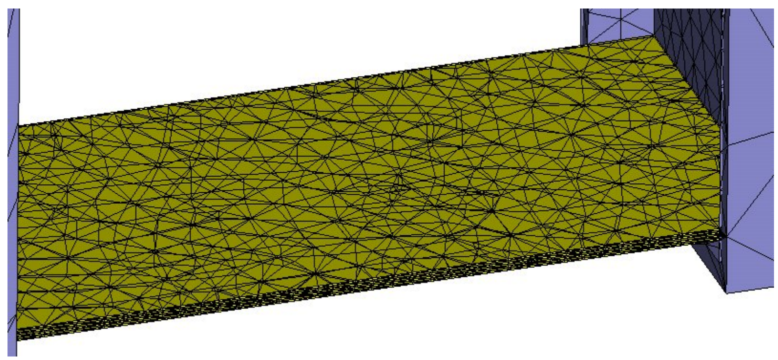
Tetrahedral mesh of test fixture

TERASPEED
CONSULTING
GROUP

MLCC model – TET mesh

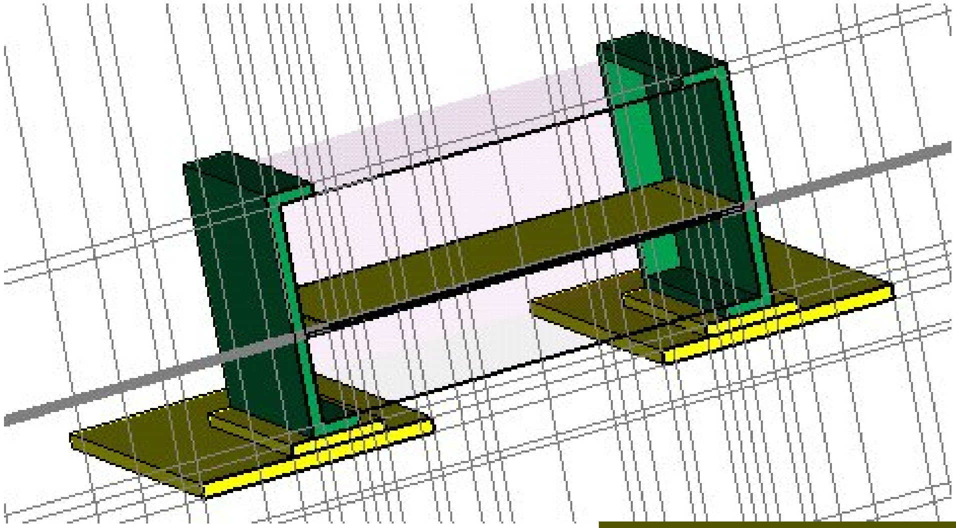


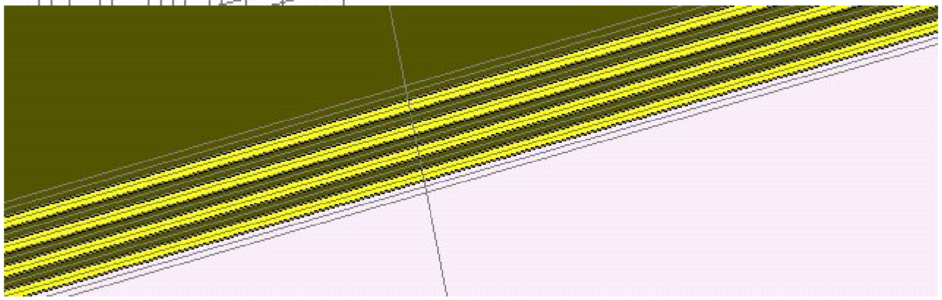




TERASPEED CONSULTING GROUP

MLCC model – HEX mesh

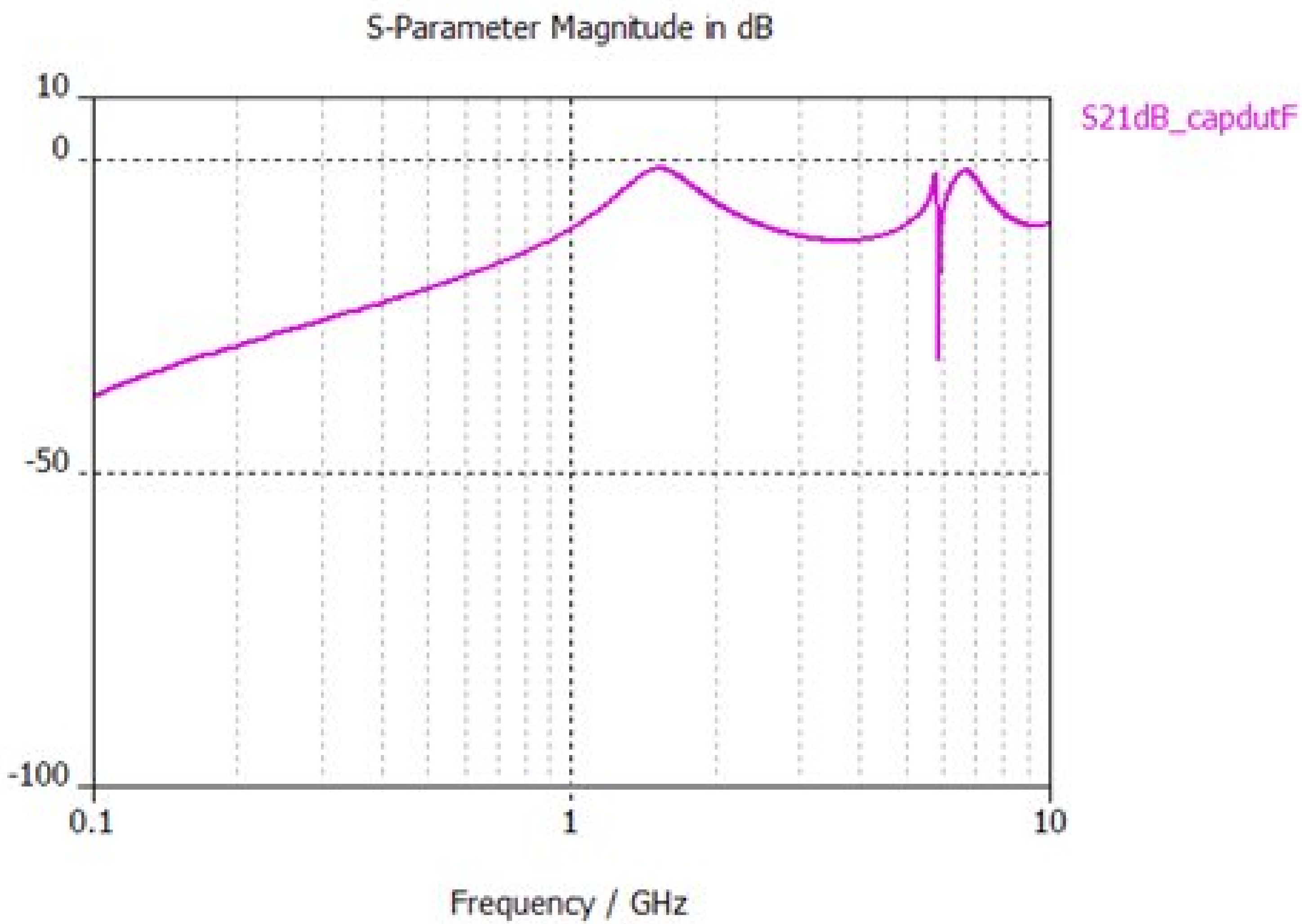




TERASPEED
CONSULTING
GROUP

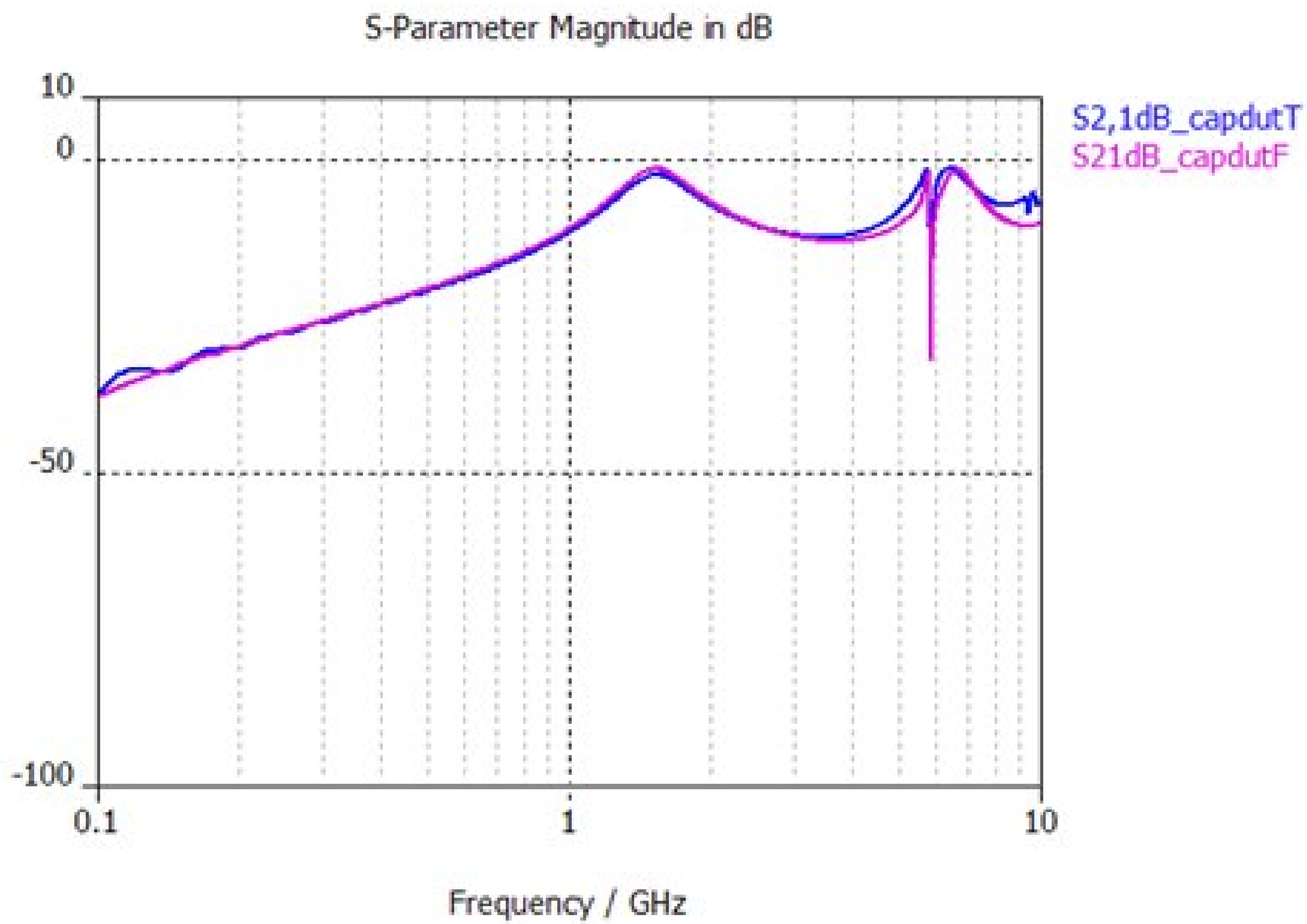
Simulation Results

Frequency Domain Solver S21



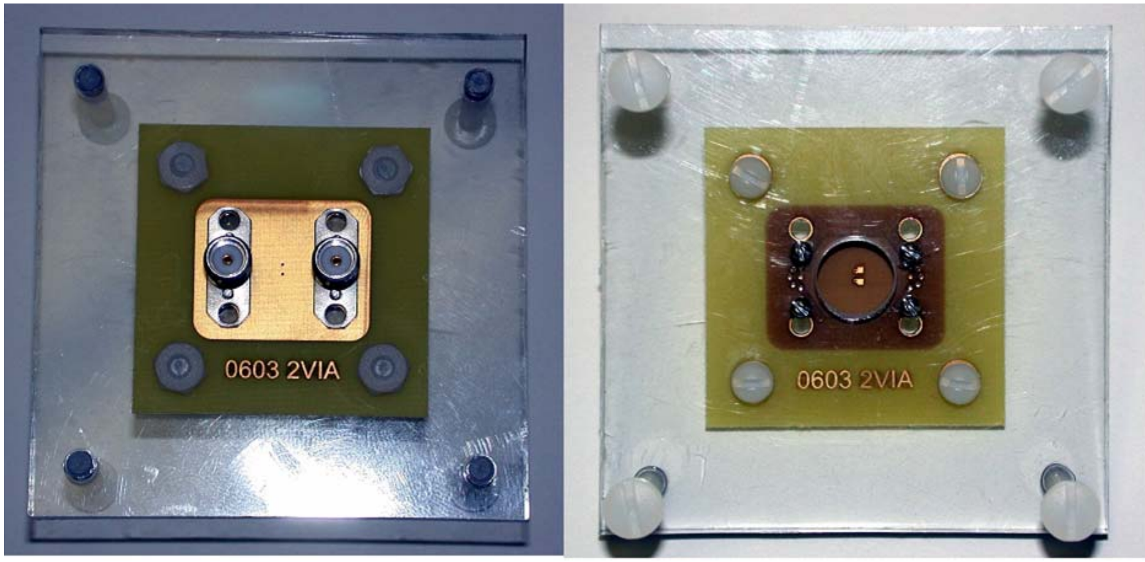
TERASPEED CONSULTING GROUP

Validation between Transient and Frequency Domain Solvers



TERASPEED CONSULTING GROUP

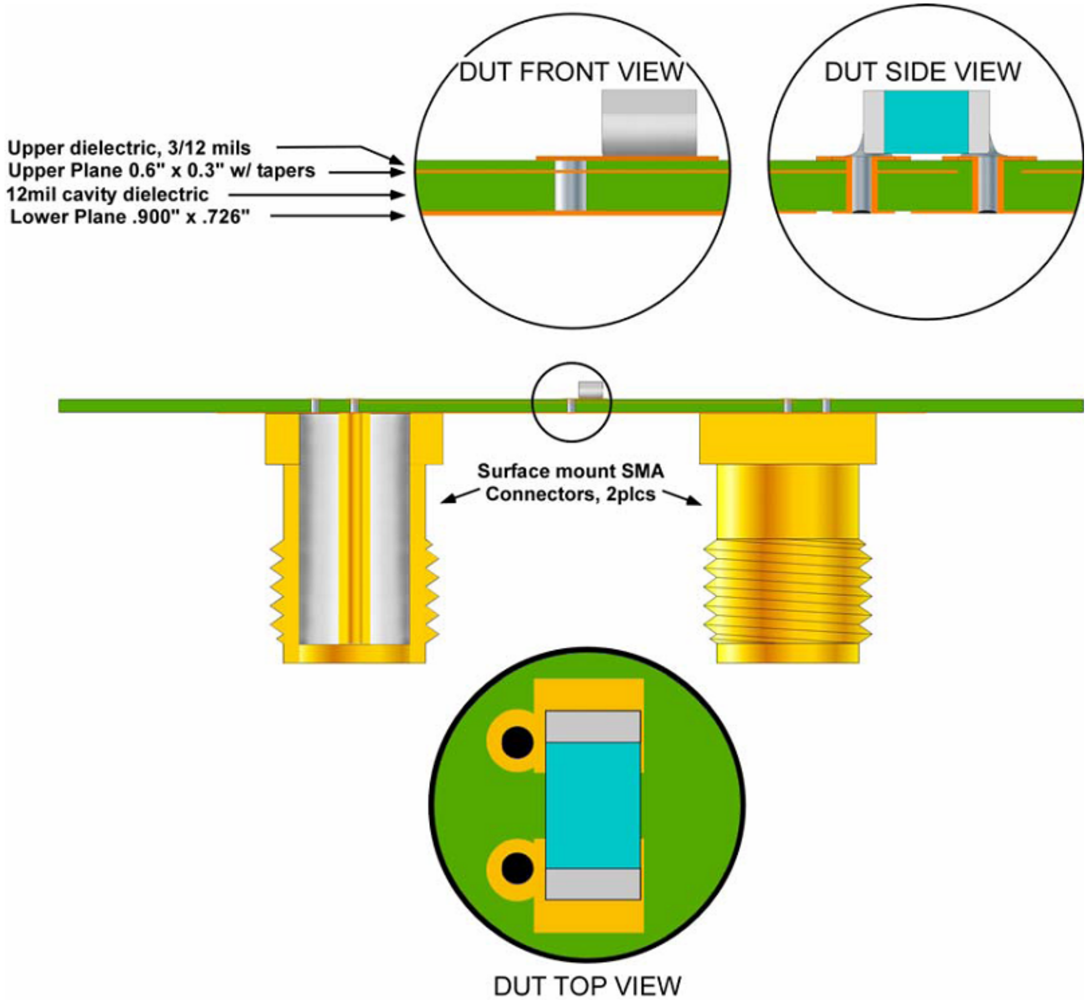
Measurement Fixture



CST

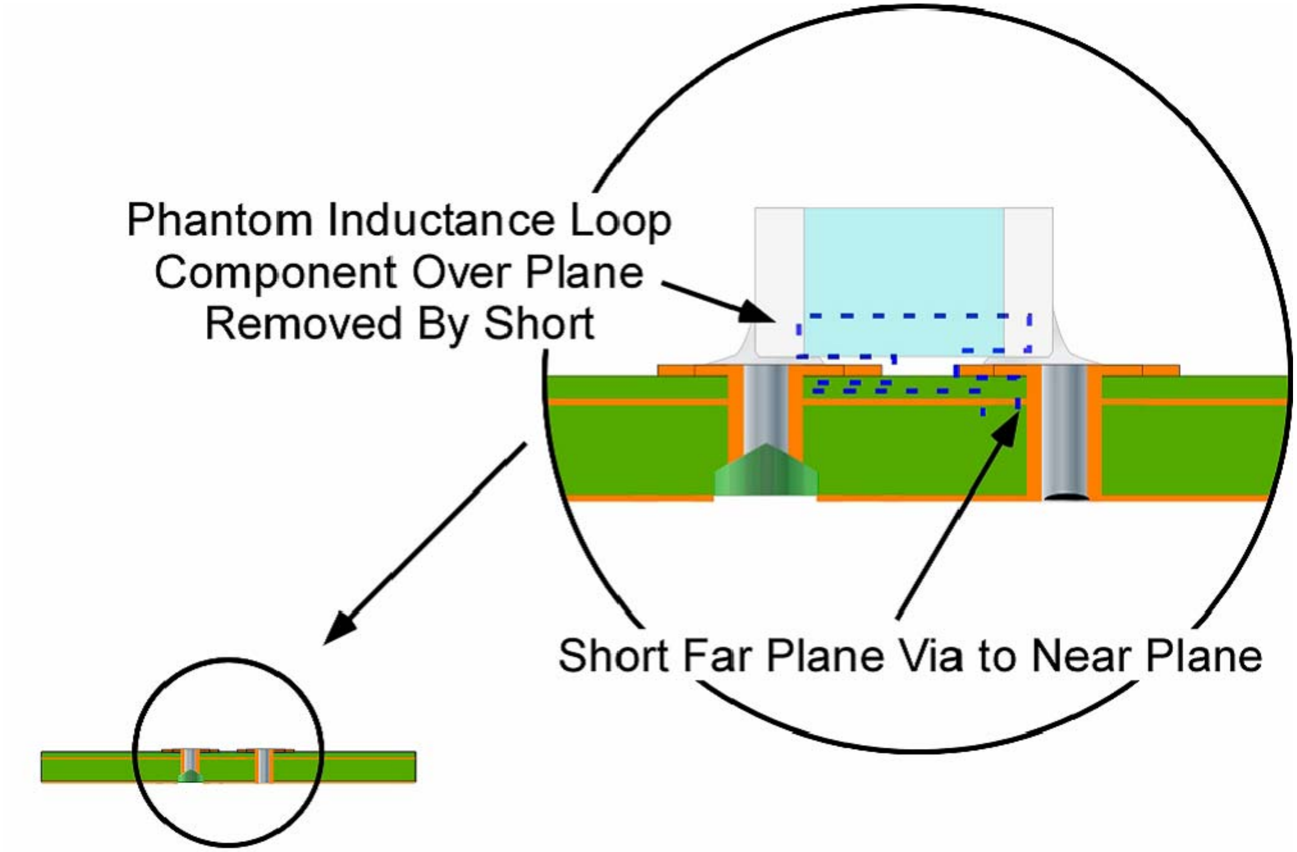
TERASPEED CONSULTING GROUP

Detailed view of fixture



TERASPEED
CONSULTING
GROUP

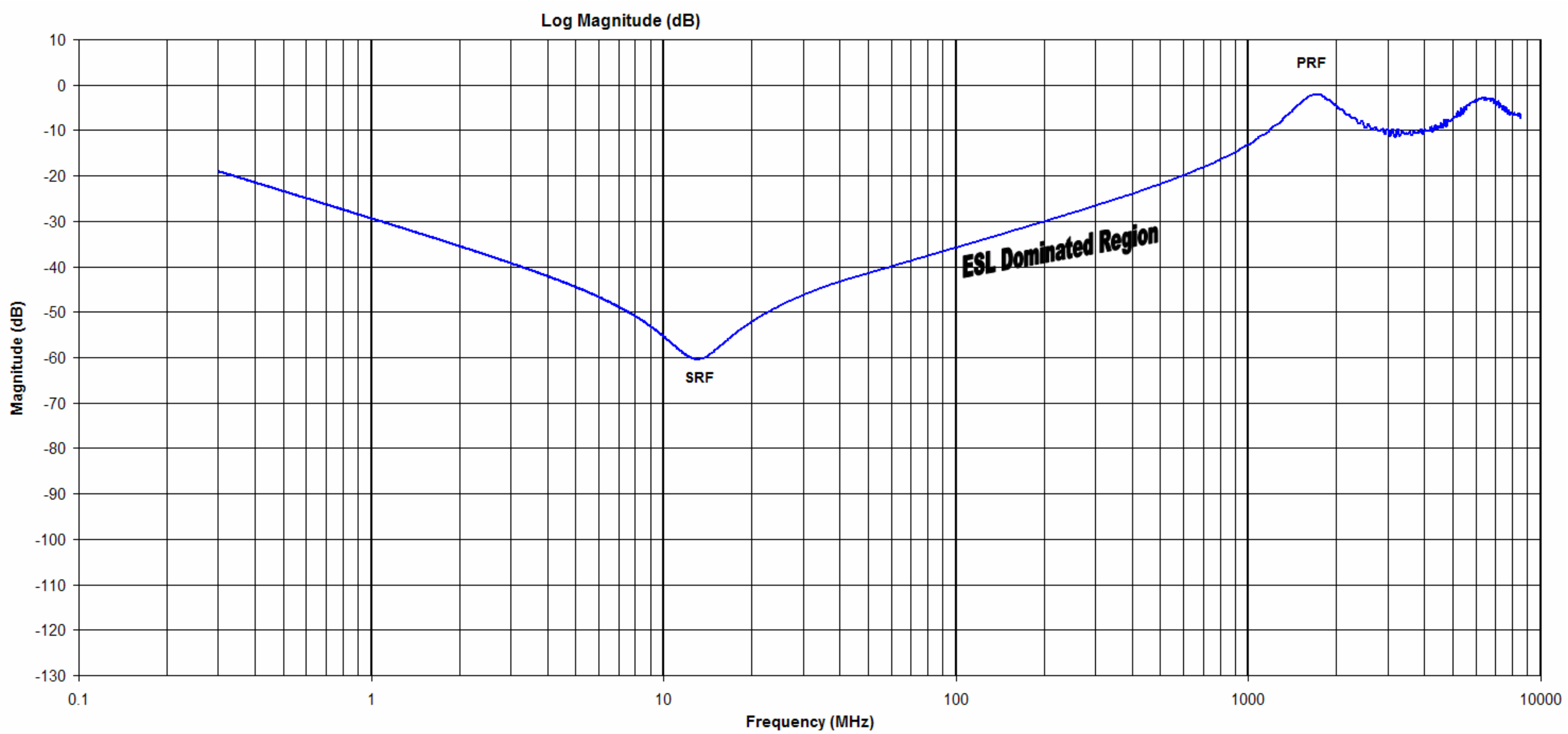
Via Short Calibration



Via short calibration

TERASPEED CONSULTING GROUP

Capacitor Transfer Impedance Measurement



0.22uF 0402 capacitor

TERASPEED CONSULTING GROUP

Simulation and Measurement Correlation

	100 MHz	200 MHz	300 MHz	400 MHz	500 MHz
Shorted Structures					
Via Short Time Domain Solver	107 pH	106 pH	107 pH	108 pH	109 pH
Via Short Frequency Domain Solver	113 pH	112 pH	113 pH	114 pH	115 pH
Via Short Measured	86 pH	85 pH	85 pH	86 pH	88 pH
Pad Short Time Domain Solver	379 pH	342 pH	367 pH	367 pH	374 pH
Pad Short Frequency Domain Solver	403 pH	404 pH	411 pH	423 pH	439 pH
Pad Short Measured	403 pH	404 pH	411 pH	421 pH	440 pH
2 mil MLCC DUT Cover Layer					
DUT Time Domain Solver	462 pH	485 pH	515 pH	532 pH	552 pH
DUT Frequency Domain Solver	506 pH	507 pH	518 pH	535 pH	709 pH
Actual DUT Measured	658 pH	646 pH	654 pH	672 pH	707 pH
8 mil MLCC DUT Cover Layer					
DUT Time Domain Solver	662 pH	640 pH	647 pH	671 pH	704 pH
Actual DUT Measured	658 pH	646 pH	654 pH	672 pH	707 pH

CST

TERASPEED CONSULTING GROUP

Summary & Conclusions

o Capacitor bypass structured can be modeled effectively with 3D full wave solvers

o Techniques have been demonstrated for accurate measurement and modeling

o Methods can be applied to calibration of PDS full wave S-parameter simulations

o Further validation studies ongoing.

o Measured and corrected MLCC capacitor library under current development.