CROSSTALK DUE TO PERIODIC PLANE CUTOUTS

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Outline

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2 – Crosstalk Theory

3 – Measurement

4 – Simulation correlation

5 – Parameterized field simulations

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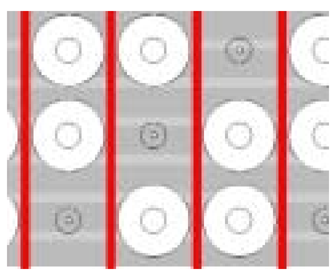
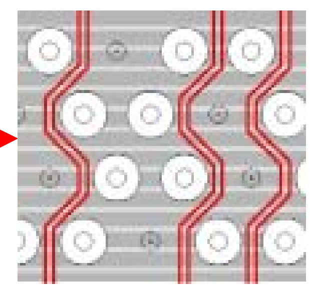
Introduction

- Multilayer pcbs have dense trace routes, forcing routing through regions containing packages, connectors, and/or multi-pin sockets
- In these regions the trace may periodically encounter regular patterns of via barrels, antipad cutouts, BGA solder balls, etc.

BGA pin-field



Conn. pin-field



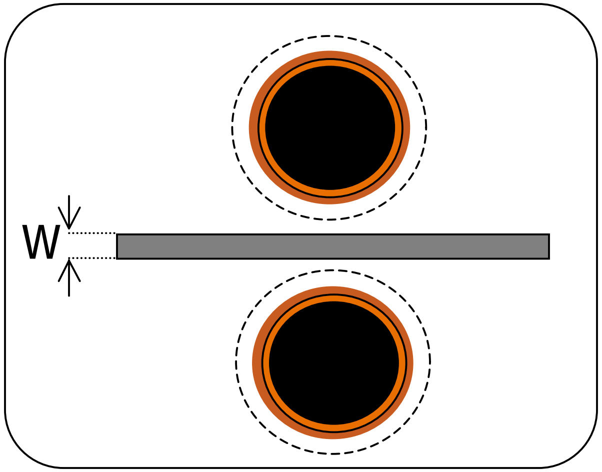
Introduction

- Single trace: Periodic discontinuities can line up these small reflections, increasing the slope of the loss curve (S12) by the presence of resonance dips [1].
- Coupled traces: Traces can get routed near to or over cutouts and thermal reliefs, due to misregistration and manufacturing tolerances, allowing for layer to layer coupling.

1. Gustavo Blando, *et al.*, Attenuation in PCB Traces due to Periodic Discontinuities, Proceedings of DesignCon 2006, Santa Clara CA

Introduction

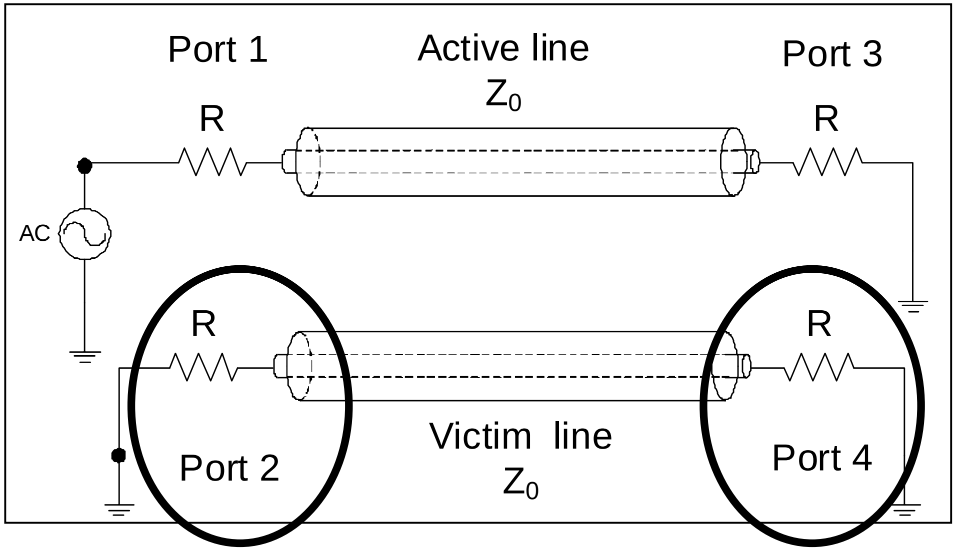
- Trace routed through a pin field, such as a BGA with antipads
- Identical trace routed below the immediate plane layer



Example: 4 mil line width, BGA (1 mm, 39.37 mil), 30 mil antipad		
	Range	**Antipad edge to trace edge separation**
Different core misregistration	+/-5 mils	-3.315 mils (-82%)
Same core misregistration	+/-3 mils	-1.315 mils (-33%)

Crosstalk Theory

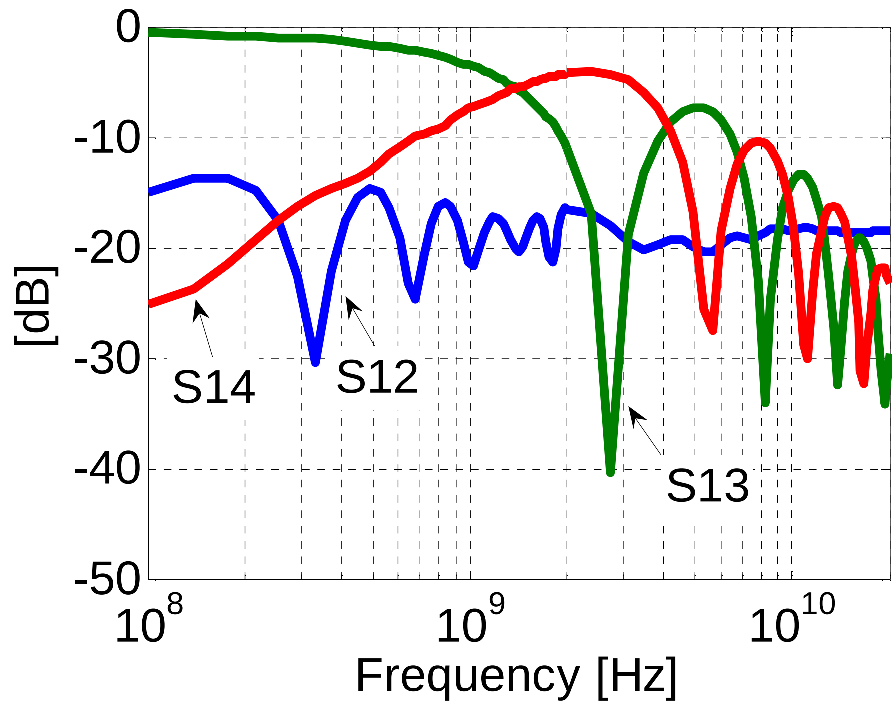
- Crosstalk is caused by the coupling of energy from one trace to another



- Coupled energy on port 2 is called the near-end crosstalk (NEXT). NEXT is proportional to the sum of the capacitive and inductive couplings. It appears on both microstrips and stripline traces
- Coupled energy on port 4 is called the far-end crosstalk (FEXT) and is proportional to the difference in the capacitive and inductive coupling. FEXT is zero for homogenous structures such as a stripline

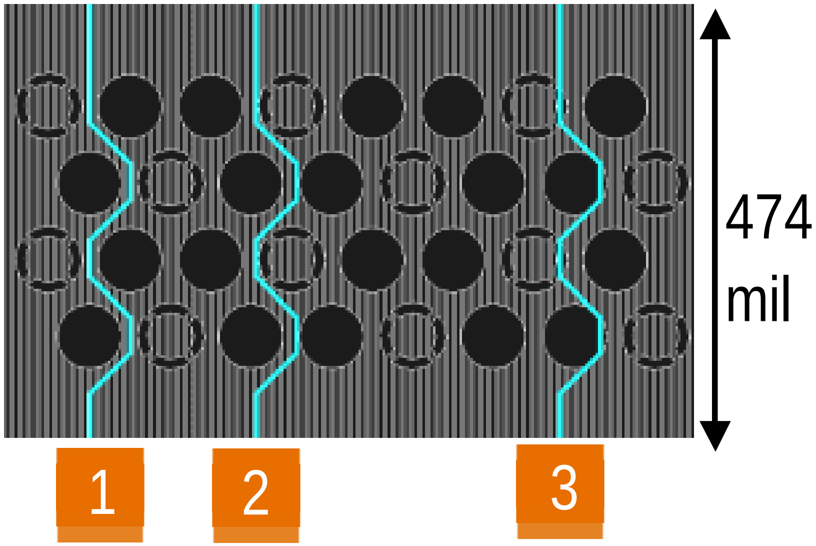
Crosstalk Theory

- Pair of 10-inch, edge-coupled microstrip traces spaced 3 mils apart over **solid** ground, where the traces are on the same side of the plane
- At low frequencies, both S12 and S14 have rising slopes
- The first maximum of the S12 profile occurs at $\lambda/4$ of the coupled line length. The subsequent peaks occur at the odd harmonics of $\lambda/4$
- S14 profile reaches full coupling at frequencies where the time-of-flight difference of the even and odd modes equals half of the period
- Subsequent S14 peaks occur at odd harmonics of the fundamental
- S13 profile has corresponding minima at the frequencies where the far-end coupling peaks
- S14 is zero for stripline

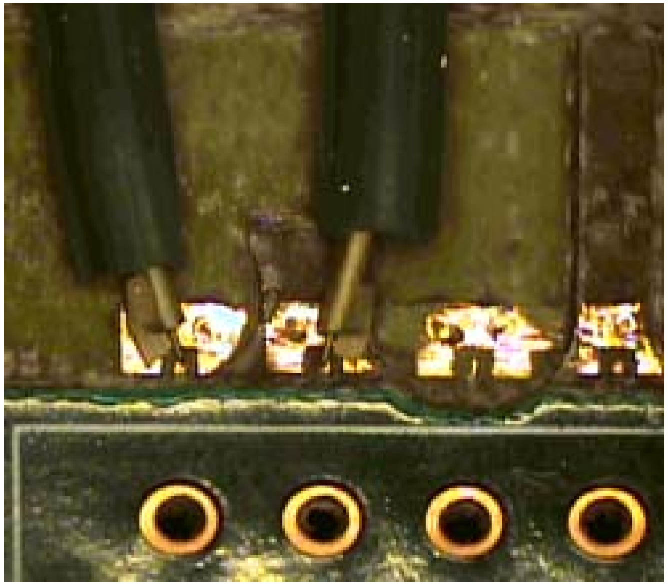


Measurements

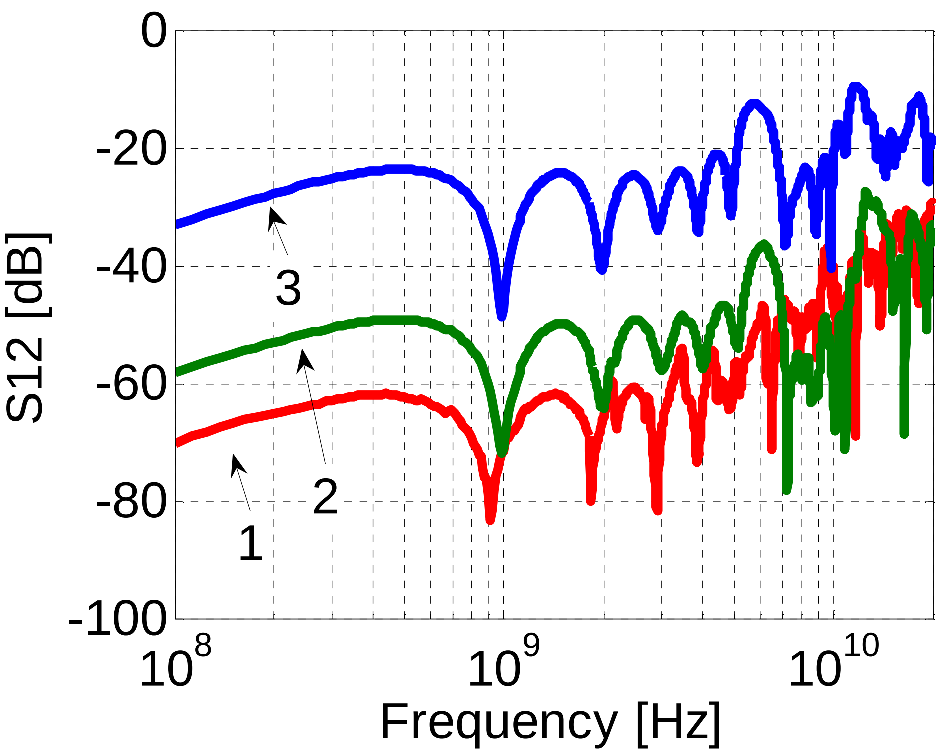
- A pair of mirrored, serpentine traces on either side of a perforated plane at three different distances from the cutout
- Unit cell, repeated six times (2.9 inch)

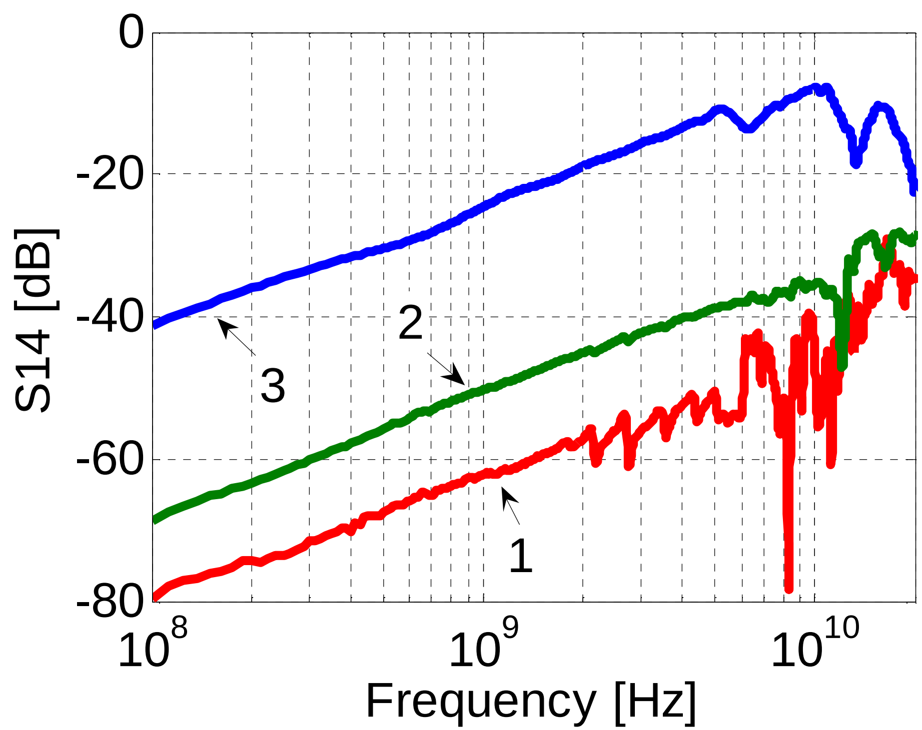


- Board milled down to contact horseshoe ground pads and signal
- Differential 500 um GSSG (Ground-Signal-Signal-Ground) picoprobes with SOLT calibration
- Four-port S-parameters were captured with an Agilent N4230A VNA from 300kHz to 20GHz



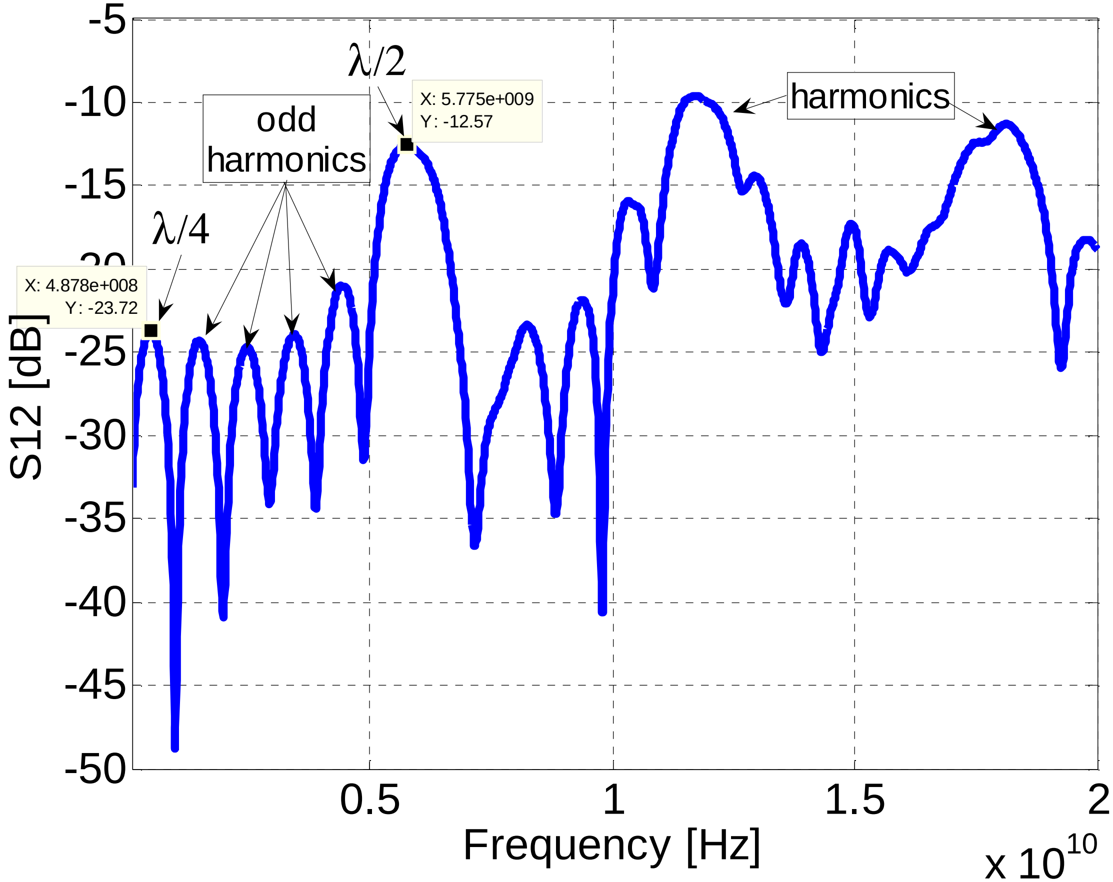
Measurements





Measurements

- Measured S12 for trace 3
- First maximum occurs at λ/4 of the total line length (2.9 inch)
- Subsequent peaks occur at the odd harmonics of λ/4
- Periodic cutouts causes a series of peaks with a fundamental corresponding to λ/2 of the unit cell length, here 474 mils
- Subsequent peaks are even harmonics of λ/2.

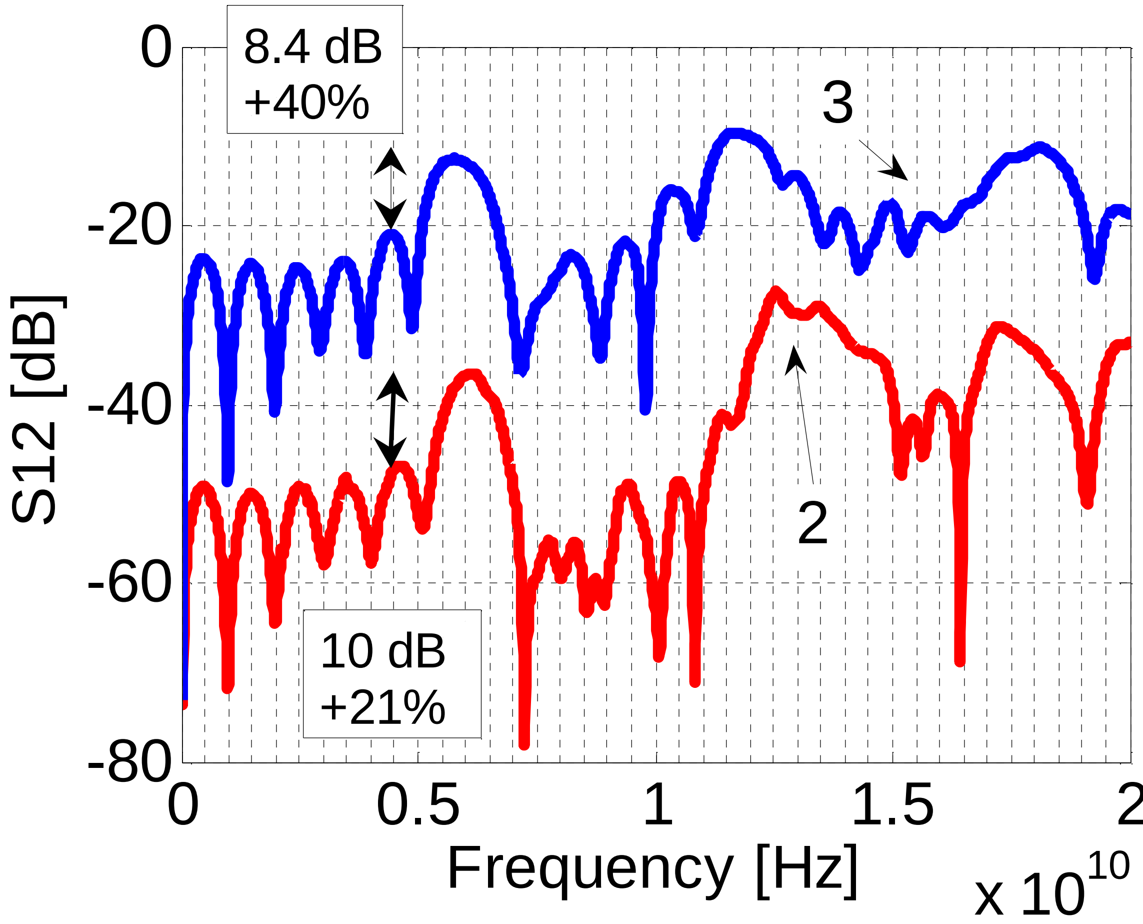


Measurements

- Relative magnitude of the λ/2 series (first peak) to the λ/4 series, for S12 is:

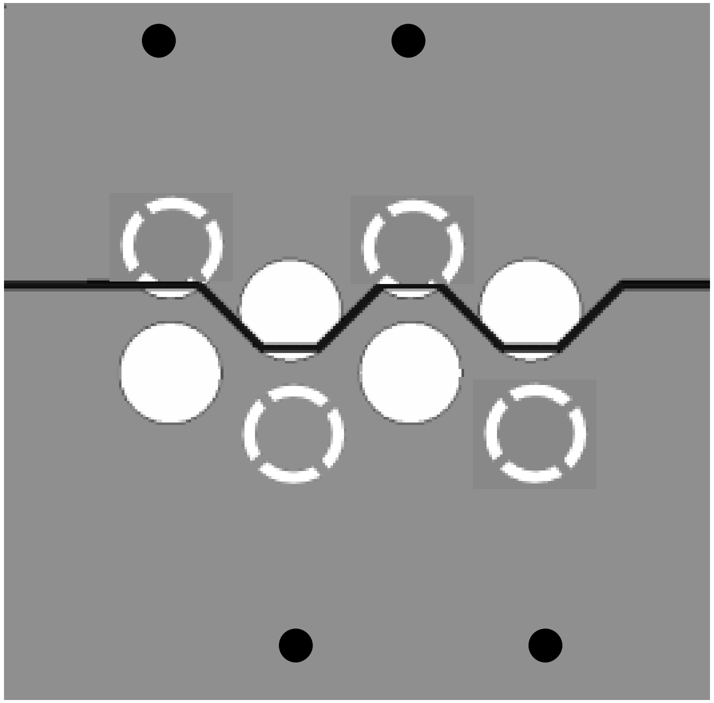
Trace 3: 8.4 dB (40%)

Trace 2: 10 dB (21%)



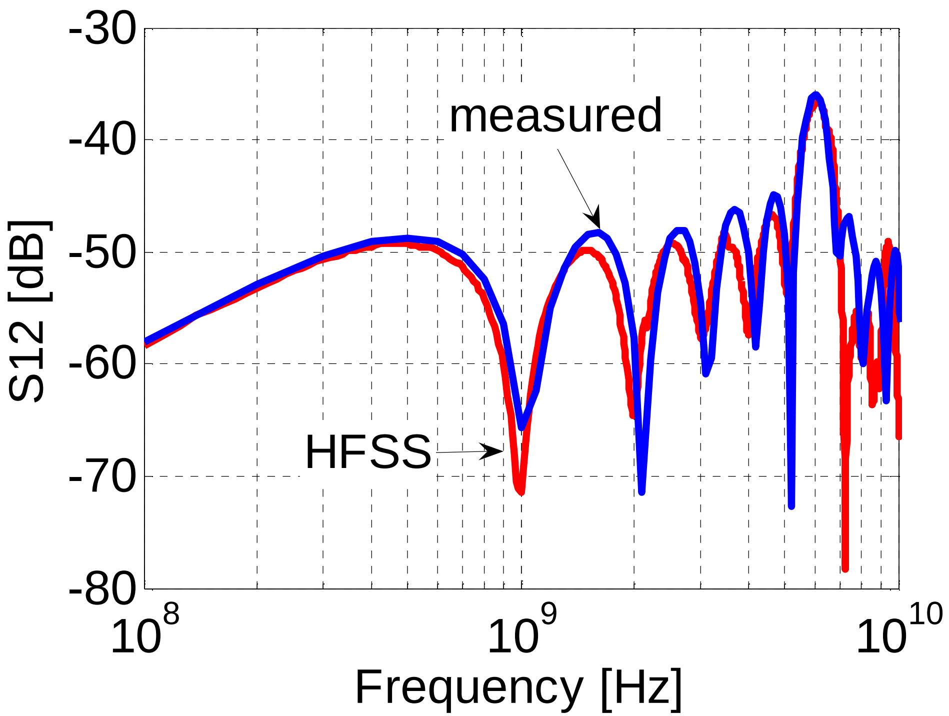
Measurement Correlation

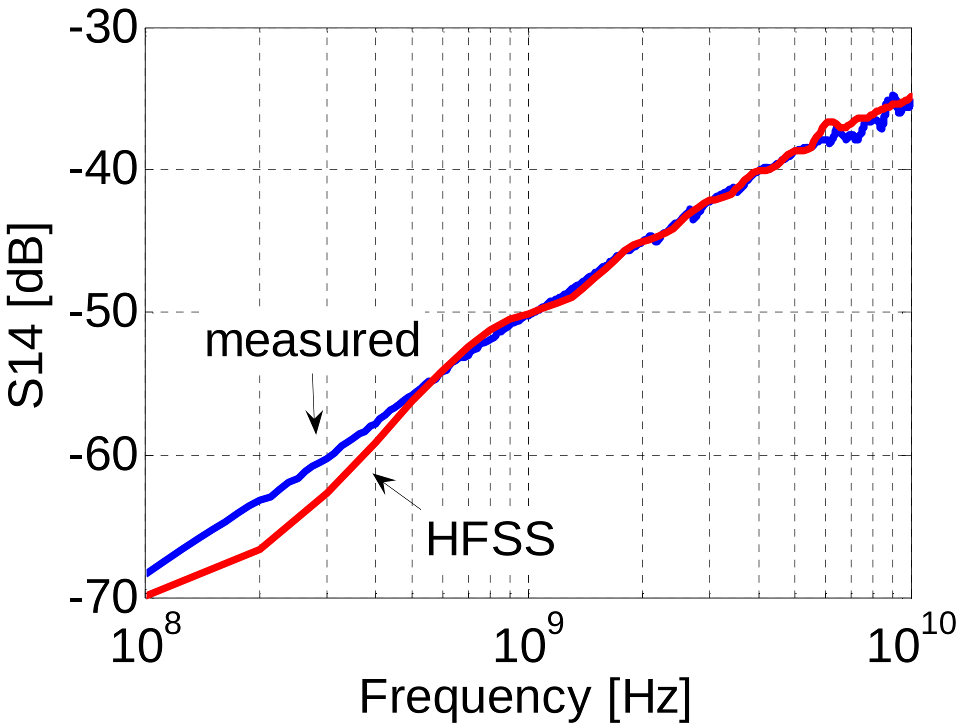
- Trace 2 & 3 (2.9 inch) simulated using Ansoft HFSS
- Simplifications:
  > Thermal relief pattern was not included
  > Vias were placed outside of the pin field
  > Only the antipads nearest to the trace were included
- Geometrical simplifications limited our range of simulation accuracy to approximately 10 GHz.
- A wideband causal model was used to capture the frequency dependence of the dielectric material



Correlation

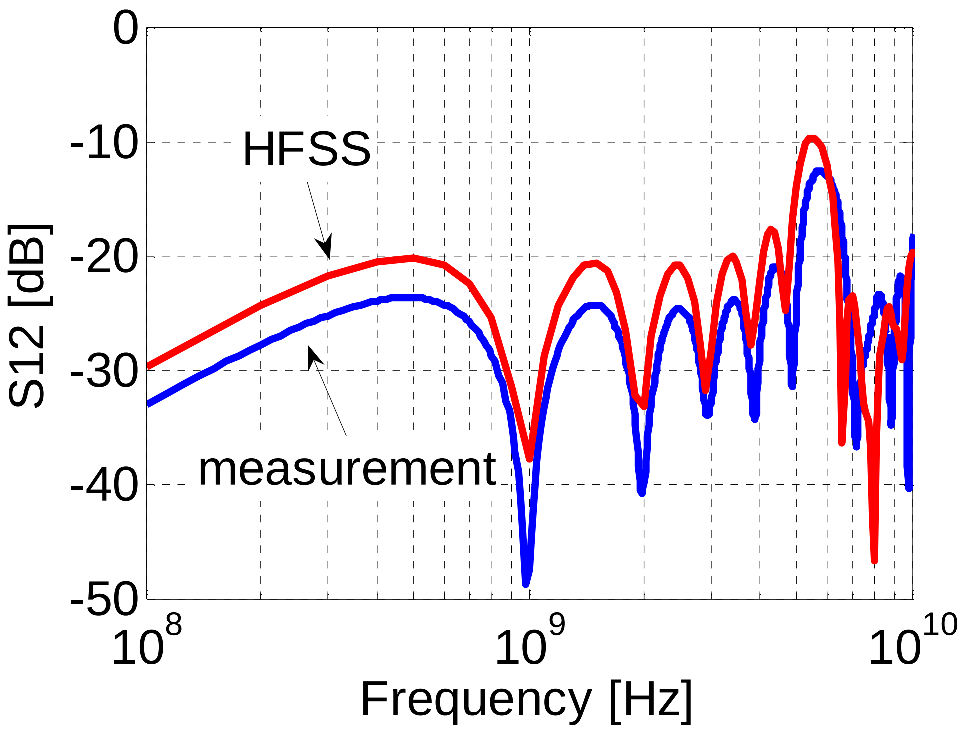
Trace 2 S12 and S14

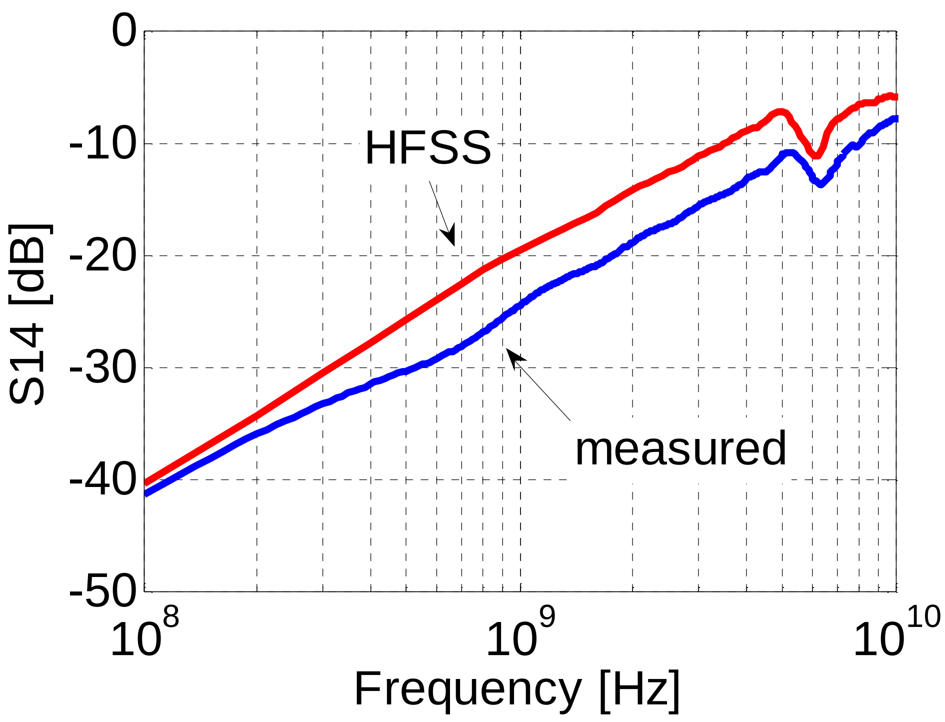




Correlation

Trace 3 S12 and S14

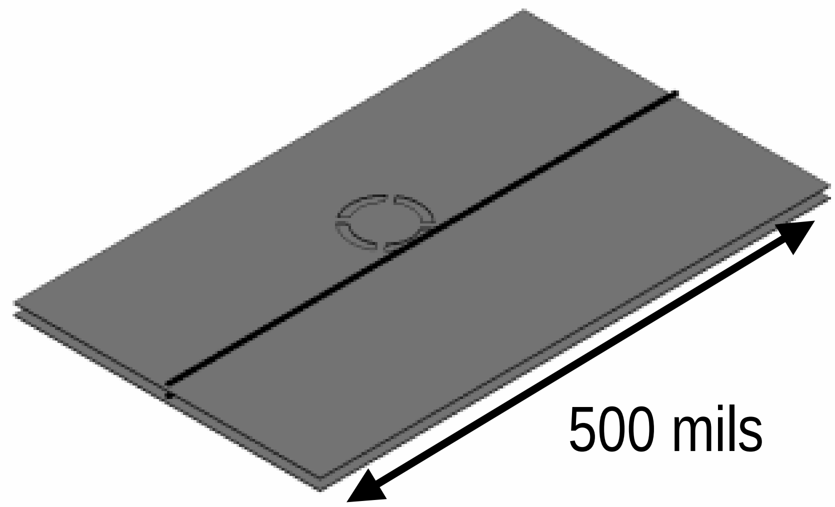




Parameterization

Parameterizing the Spacing between Trace and Cutout

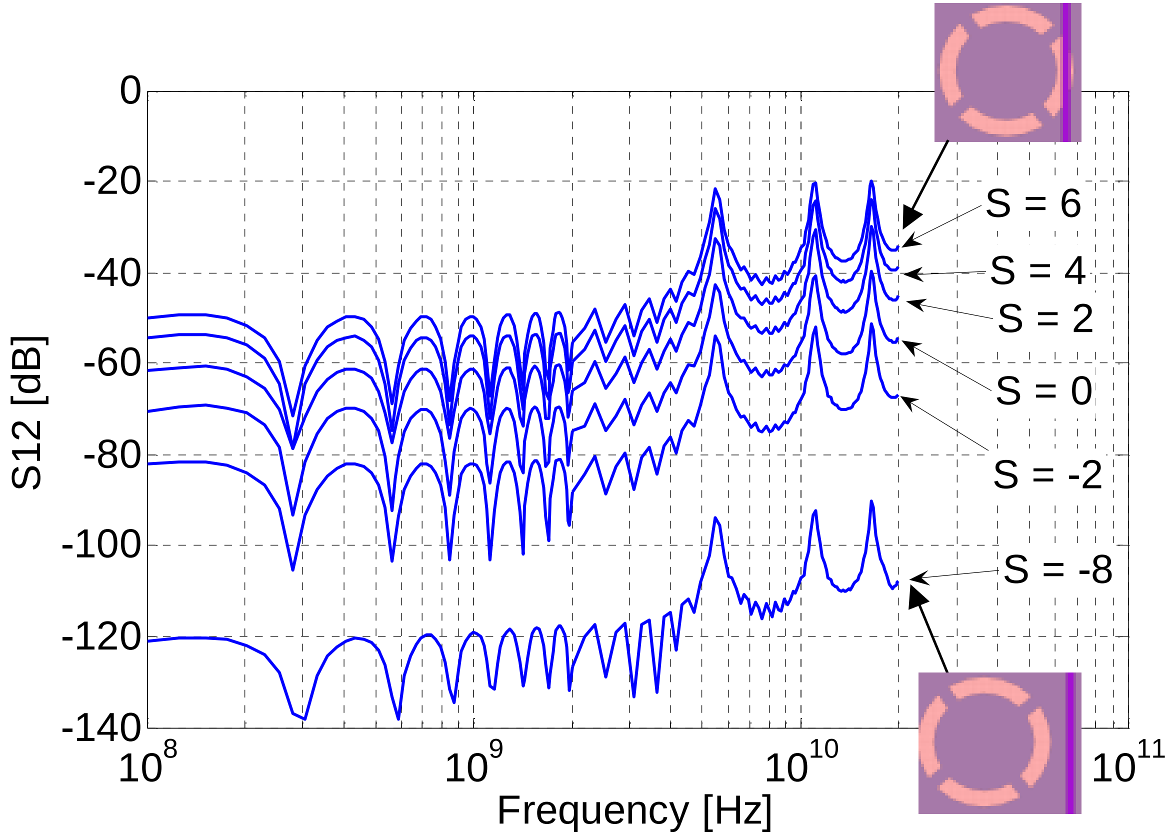
- 4-mil wide traces and 4 + 4 mil thick dielectrics
- Single cutout with a thermal relief pattern located next to the trace, centered
- Unit cell length is 500 mils. 20 unit cells concatenated in MATLAB for a total length of 10 inches
- Trace to cutout perimeter distance (s) was swept from 6 mils to -8 mils
- Positive s value is over the cutout
- s = 0 means trace routes along the edge



Parameterization

Parameterizing the Spacing between Trace and Cutout

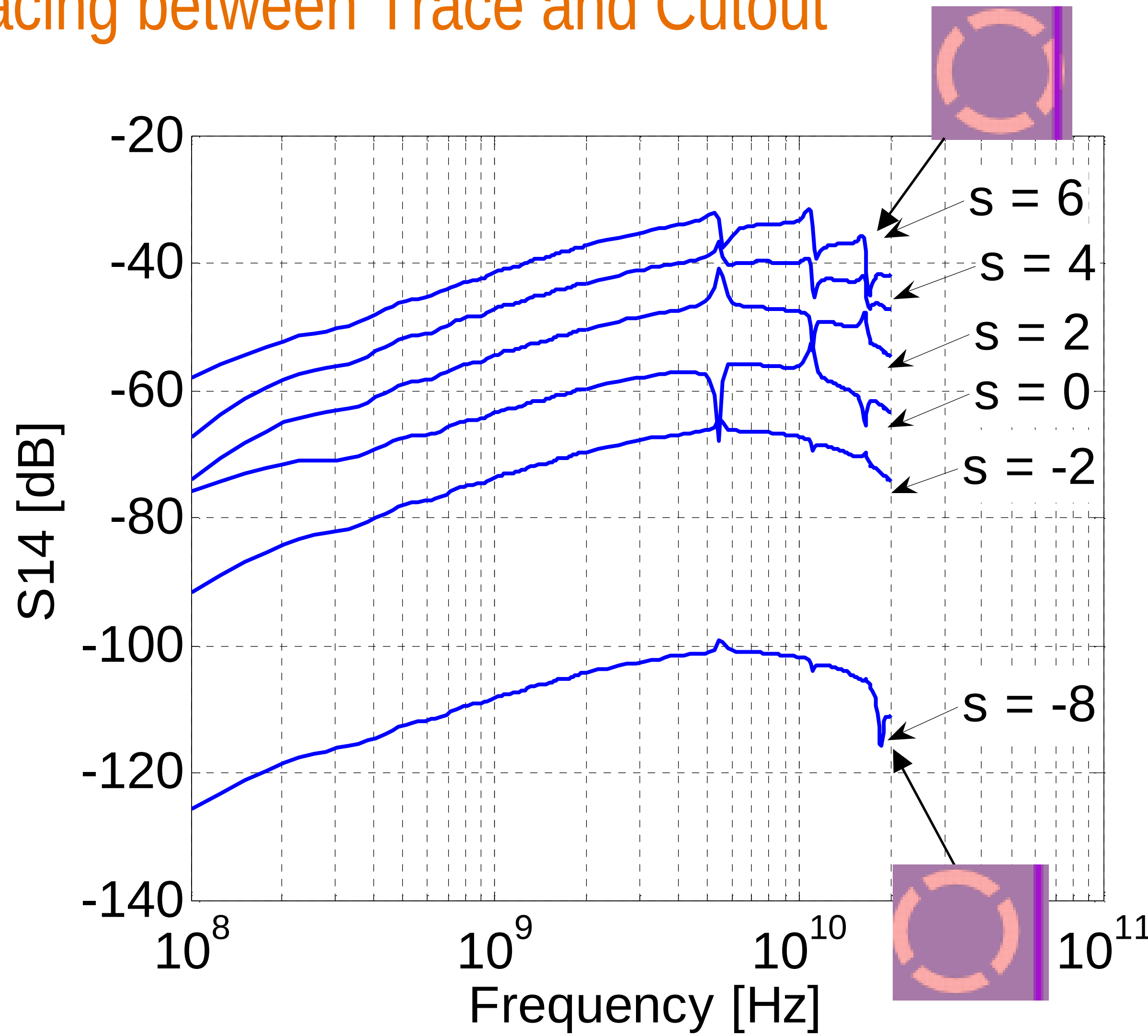
- First maximum of the S12 profile occurs at $\lambda/4$ of the total line length (10 inch)
- Subsequent peaks occur at the odd harmonics of $\lambda/4$
- $\lambda/2$ series of peaks due to periodic coupling start at 5.45 GHz, corresponding to $\lambda/2$ of the unit cell length (500 mils)
- Subsequent peaks are at even harmonics of the fundamental



Parameterization

Parameterizing the Spacing between Trace and Cutout

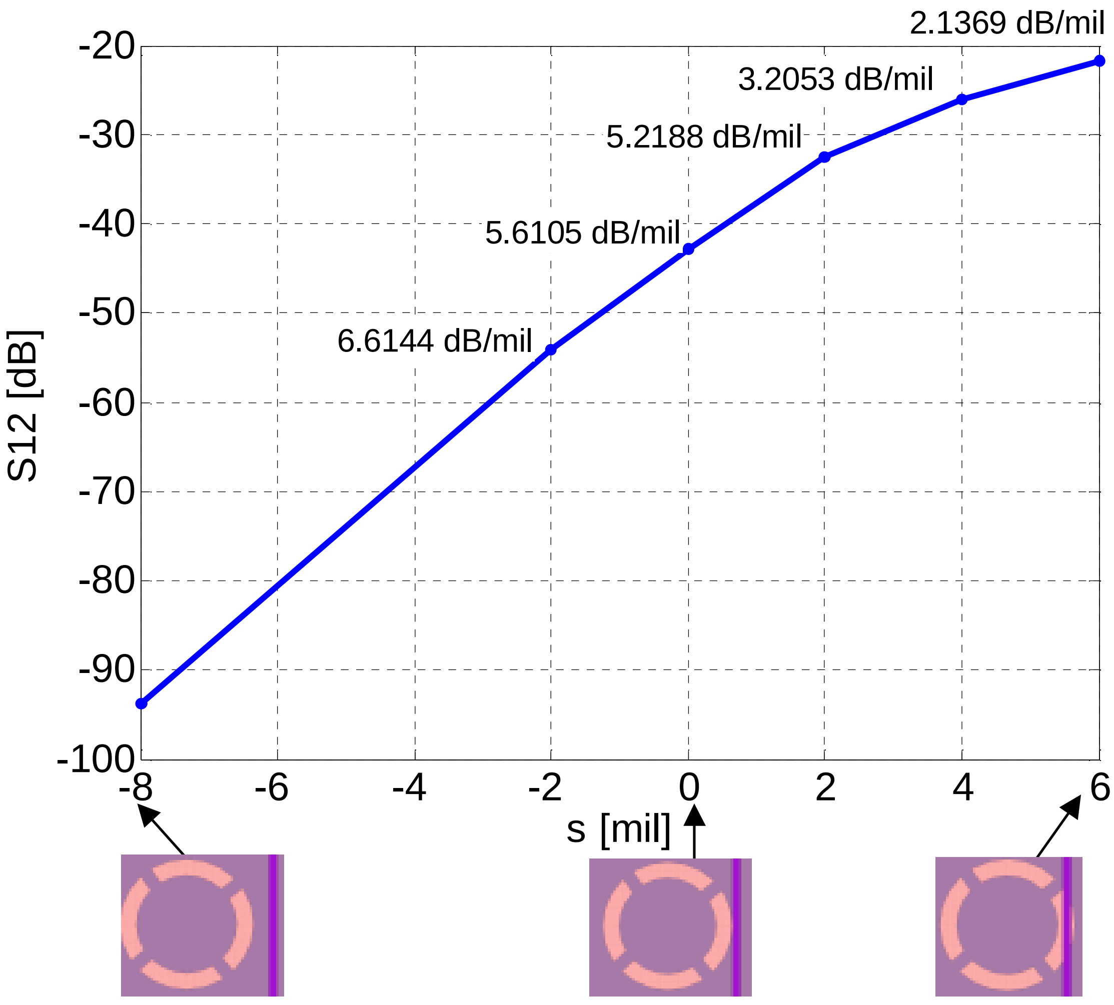
- S14 profile also shows a series of peaks and dips starting at the λ/2 frequency (5.45 GHz)



Parameterization

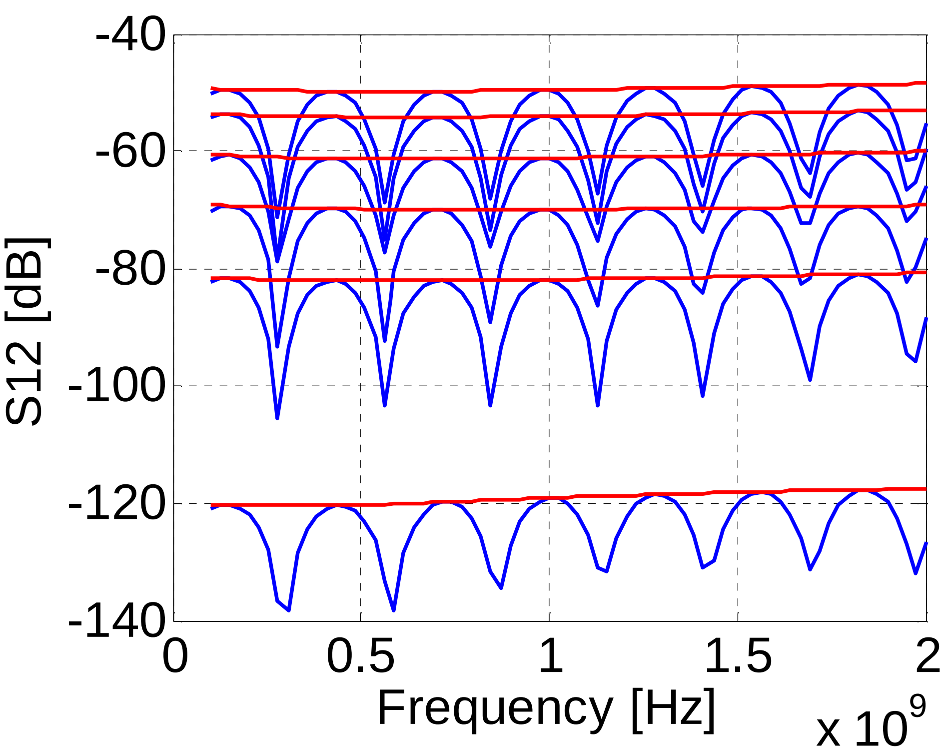
Parameterizing the Spacing between Trace and Cutout

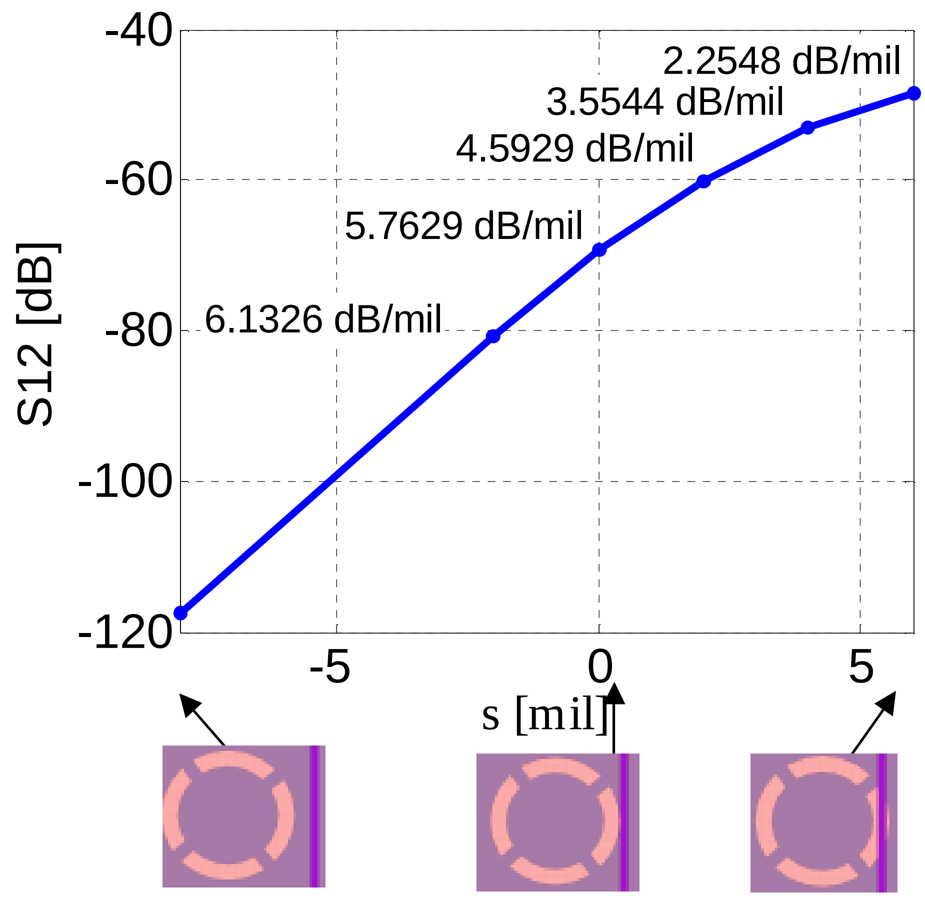
- S12 magnitude of the first $\lambda/2$ peak at 5.45 GHz as a function of the spacing, *s*
- S12 coupling increases at approximately 5-6 dB/mil as the trace moves closer to the cutout edge
- With the trace 4 mils over the cutout, the coupling starts to saturate



Parameterization

Parameterizing the Spacing between Trace and Cutout

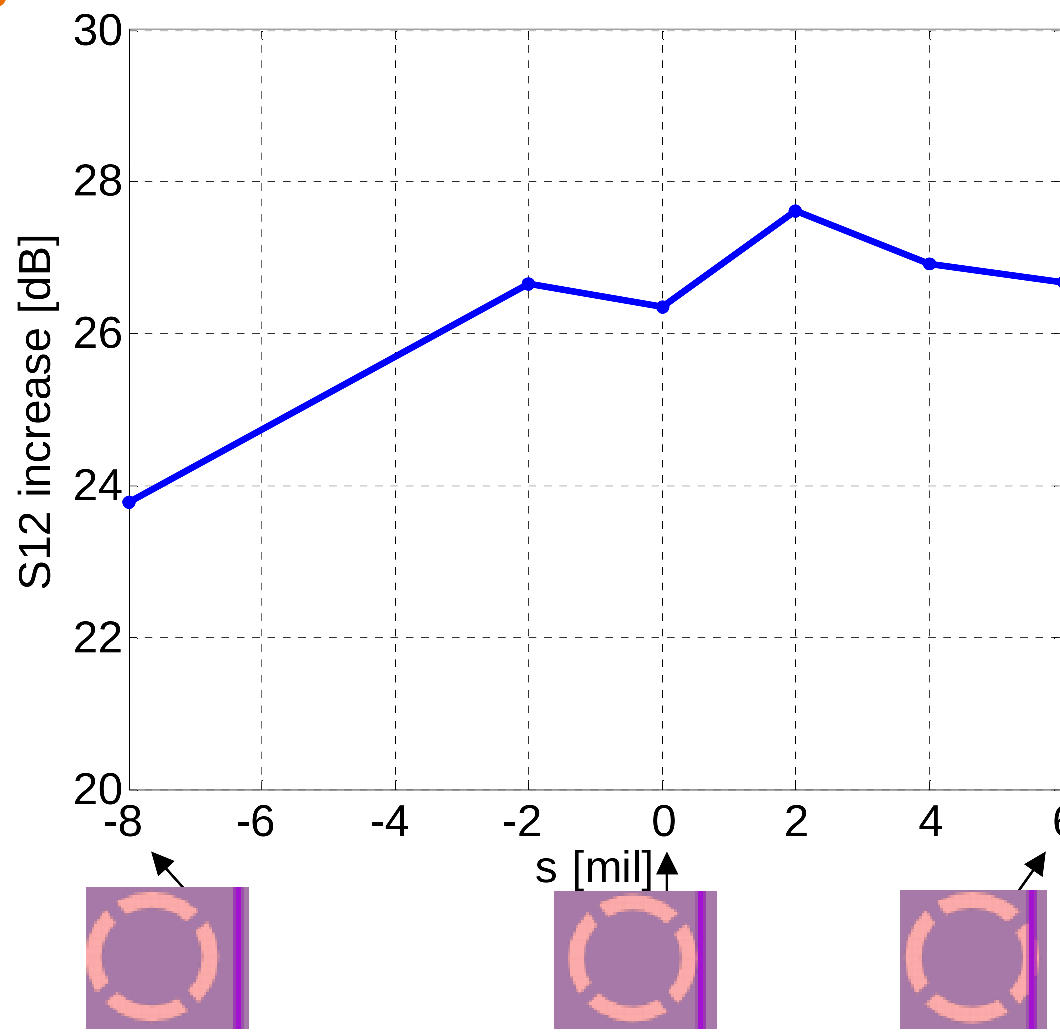




Parameterization

Parameterizing the Spacing between Trace and Cutout

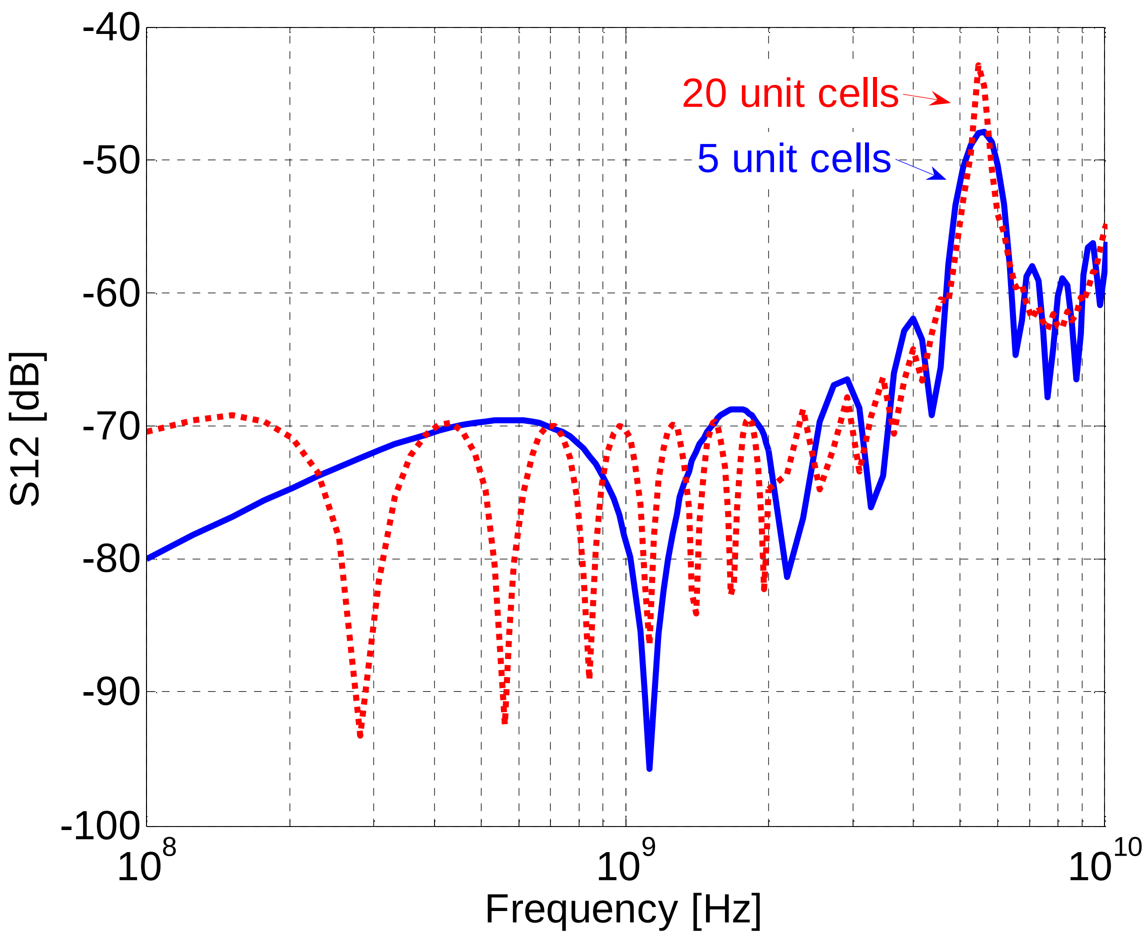
- Magnitude difference between the λ/4 peak envelope and first λ/2 peak
- > 24 dB increase in the S12 coupling across range of separations



Parameterization

Parameterizing the Number of Cutouts

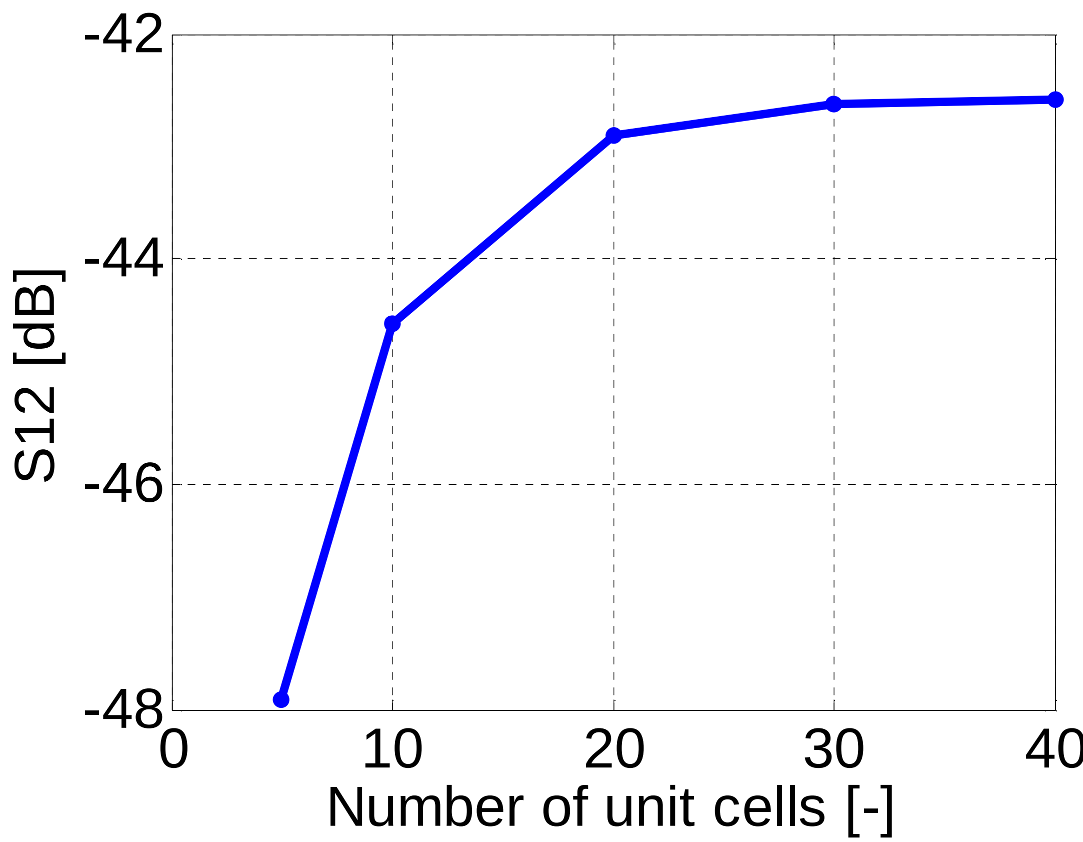
- Spacing fixed at zero
- 500-mil unit cell concatenated using 5, 10, 20 and 30 unit cells
- With 5 unit cells, the λ/4 fundamental is pushed to a center frequency four times higher
- λ/2 fundamental remains the same because the unit-cell length dictates the location of the first λ/2 peak



Parameterization

Parameterizing the Number of Cutouts

- Magnitude of the first $\lambda/2$ peak as a function of number of cells
- Saturation occurs because eventually we get a uniform structure and the per-unit-cell characteristics become stable
- Same characteristic observed on loss of periodic discontinuities



Conclusions

- Measured and simulated data of traces on opposite sides of a reference plane, passing close to or over periodic plane cutouts exhibit non-zero high-frequency crosstalk.
- The near-end crosstalk due to periodic apertures show two distinct signatures:
  - Quarter-wave peaks determined by the full coupled length. This was below 1%, even over the voids.
  - Half-wave peaks determined by the length of between two cutouts. These are 1% with edge aligned and 10% when the trace passes over the void.
- The half-wave series of peaks depend on the number of periodic voids, and it shows saturation with large number of cutouts.
- Far-end crosstalk due to vertical coupling through plane voids is also non zero, even if the cross sections above and below the perforated plane form homogeneous striplines.