Additional Trace Losses due to Glass-Weave Periodic Loading

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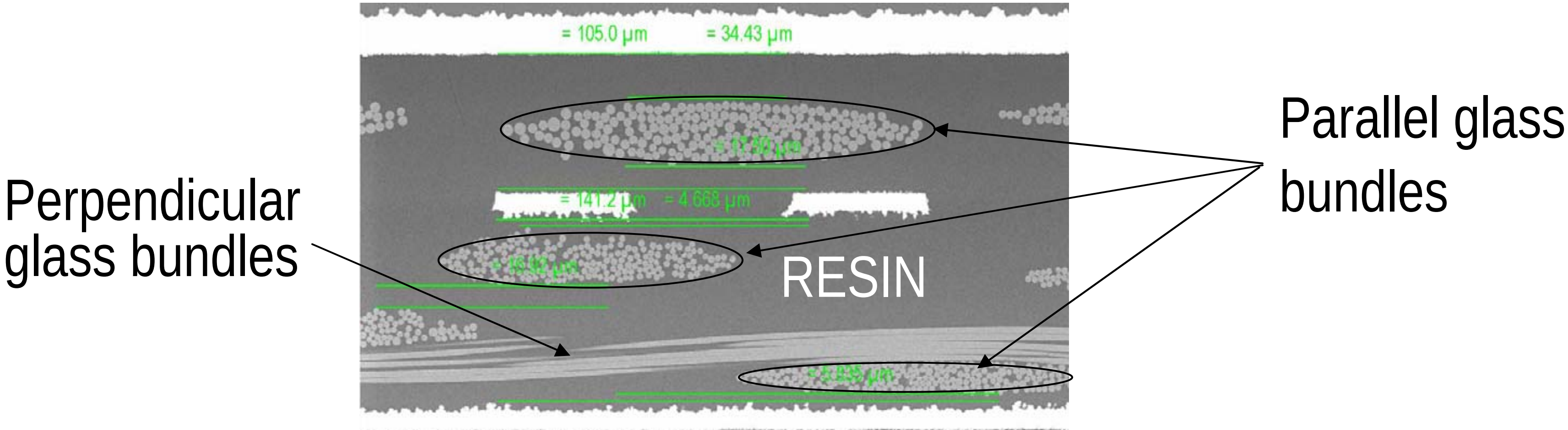
Introduction

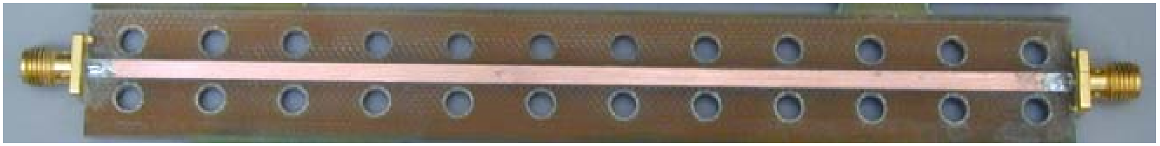
- PCB laminates are composed of resin and a glass fabric
- Two materials have different electrical properties
- Previous publications have looked at the impact of this on differential skew
- In this paper we look at the impact of this on signal loss
- The effect on signal loss is due to periodic loading of the interconnect which alters Dk and Df along the trace

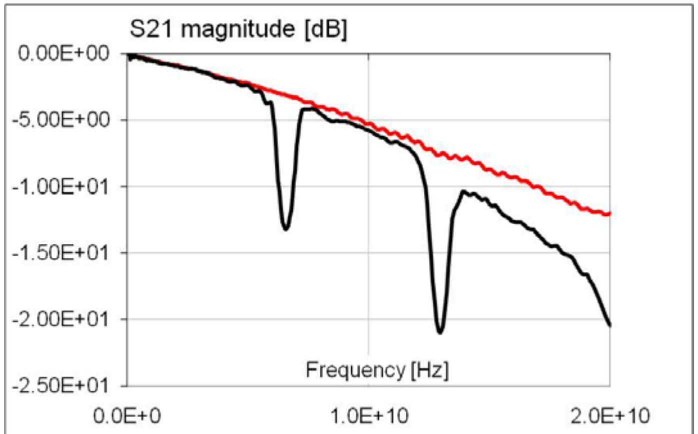


Introduction

- Periodic loading of transmission lines is well understood.
- Prior studies looked at the impact of periodic loading due to plane cutouts on both loss and crosstalk
- Results in a fundamental resonance where the distance is one half of a wavelength
- Creates peak in reflection profile and dip in insertion loss at that frequency
- Magnitude of dip depends on number of discontinuities and size of the discontinuity

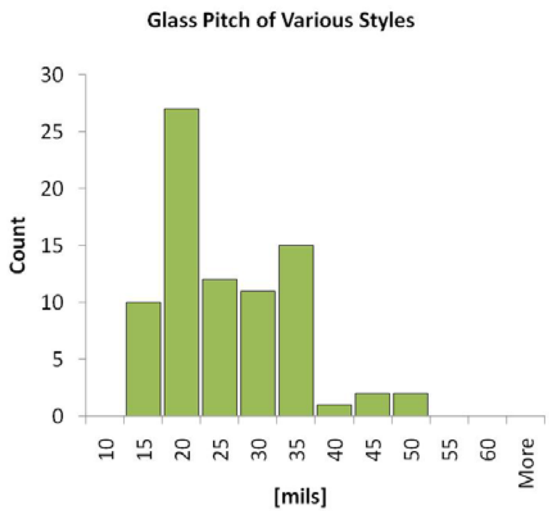
Half wave resonance is 1/ 2*500mils*150ps/in=6.6GHz

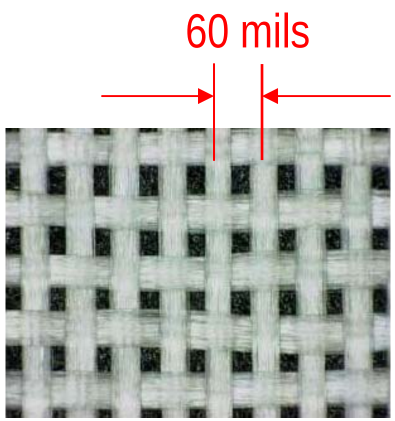




Introduction

- Glass weave periodic loading has been ignored presumably due to the relative high half-wave resonance it will establish
- A number of factors which we will cover make this important now
  > Data rates are increasing
  > Steepening of loss curve below fundamental
  > Lower frequency resonances can be established





1/ 2*60mils*150ps/in = 55 GHz

Agenda

- Examine physical dependencies such as impact of glass thickness, proximity and glass pitch
- Investigate how trace route angle can set up secondary resonance patterns
- Impact of meandering trace routes
- Test structure measurements
- Conclusions

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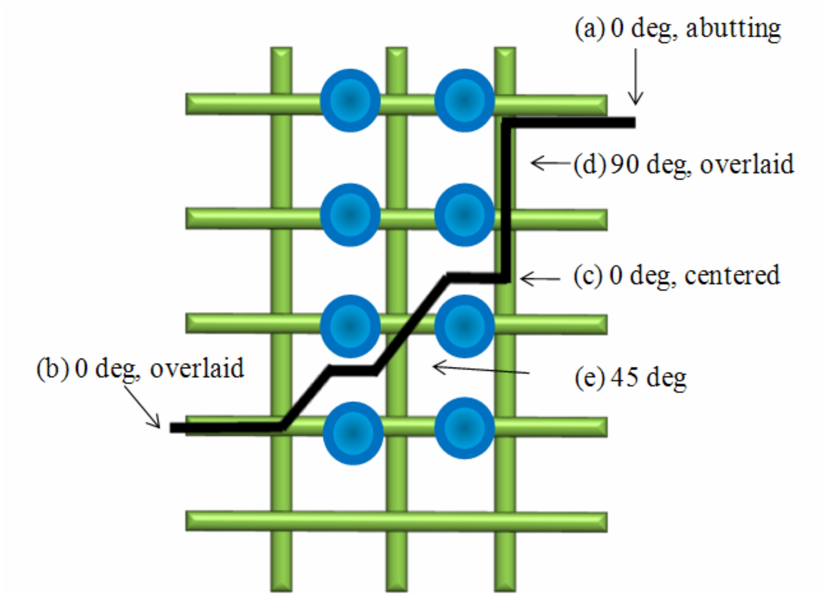
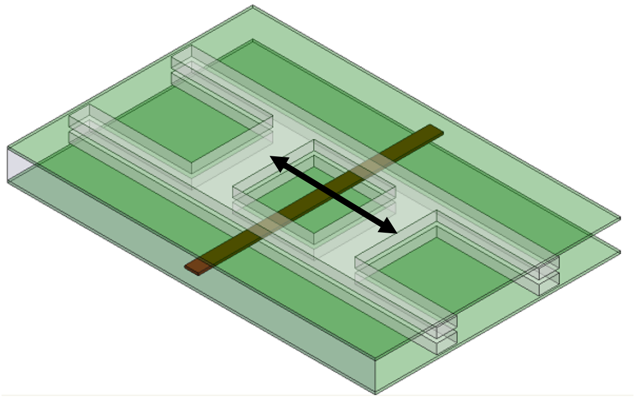
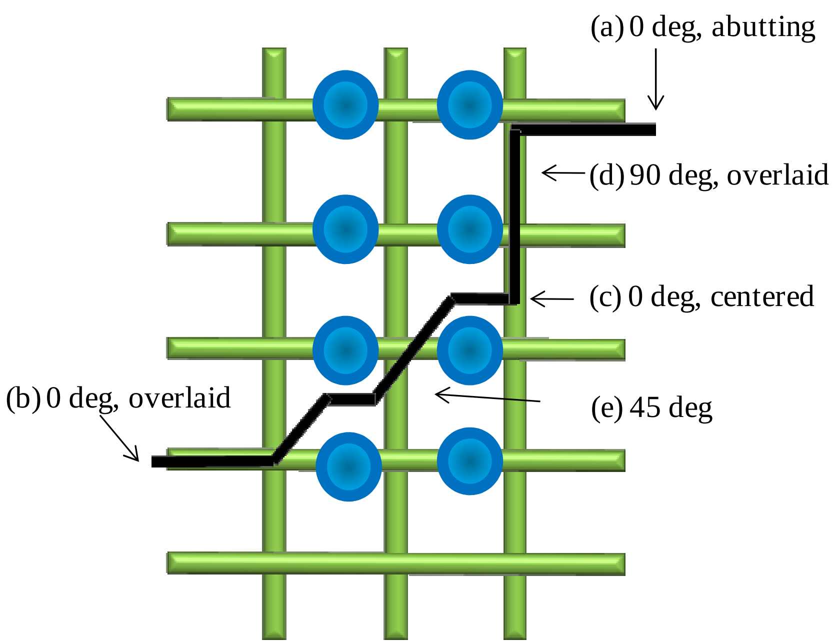
Examining the Dependencies

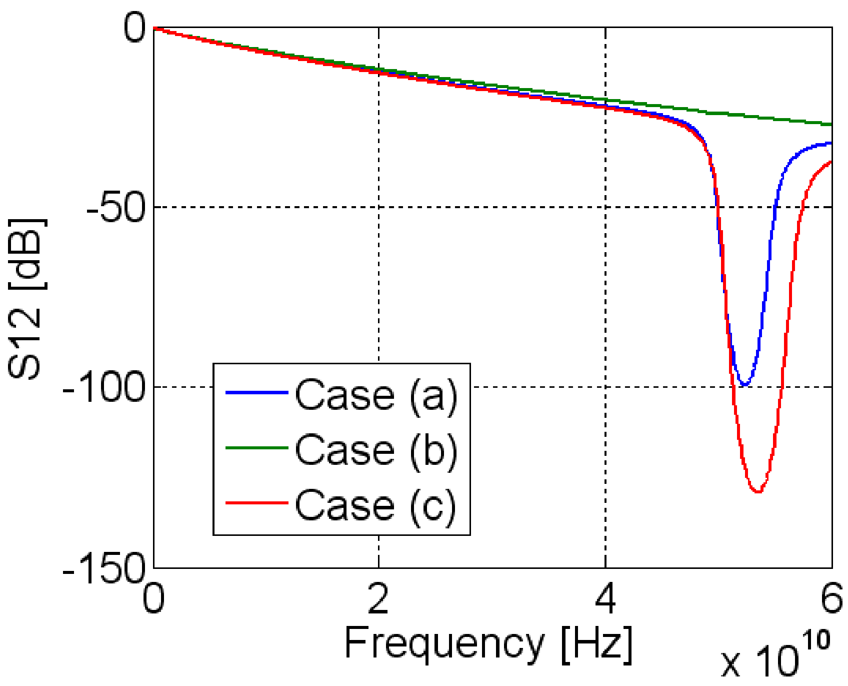
- Examined three Cases (a)-(d); Case (e) will be looked at later (as well as meander routes)
- Created a simplified structure representing a unit cell
- Selected a range of values based on glass types



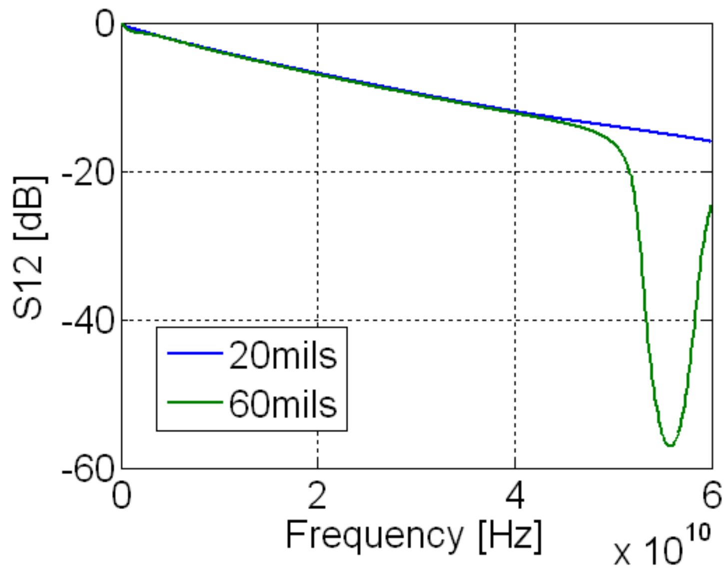


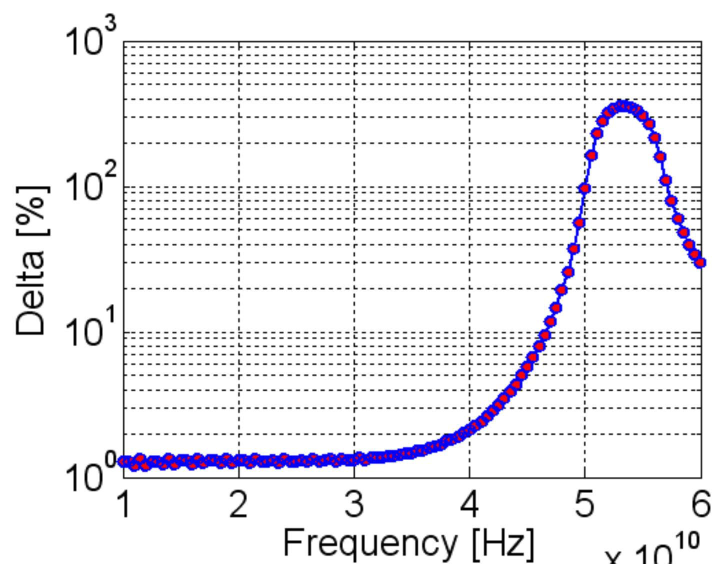
Examining the Dependencies



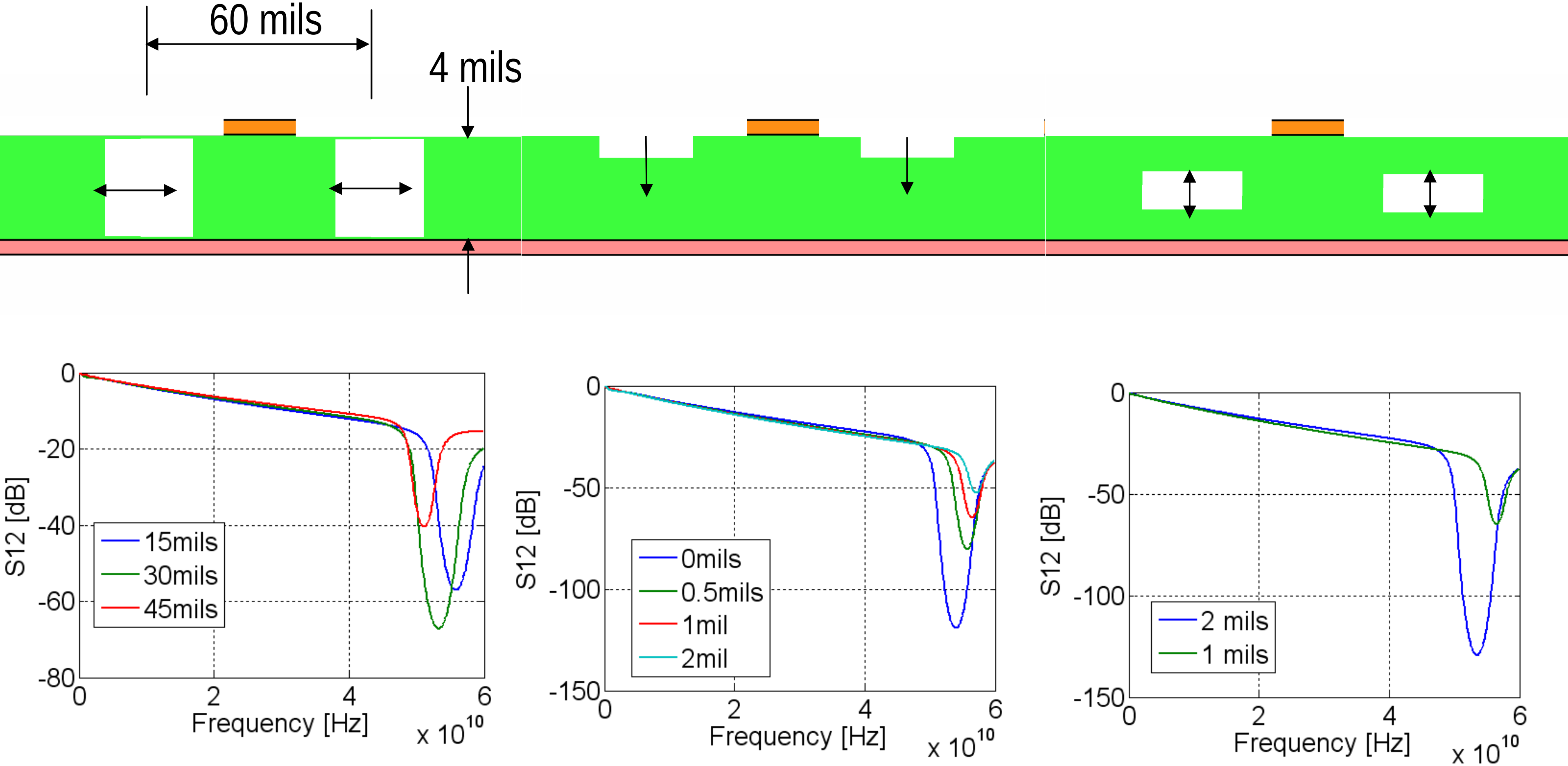


Examining the Dependencies





Examining the Dependencies



Section Summary

- The glass weave resonance frequency corresponds to the half wave resonance distance between bundles (pitch).
- Although the resonance frequency can be relatively high (dependent on the bundle pitch) there is additional low frequency loss due to this resonance.
- Wider bundles, increased weave thickness and closer proximity to the trace increases the magnitude of the periodic resonance
- Going forward, when this resonance is generated by a simple repeating unit cell we call this a single-cell periodicity (SCP)

Agenda

- Examine physical dependencies such as impact of glass thickness, proximity and glass pitch
- Investigate how trace route angle can set up secondary resonance patterns
- Impact of meandering trace routes
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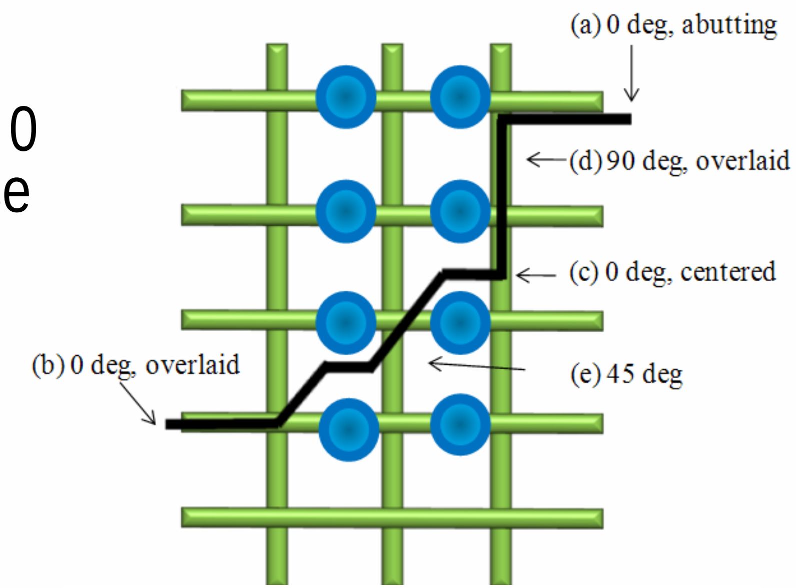
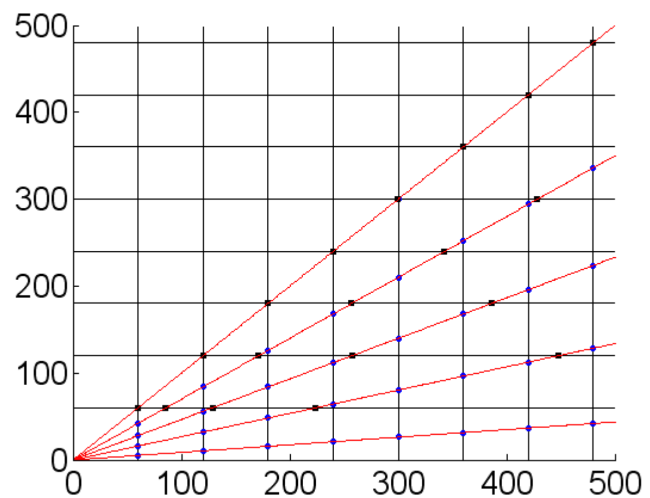
- Conclusions

Impact of Trace Route to Glass Weave Angle

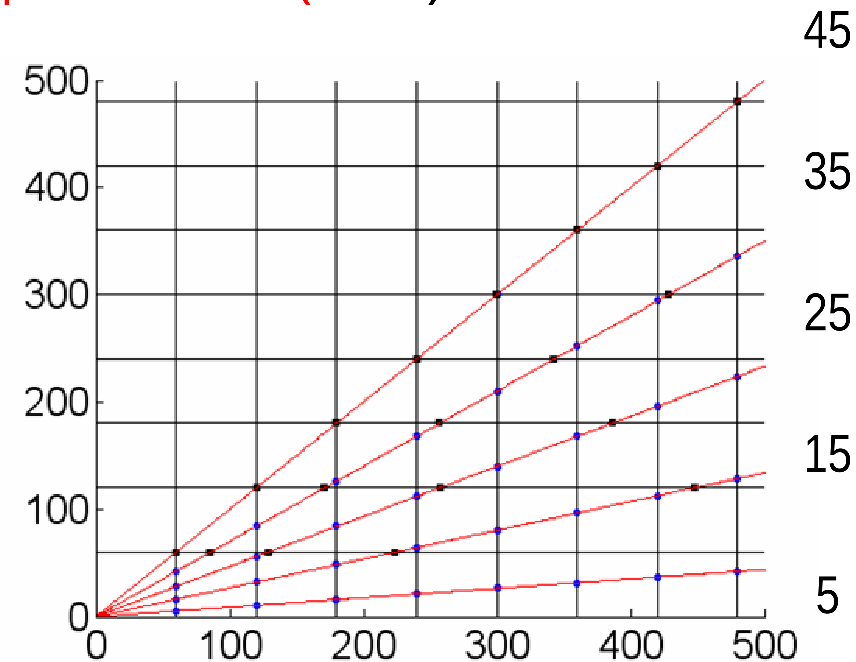
- Looked at traces crossing the weave at 0 or 90 – Cases (a)-(d) – now look at Case (e) and arbitrary angles ($0 < \theta < 45$)
- Due to symmetry, also covers $45<\theta<90$
- Glass weaves are typically oriented parallel to the board edges
- Note that even if a trace is also routed parallel to the board edges (0 or 90), there will likely be some small angle that arises
- For now we look at straight traces only (meandering will be covered later)



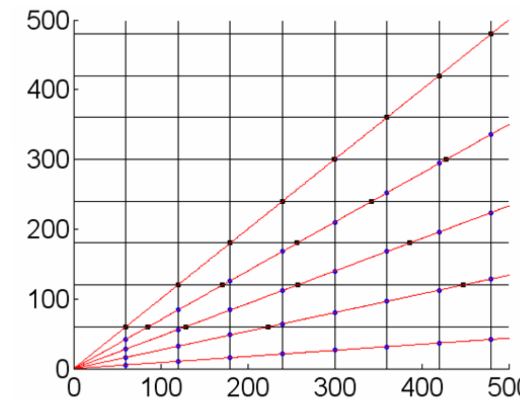


Impact of Trace Route to Glass Weave Angle

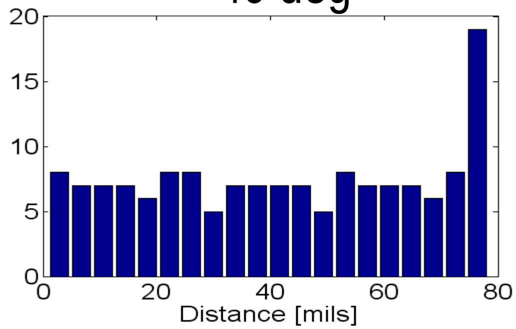
- Example of trace routed in 10 degree steps using Matlab
- 0, 45, 90 only result in a single periodicity (i.e. SCP)
- 45 deg routes will have lowest frequency SCP
- Other angles will have periodicities which span multiple cells – we call these multi-cell periodicities (MCP) – now we look at these in detail



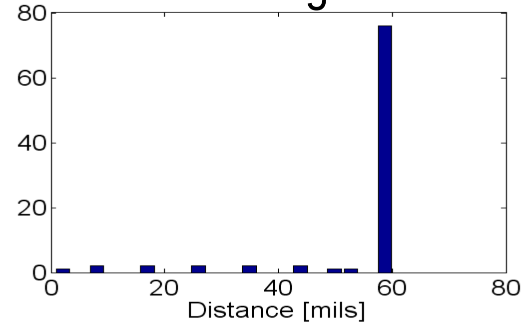
Impact of Trace Route to Glass Weave Angle



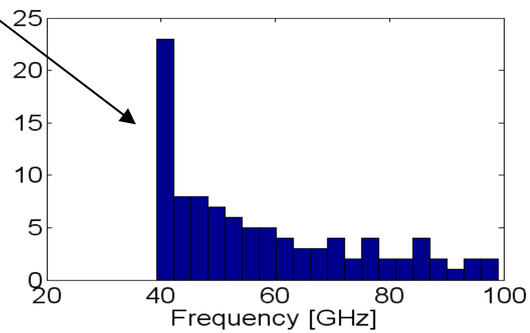
40 deg

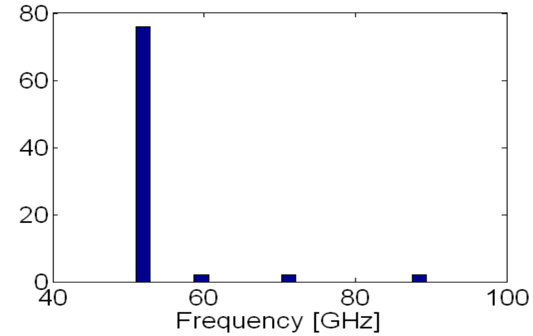


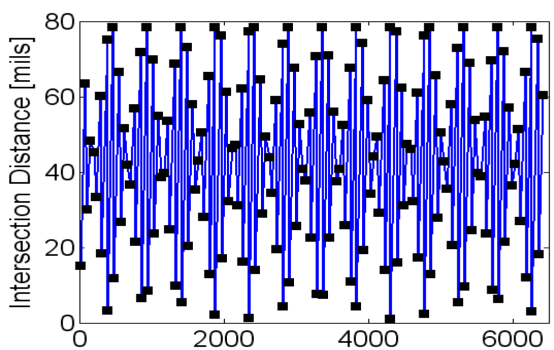
5 deg

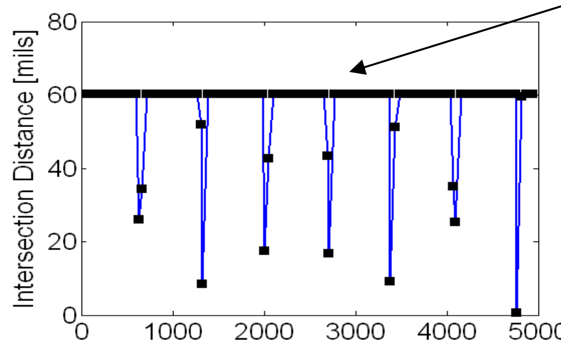


SCP freq decreases as move towards 45 degree







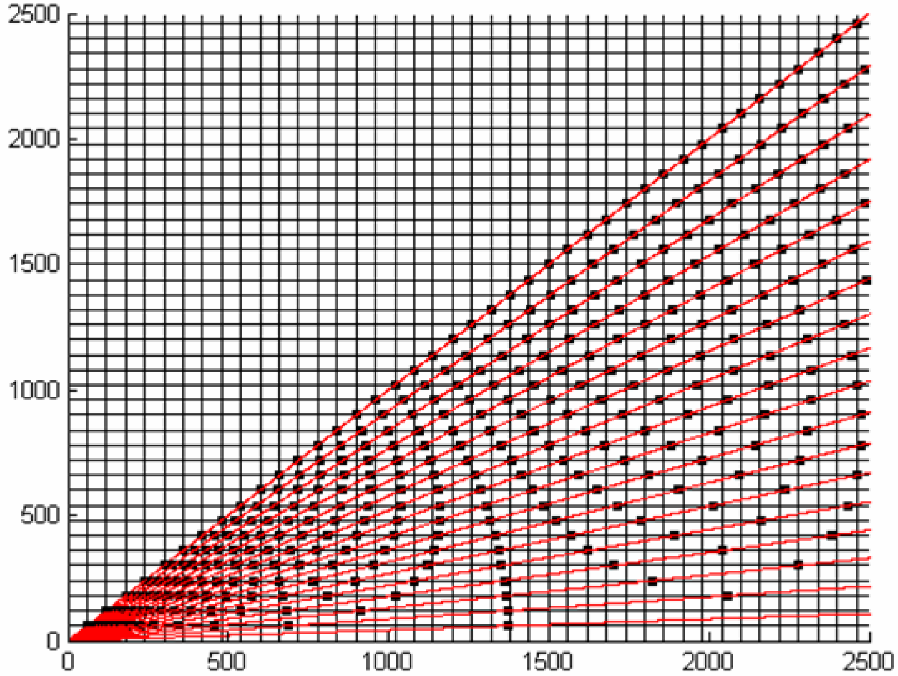


Repeating long range pattern (i.e. MCP)

Separation increases as approach 0 degrees

Impact of Trace Route to Glass Weave Angle

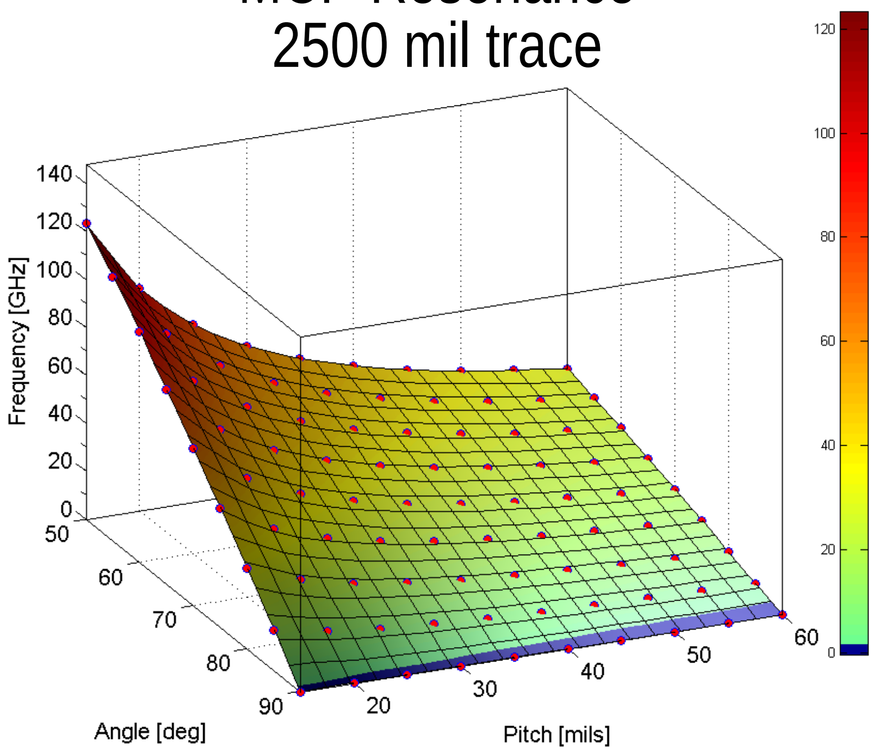
Plot of horizontal crossings for different trace route angles for a 2500 mil trace

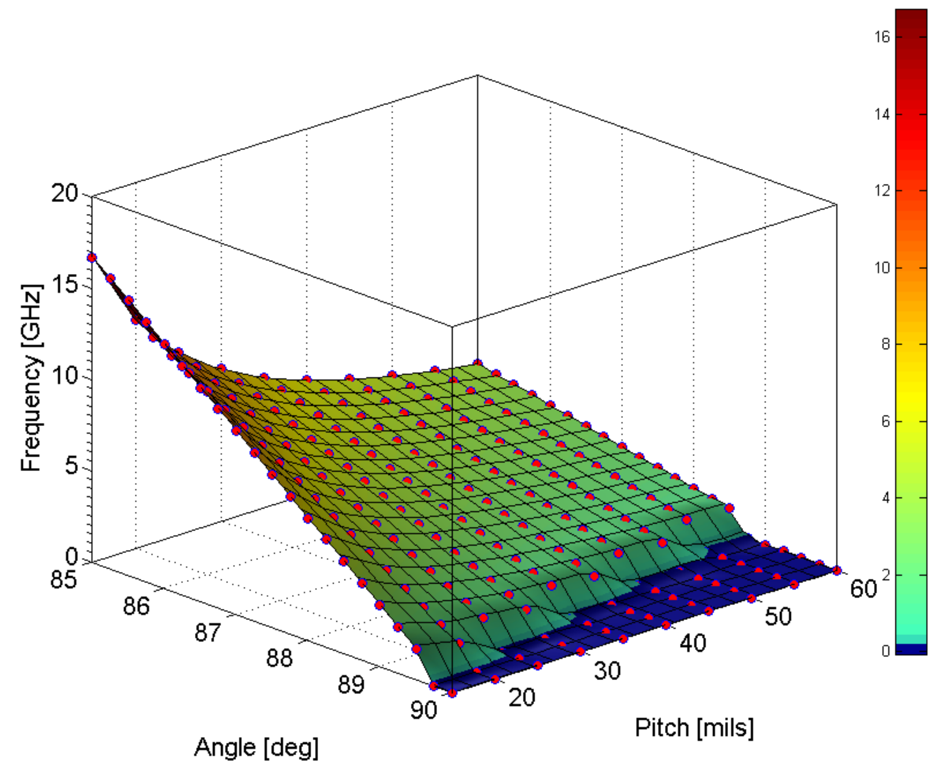


Decreasing MCP resonance frequency

Impact of Trace Route to Glass Weave Angle

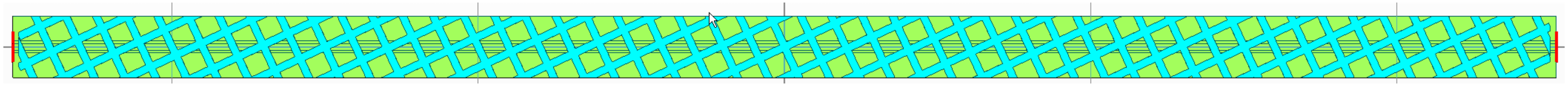
MCP Resonance
2500 mil trace





Impact of Trace Route to Glass Weave Angle

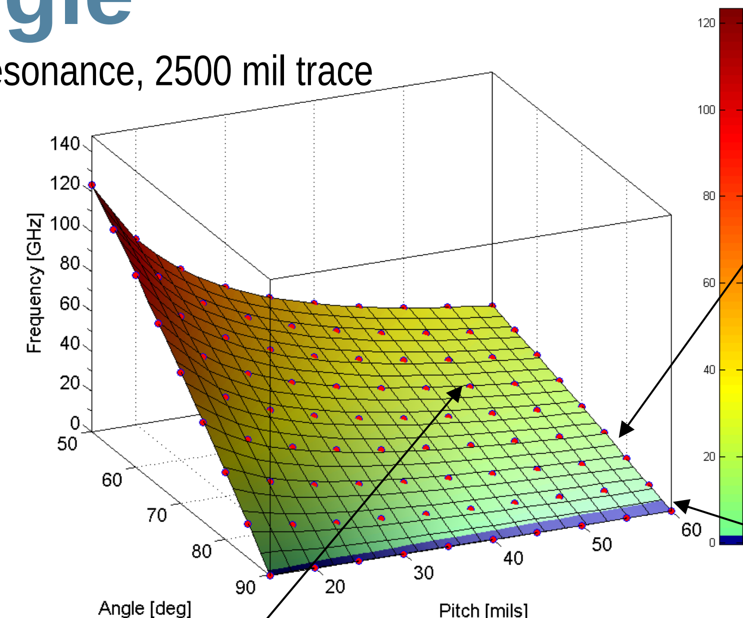
- Surface plots were generated using Matlab, assuming infinitely thin grid and that the long range periodicities could in fact be established
- To validate MCPs (beyond Matlab) we used CST MWS.



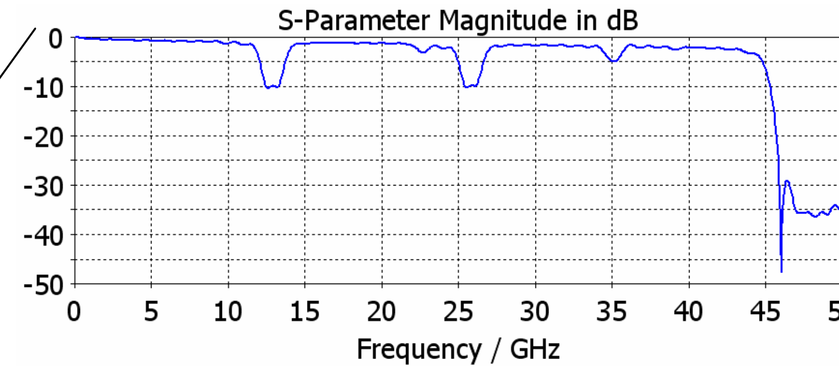
- CST allowed us to simulate the whole route, without resorting to concatenating unit cells in HFSS

Impact of Trace Route to Glass Weave Angle

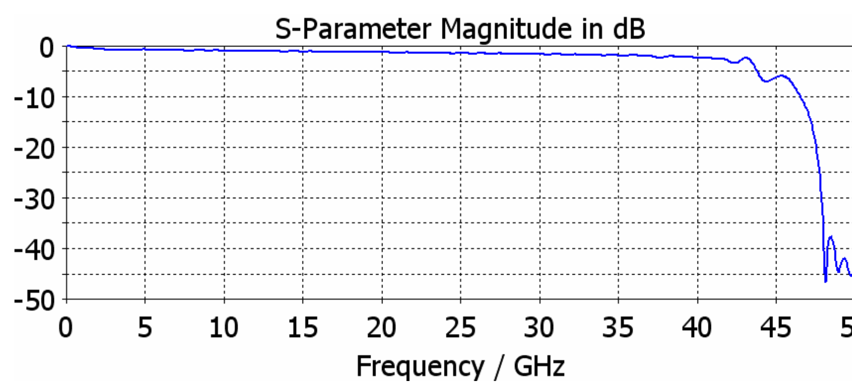
MCP Resonance, 2500 mil trace



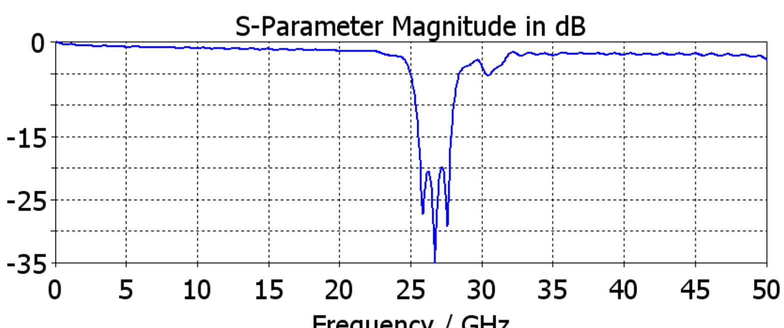
(θ=75, pitch=60, Zres=12.4G)



(θ=88, pitch=60, Zres=SCP)



(θ=60, pitch=50, Zres=28G)



Section Summary

- The lowest possible SCP is with a 45 degree route for a square grid
- When the angle between the glass and trace is other than 0, 45 and 90 degrees it is possible to observe a much lower frequency periodic loading. This type of periodic loading is called Multi-Cell Periodicity (MCP).
- Glass-weave pitch and route angle determine the MCP resonance frequency (as well as the dielectric constant).
- The lowest MCP resonance frequency occurs with widely pitched glass-weaves and trace route angles close to 0 (or 90) degrees.

Agenda

- Examine physical dependencies such as impact of glass thickness, proximity and glass pitch
- Investigate how trace route angle can set up secondary resonance patterns
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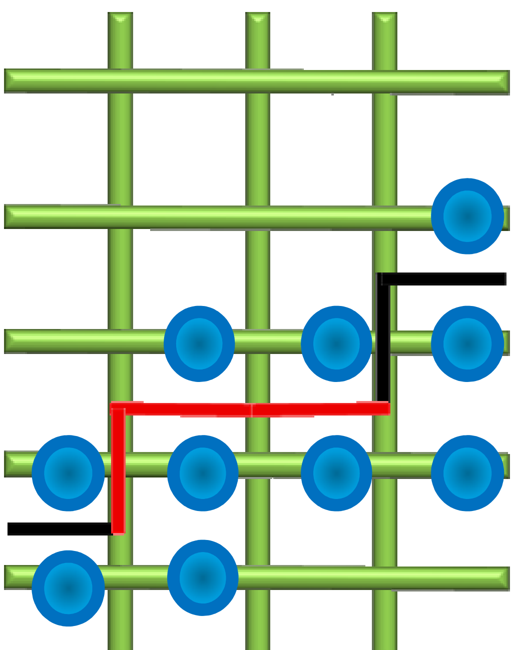
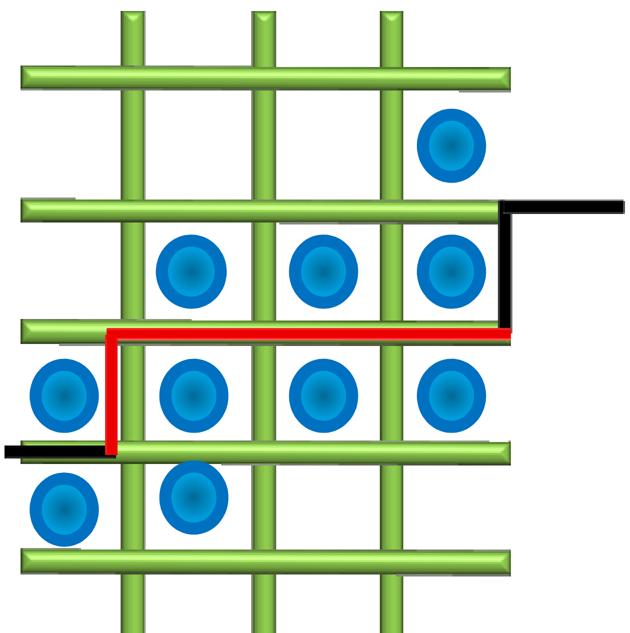
Impact of meandering trace routes

- MCP resonances are created when the trace is slanted with respect to the glass bundles, creating periodicity over several or many glass-weave cells.
- MCP can be introduced even if the trace is not slanted due to the trace routing itself. Consider a trace routing through a BGA pin field with plated through hole (PTH) vias





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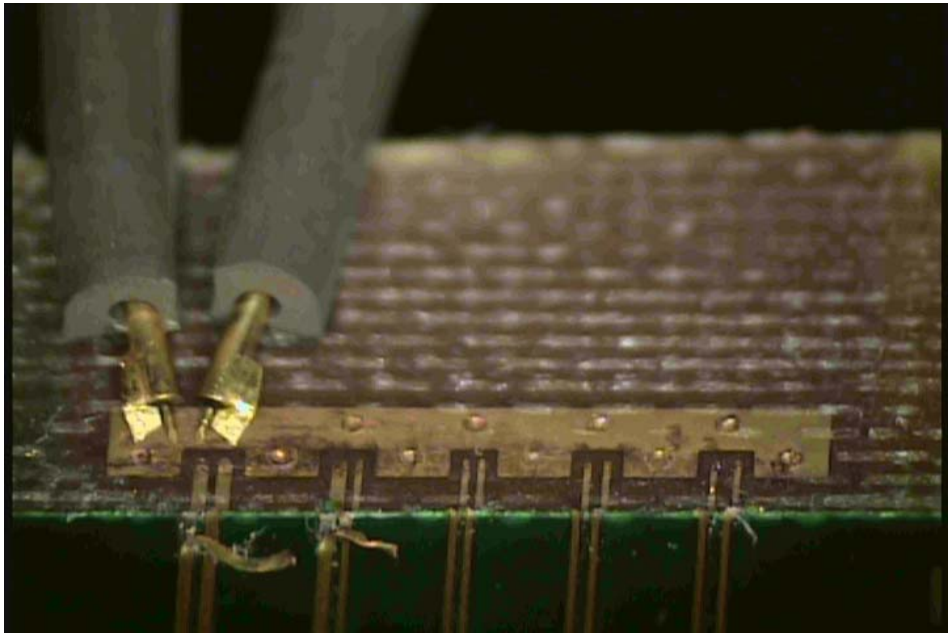
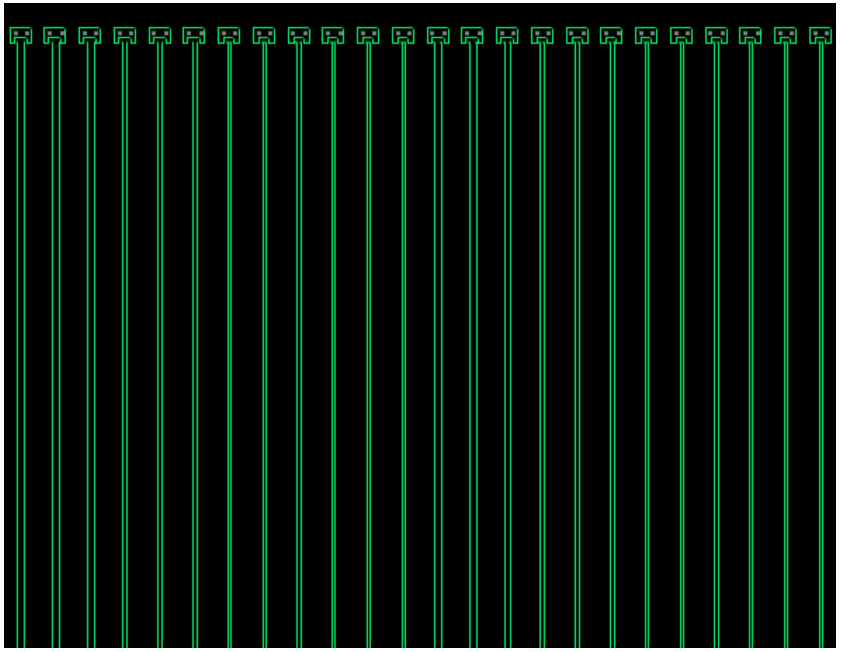
Test Structure Measurements

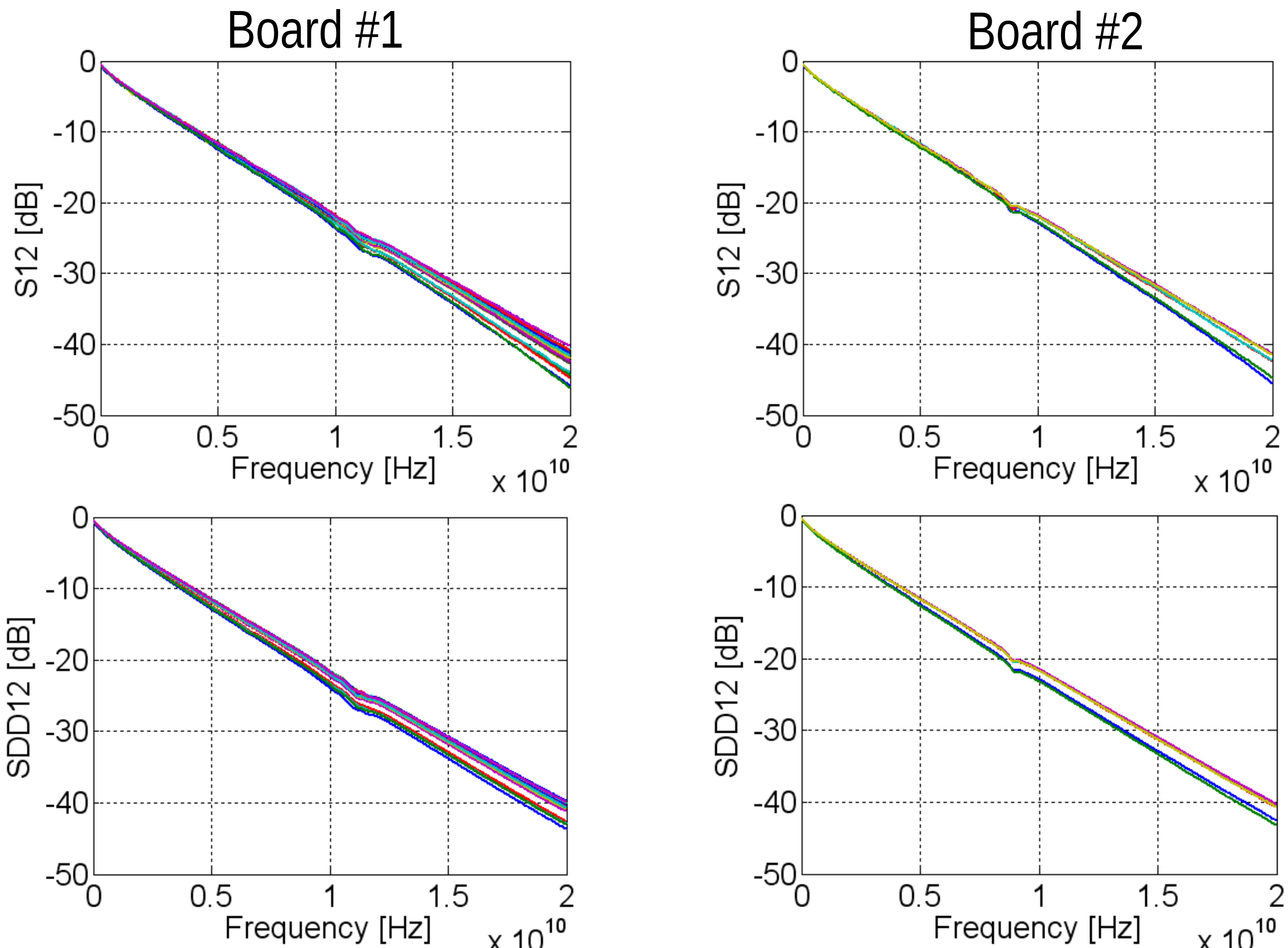
- Test board was designed with 14-inch differential pairs routed parallel to the board edge on different layers and different pitches
- Striplines pairs were measured using VNA to 20 GHz





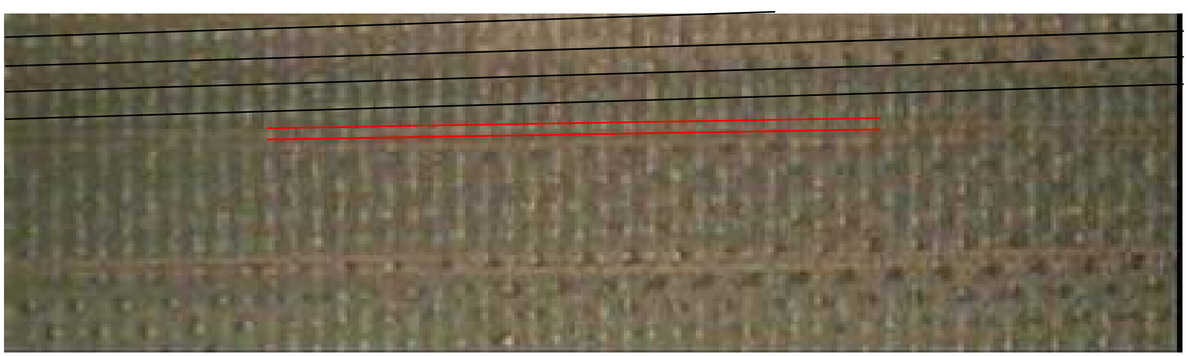
Test Structure Measurements

Two ‘identical’ boards showed resonances at 11.1 GHz (board #1) and 8.9 GHz (board #2)



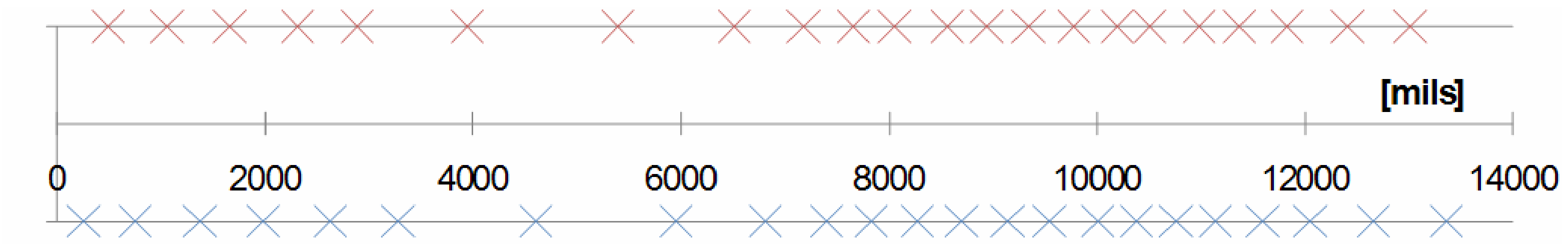
Test Structure Measurements

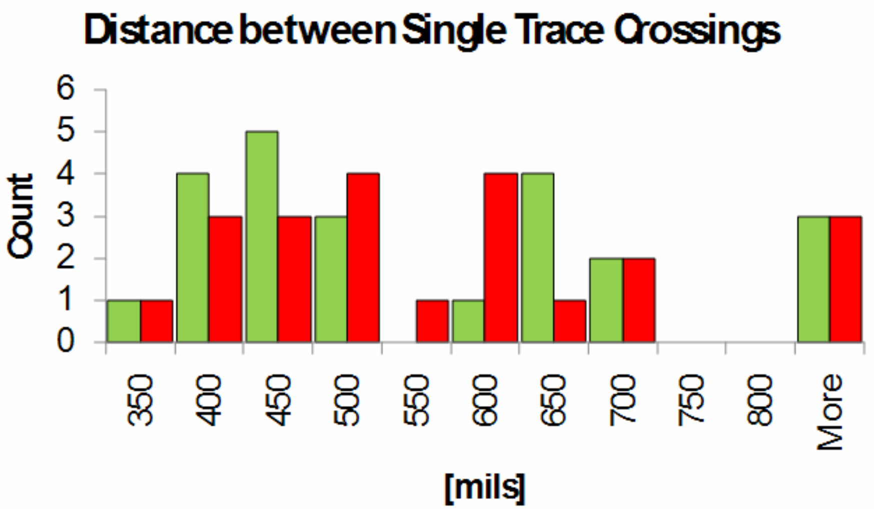
- Test board #1 was milled down from opposite sides
- Can then measure where parallel bundles cross each side of the differential pair



Test Structure Measurements

Distance between parallel bundle crossings (either side of the diff pair)

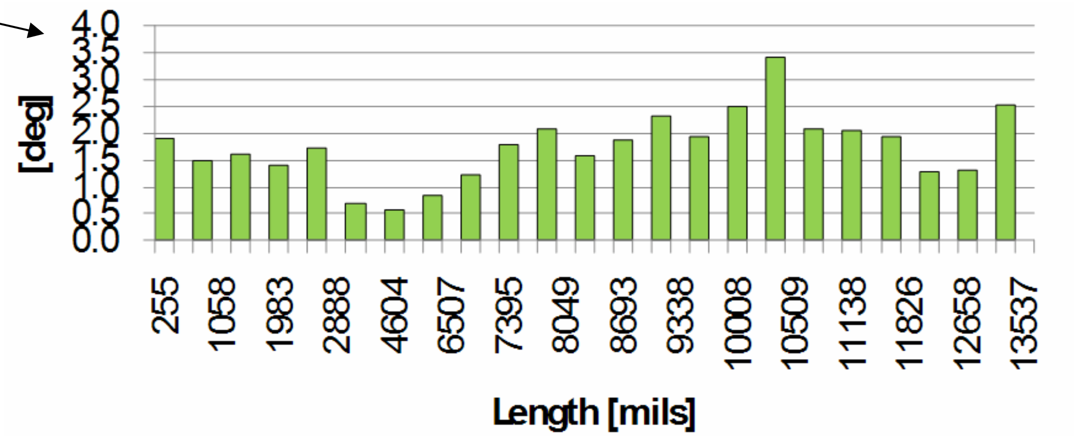


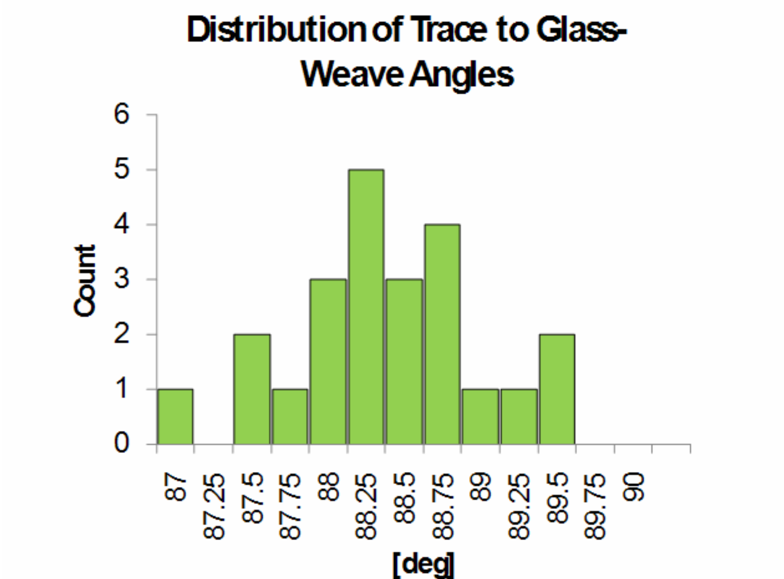


Test Structure Measurements

Nominally 90 but varies up to 4 deg!

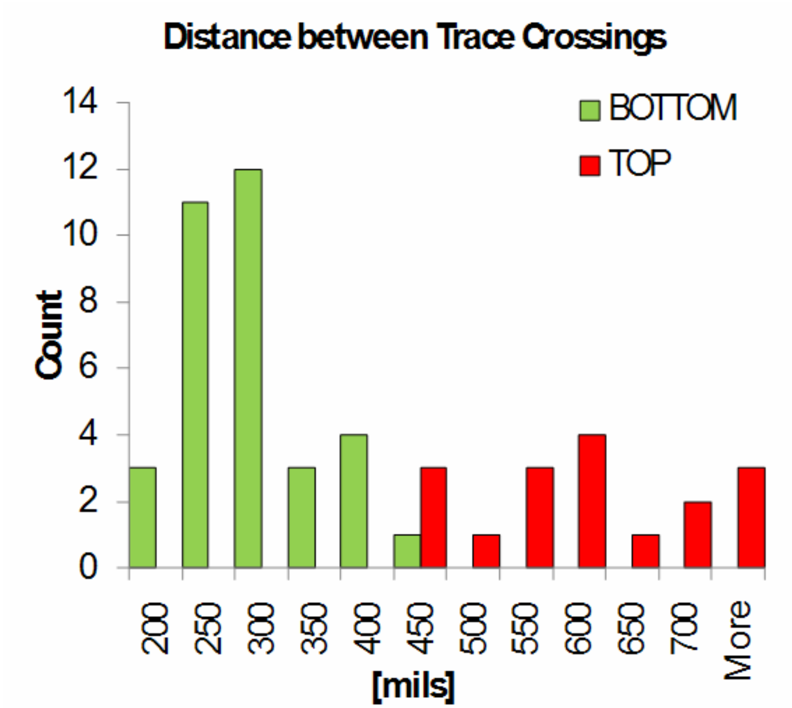
Also not constant angle!



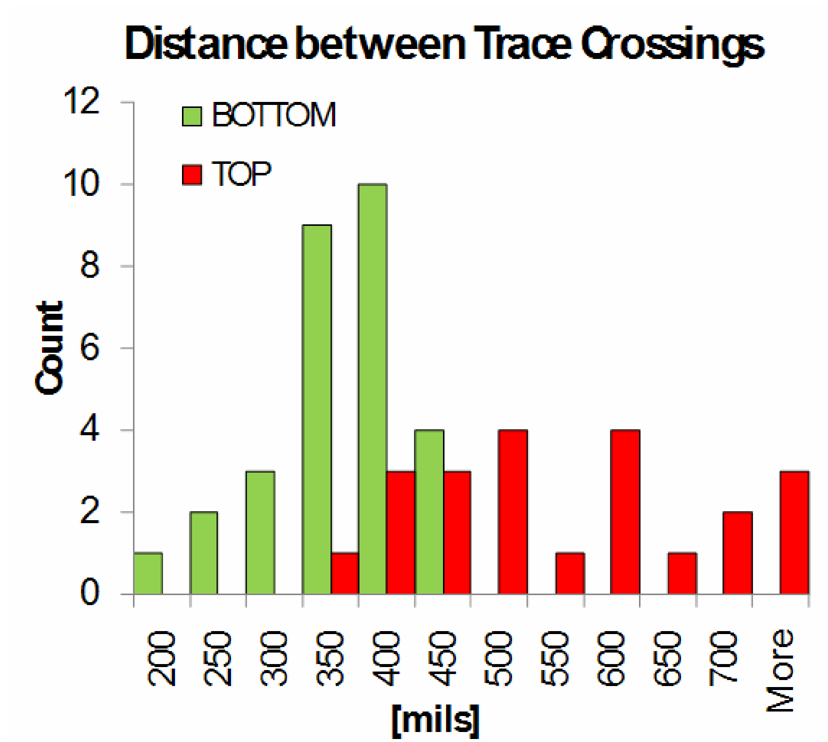


Test Structure Measurements

Board #1

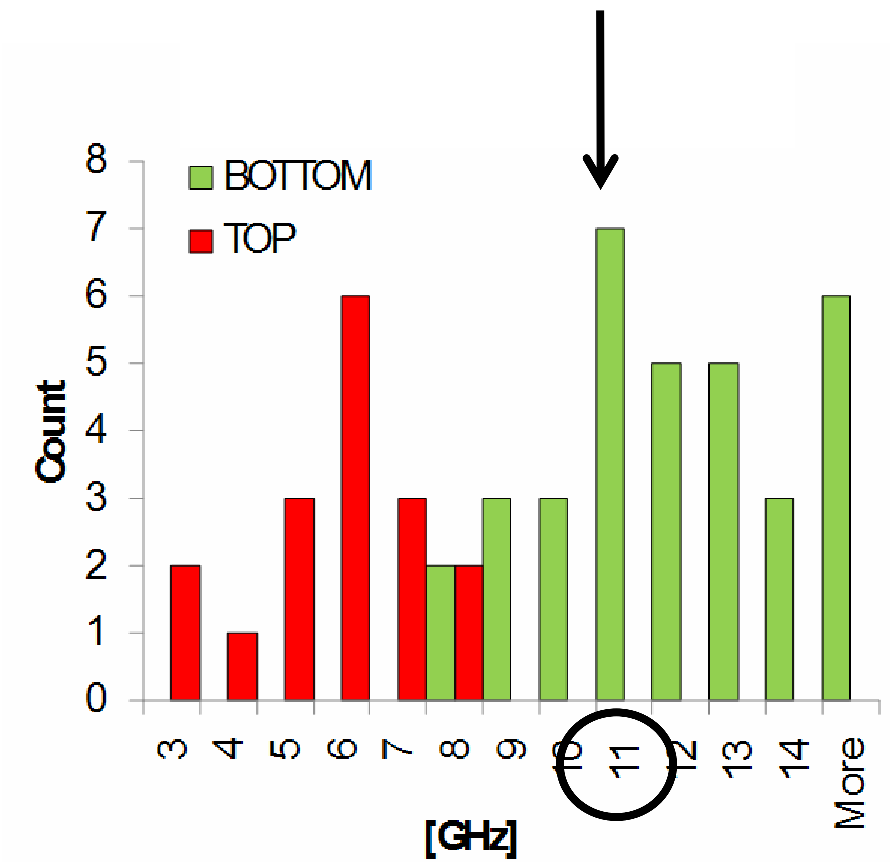


Board #2

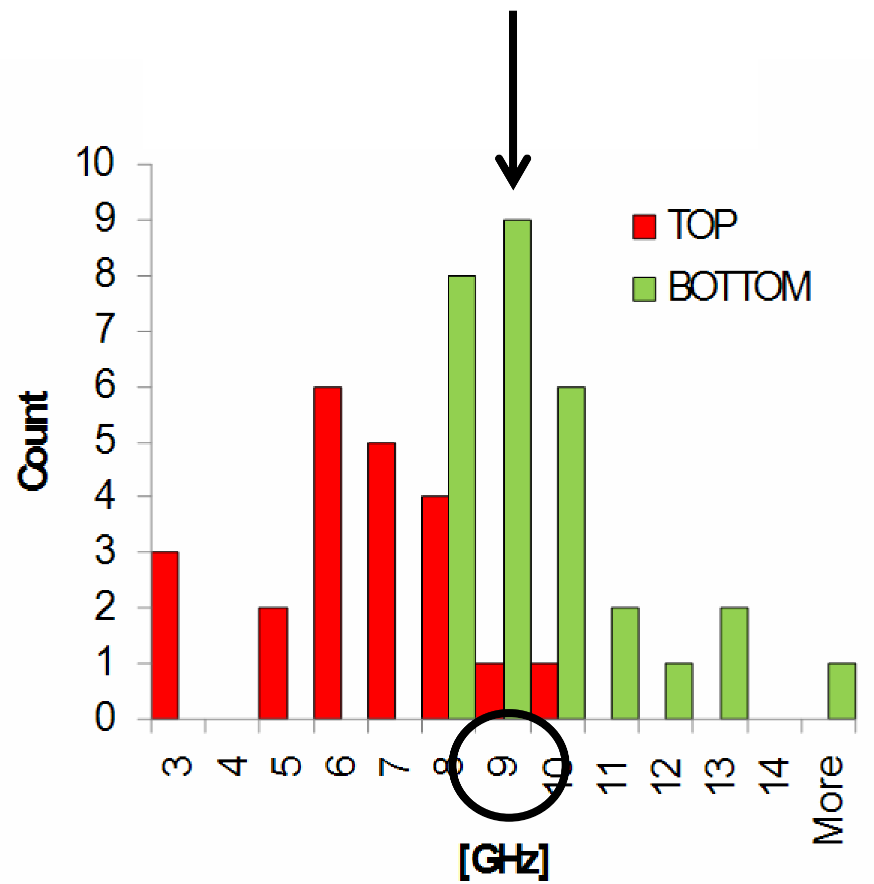


Test Structure Measurements

Board #1



Board #2

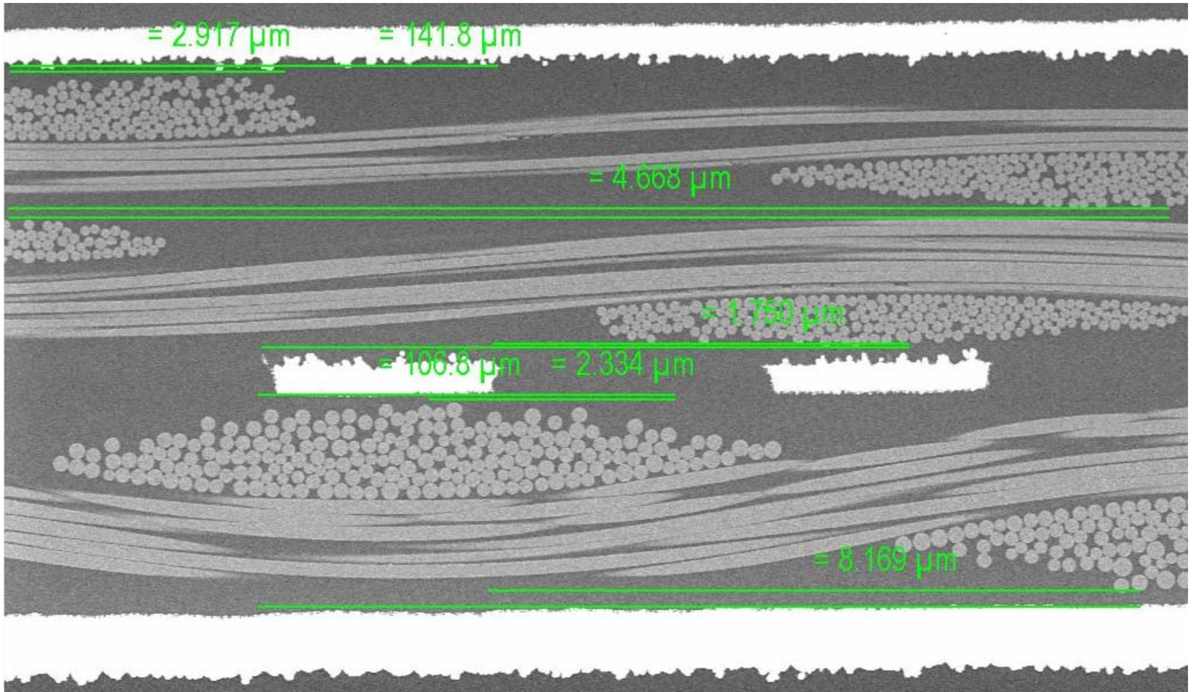


Test Structure Measurements

SEM data confirmed two suspicions:

> Upper level dielectric are fairly well aligned (consisting of two independent weaves)

> Vertical separation of glass from trace is very small (~0.1mils) (which we know increases the glass weave resonance)



Section Summary

- Trace to glass-weave routing angle can vary by layer and can be different above and below the trace.
- Trace to glass-weave routing angle can vary along the trace length
- A wide distribution of resonances can be introduced due to the variation in glass-weave angle along the trace's length.
- Measurement results showed an insertion loss dip at two different frequencies on two otherwise identical boards, which showed correlation to the distribution of MCP trace crossings.

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Conclusions

- Identified a new trace loss mechanism due to glass-weave periodicity
- Glass-weave periodic loading was demonstrated using physical measurements and s-parameter measurements of test boards, field solvers (CST and HFSS) and Matlab simulations
- Two terms identified: SCP and MCP
- SCP have a high resonance frequency but there is additional loss below fundamental
- MCP come about when longer range unit cells are established introducing much lower resonances

Conclusions

- 45 degree routes are preferred to minimize differential skew but results in lowest SCP
- 0 and 90 degree routes, on the other hand, have their own issues due to MCPs
- Glass-weave routing angle was found to vary layer by layer and along the entire length of the trace
- Due to the random nature of the weave simulating this effect a priori is not feasible

Conclusions

Possible mitigation strategies:

- Tightening the weave by spreading out the glass fabric
- Increase resin Dk
- Decrease glass Dk
- Randomized routing angle
- Randomized jogging patterns

THANK YOU!