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Quantifying Glass Induced Skew on Printed Circuit Boards

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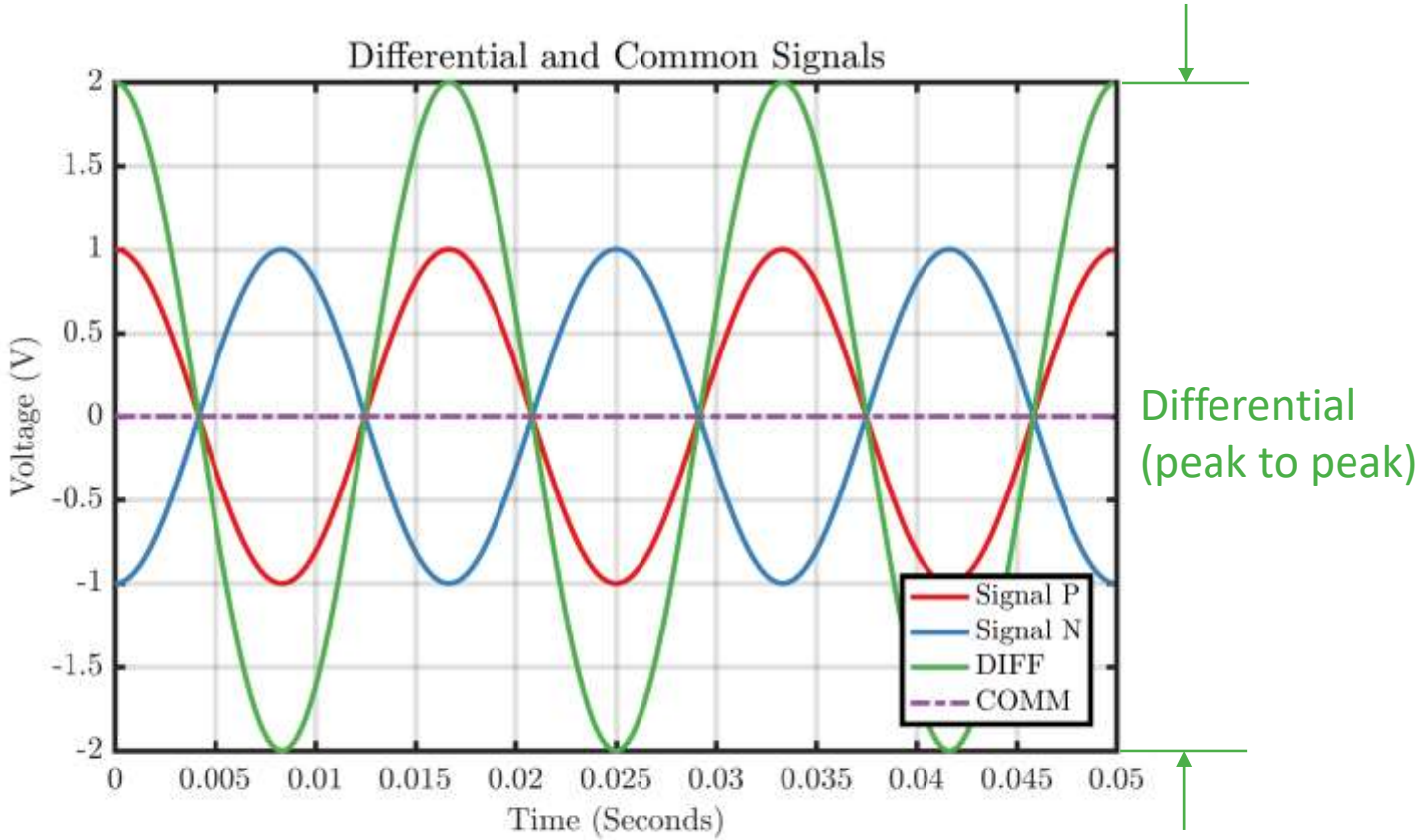
INTRODUCTION

- PCB laminates are composites (resin + glass weave)
- Mechanically spread, square weave glass fabrics exist
- Signal velocity changes with material
- How much differential skew on mechanical spread weave?
- One mitigation option explored
- Measurements based

Ideal Differential Signal

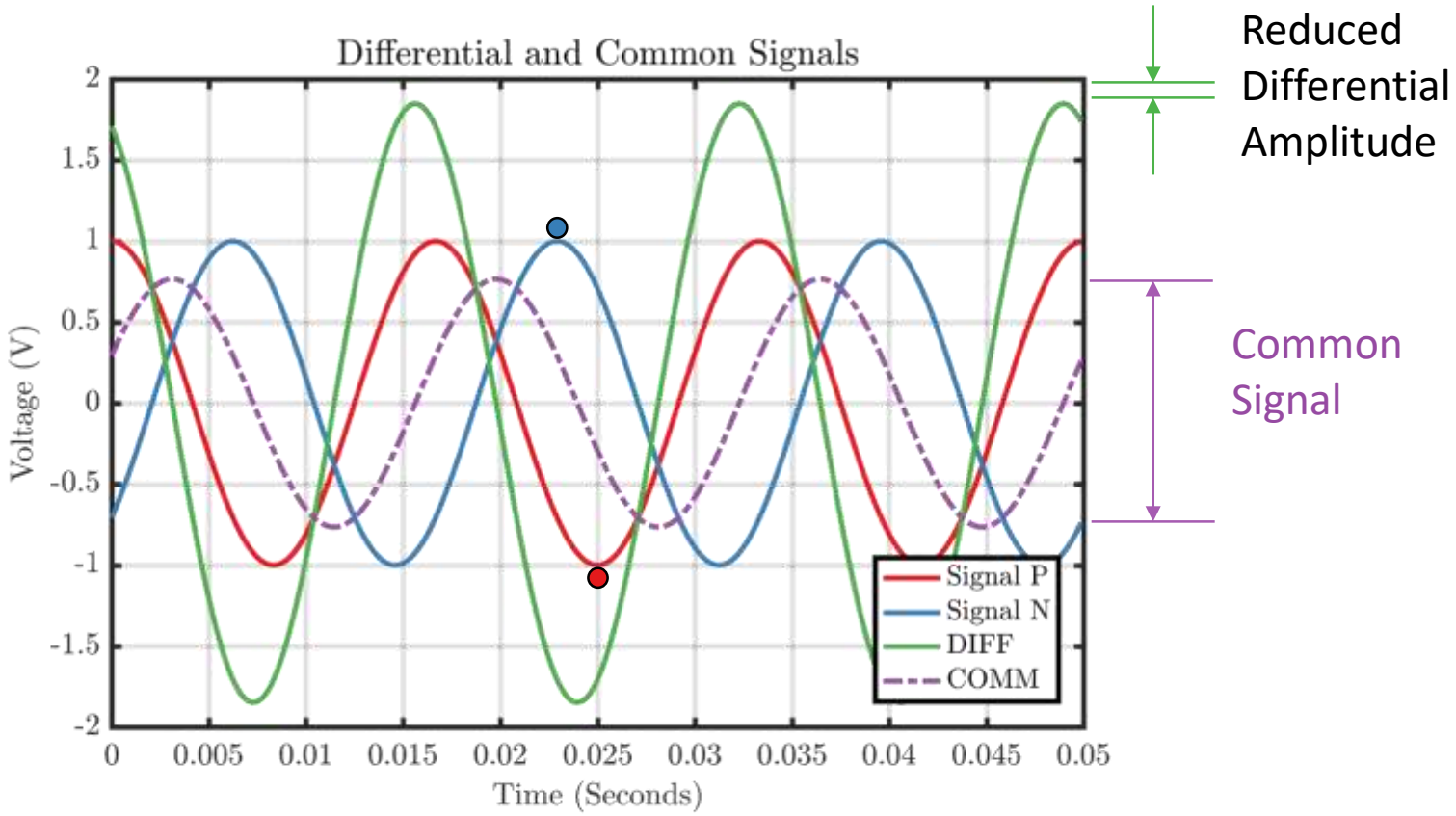
Signal P – Signal N perfect alignment

- Differential amplitude is twice signal ended amplitude
- No common mode



Ideal Differential Signal with Skew

- Misalignment (skew)
- Reduced differential amplitude
- Creates common mode

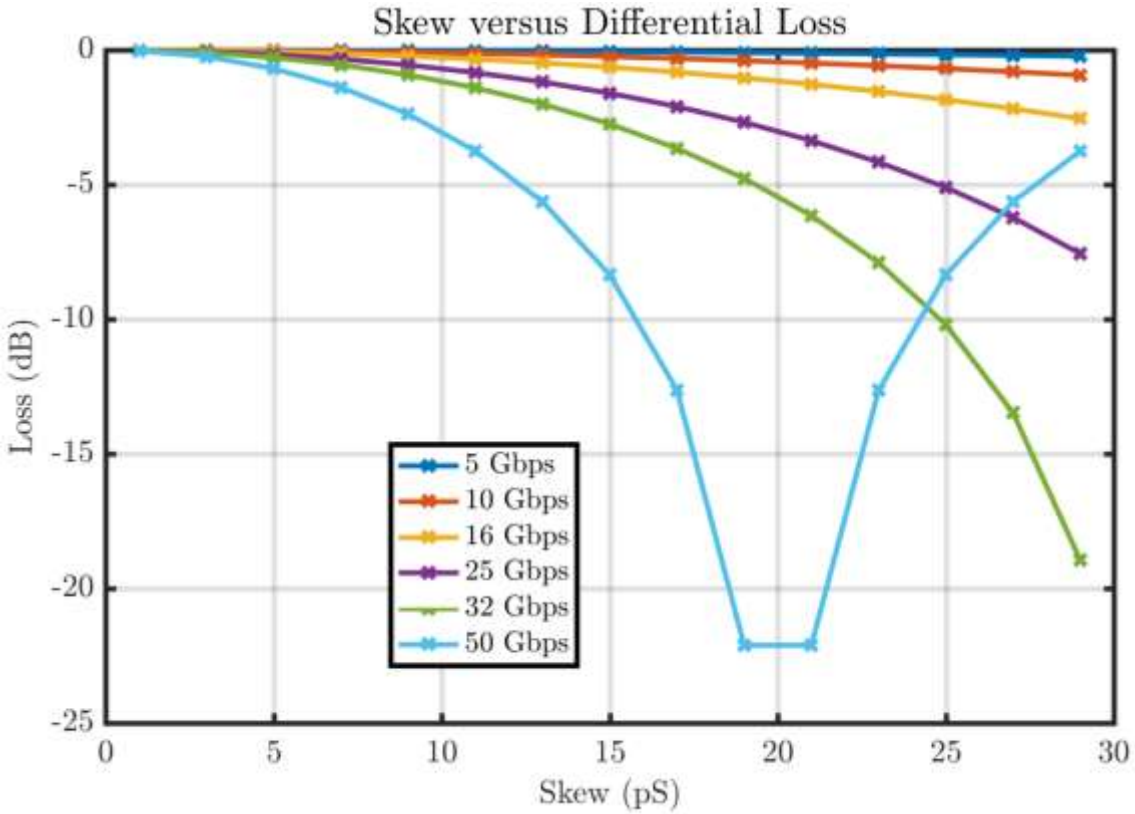


Impact on Differential Attenuation

- Bound additional loss from skew
- Assuming sinusoidal signals
  - Not how signaling is done for data bus
- 50 Gbps (25 GHz)
  - 5 pS ~ 1 dB (11%)

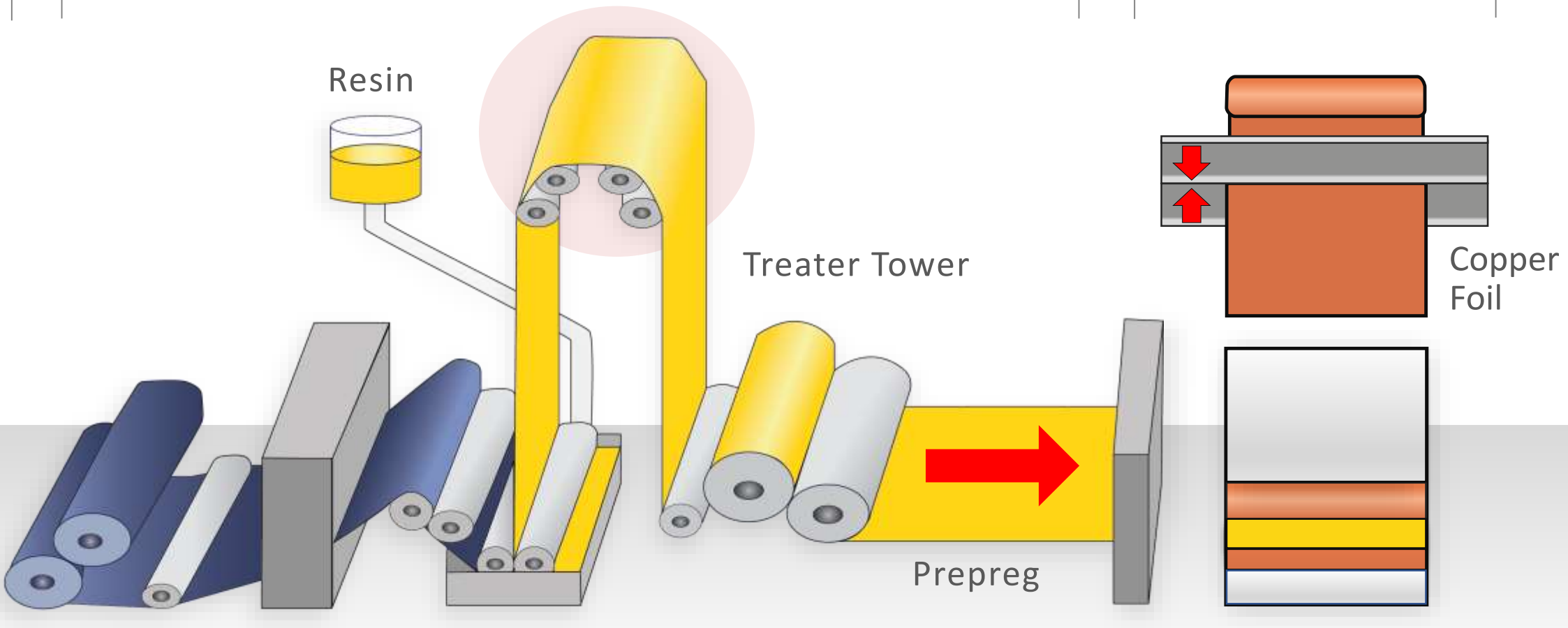
$$20log\left[cos\left(\frac{Delay\ *\pi}{2\ *UI}\right)\right]$$

$UI\ in\ pS$
$Delay\ in\ pS$



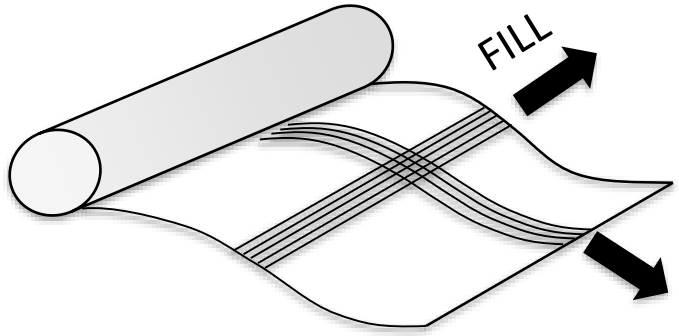
Laminate Manufacturing

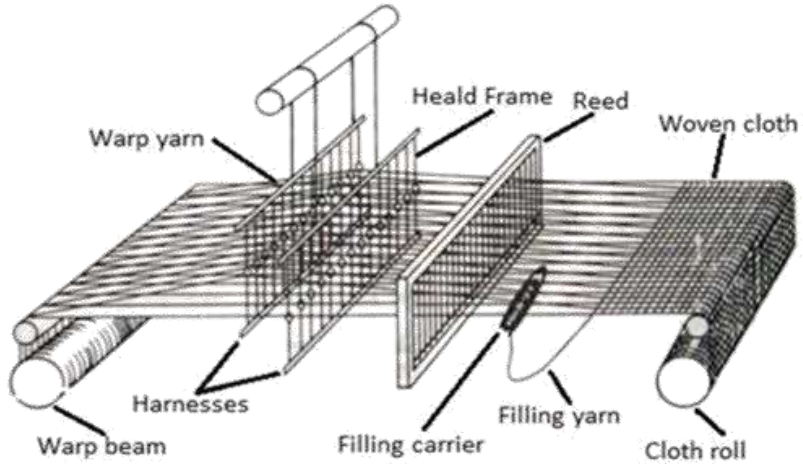
RAW MATERIALS | **IMPREGNATION** | **LAY-UP**



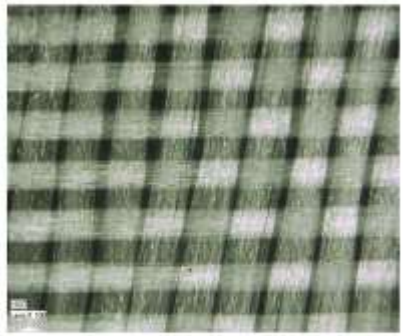
https://www.isola-group.com/wp-content/uploads/Understanding-Laminate-Prepreg-Manufacturing.pdf

Weaves (GRAIN\WARP and FILL)





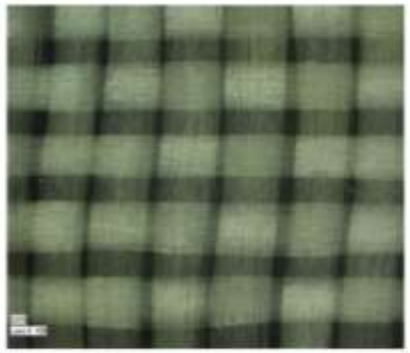
isola **Woven Glass Fabric**



1035
Warp & Fill Count: 66 x 68 (ends/in)
Thickness: 0.0011" / 0.030 mm

Photos courtesy of Isola R & D Laboratories

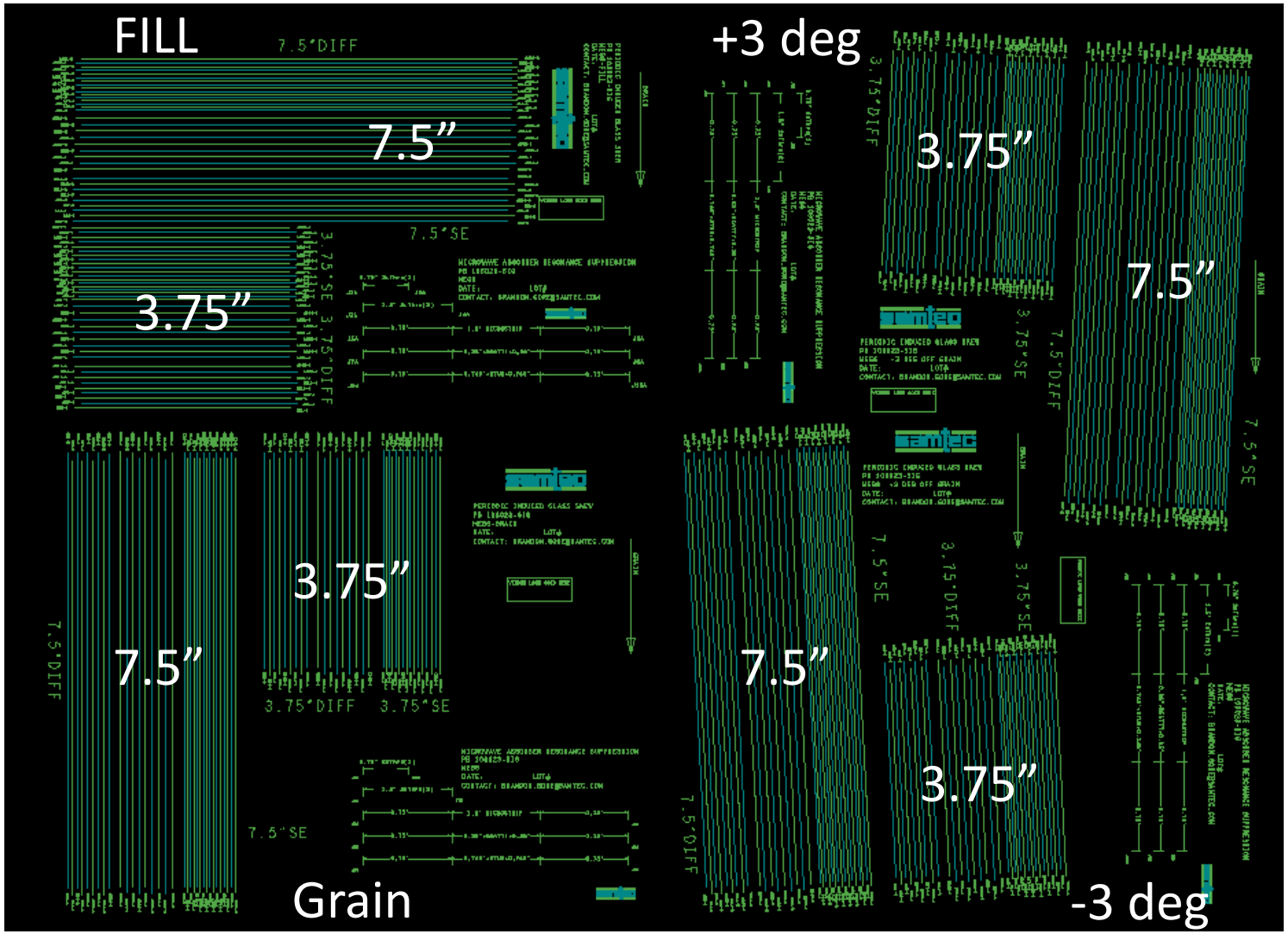
isola **Woven Glass Fabric**



1078
Warp & Fill Count: 54 x 54 (ends/in)
Thickness: 0.0017" / 0.040 mm

Photos courtesy of Isola R & D Laboratories

Glass Characterization Test Vehicle



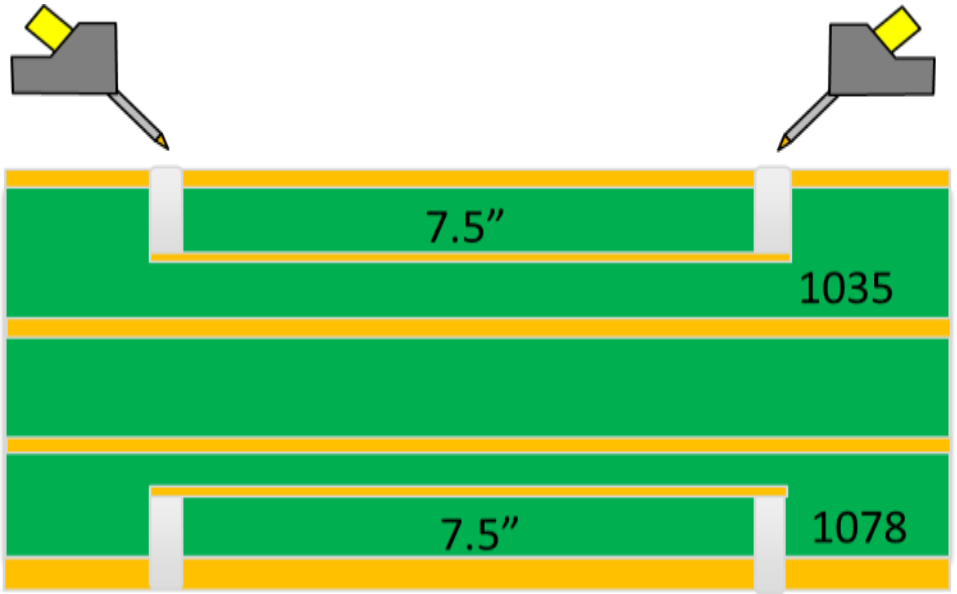
VNA measurements

- Layer 2 and Layer 5 routing
- Via-in-pad, optimized launch

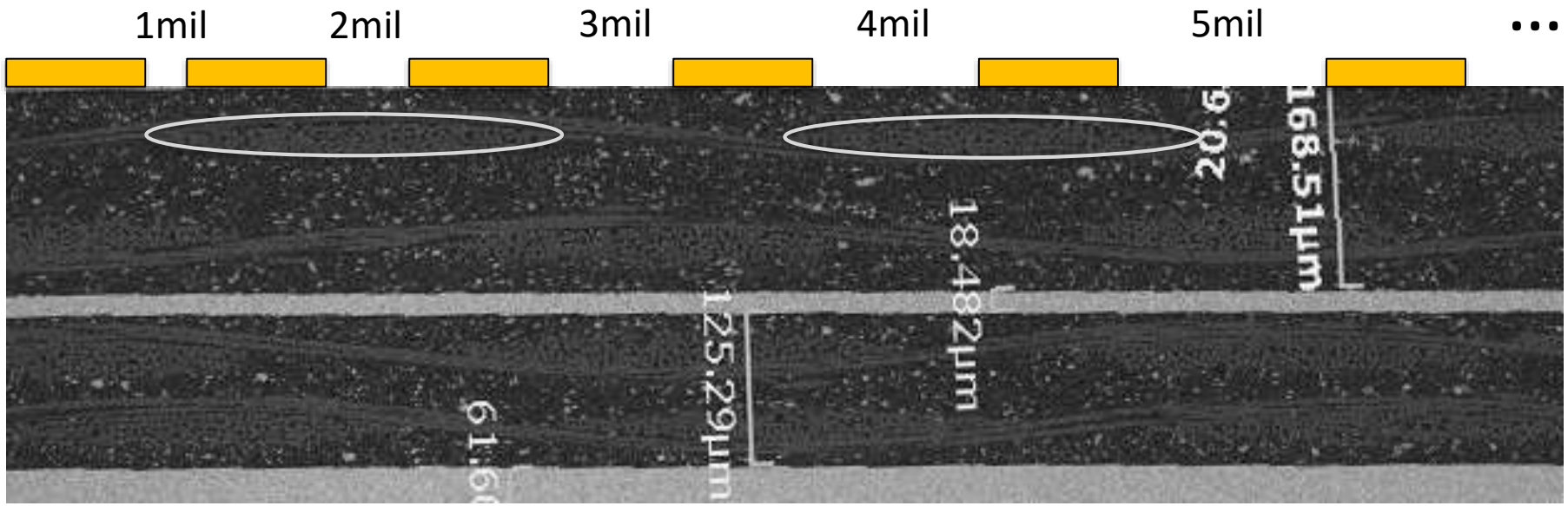
Dense probe sites

- 450um pitch G-S-G micro probes
- Layer 2 and Layer 5 routing

Panasonic MEGTRON 6



Increment to Measure Skew



Offset to avoid tight trace coupling and accommodate probing footprint

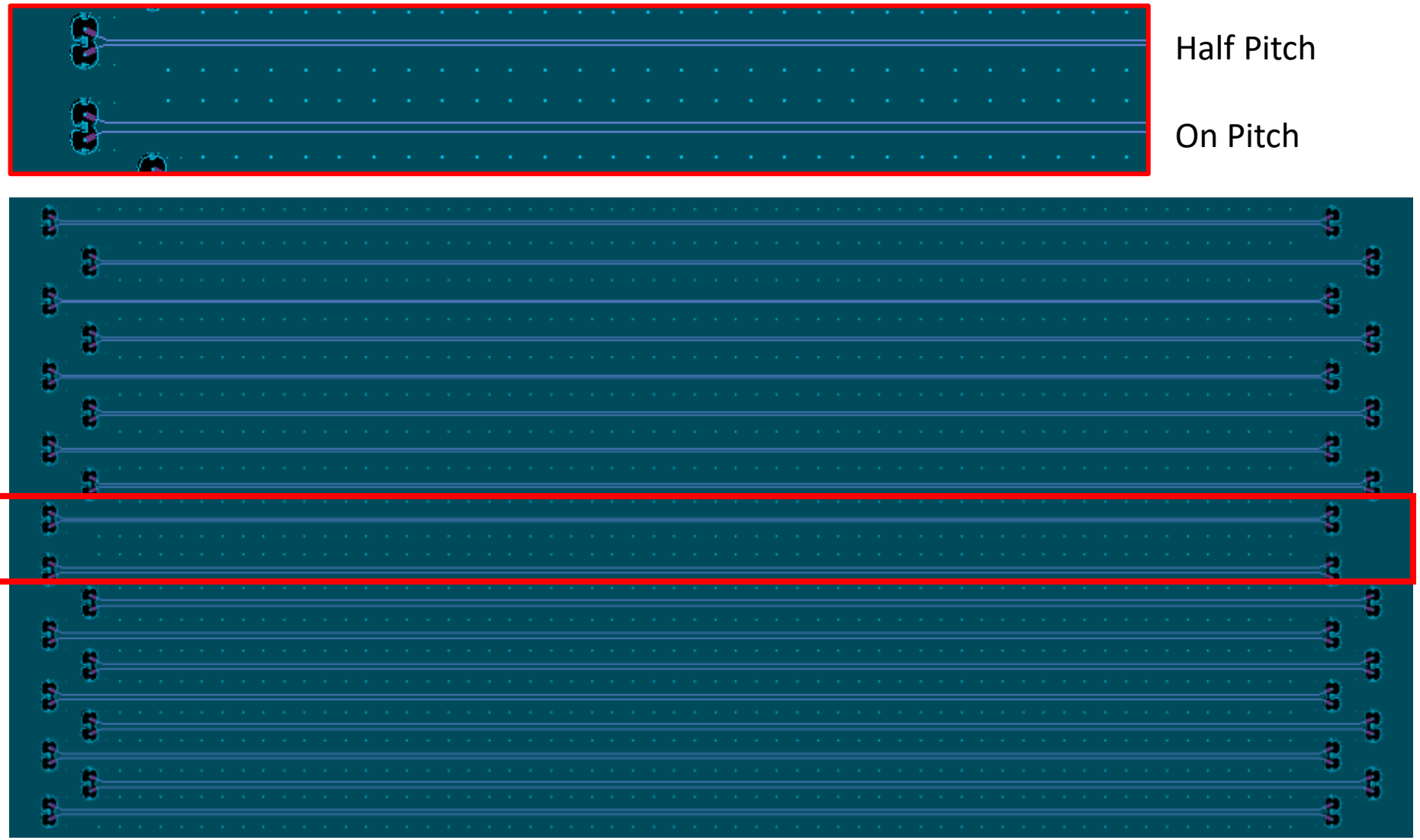
Number of measurements equal to glass pitch

- 1035 -> 16 increments
- 1078 -> 19 increments

Target trace width \ glass pitch

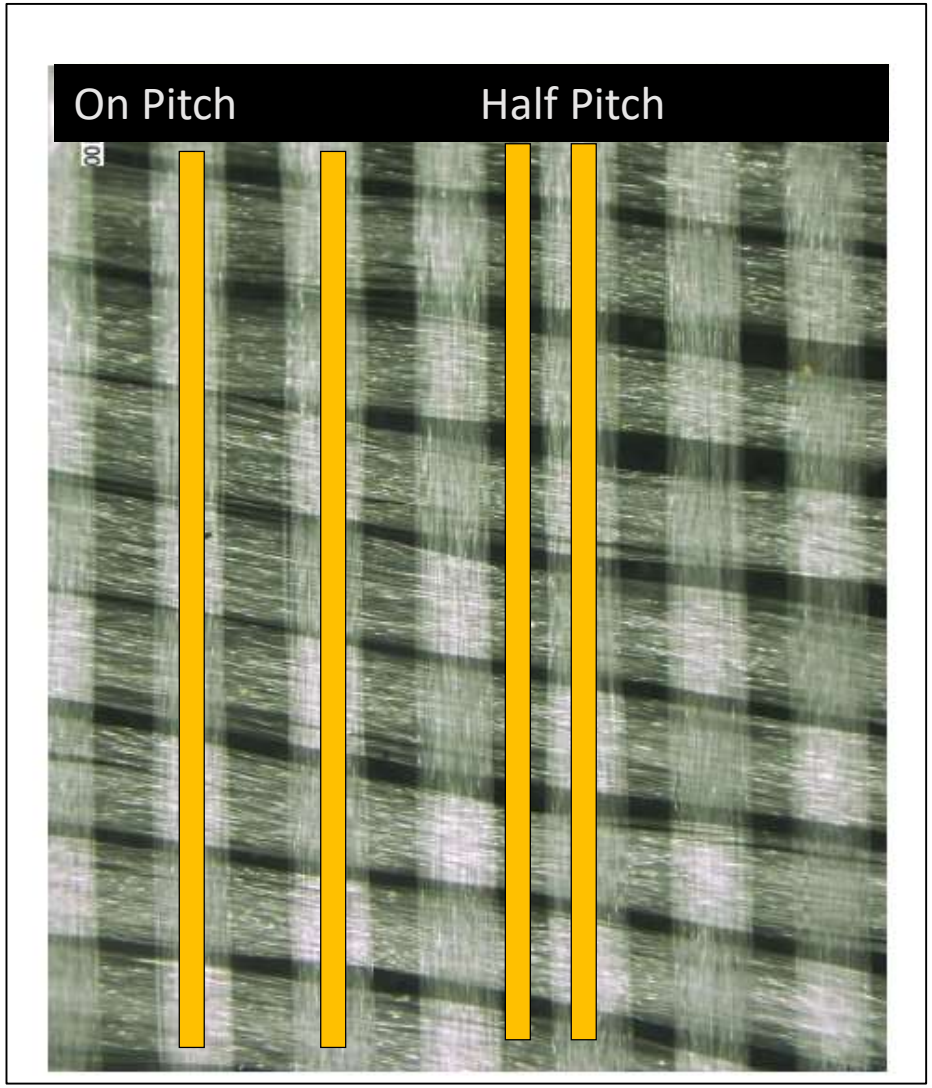
- 4.75\14.7 = 32.3%
- 5.75\18.5 = 31.2%

Differential Experiments

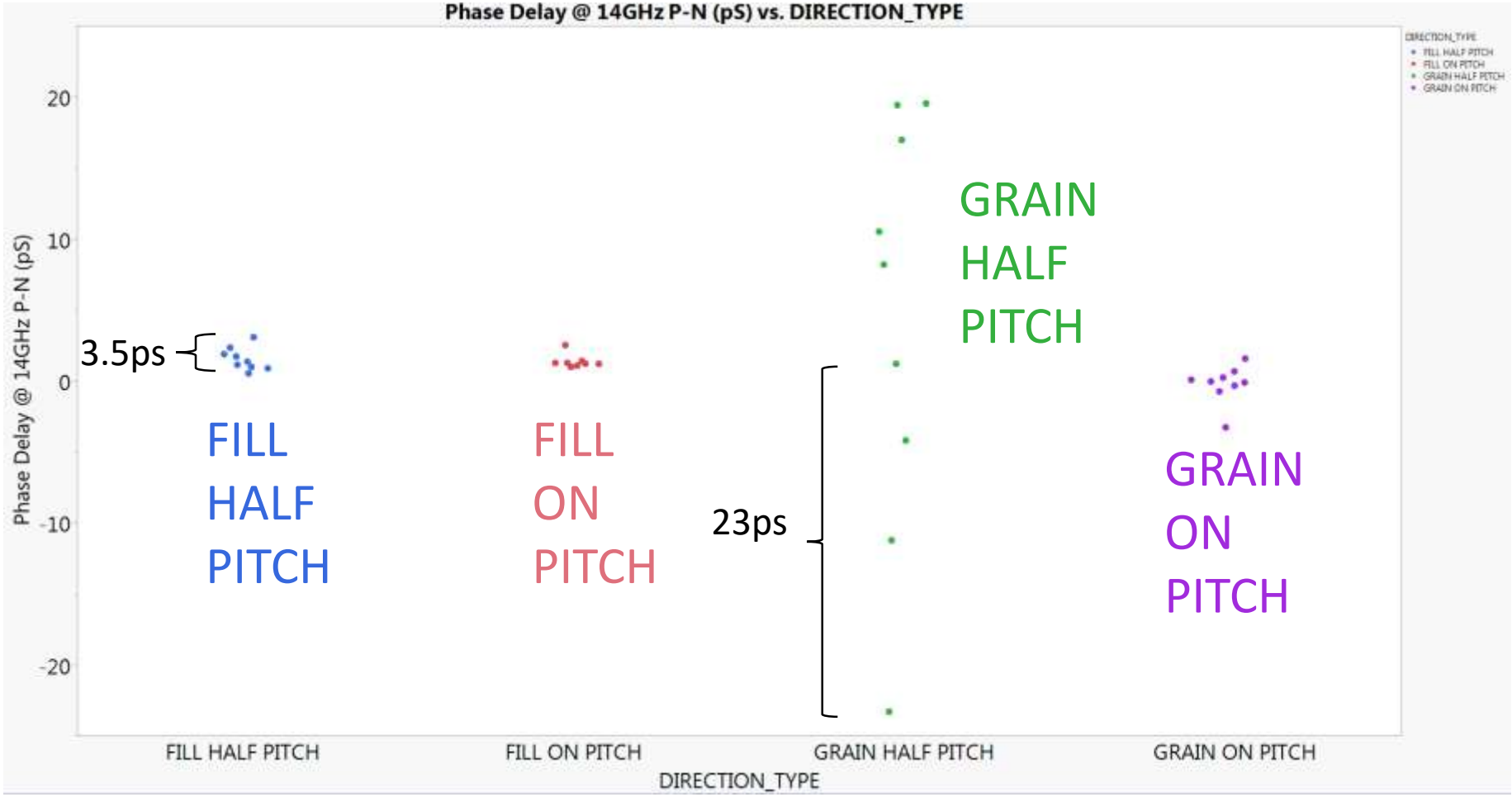


Half Pitch vs. On Pitch

- Keep the pitch of the differential pair similar to the pitch of glass bundles
- Half pitch is likely an extreme case for tight weave fabrics



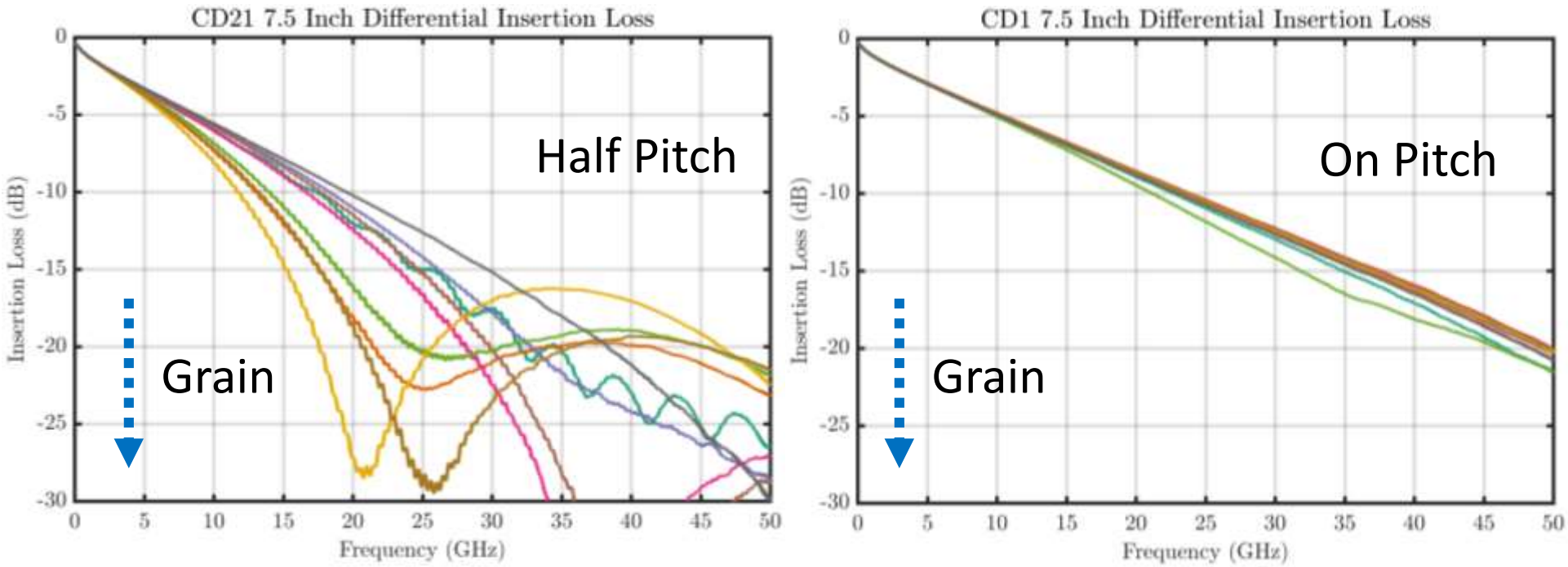
1035 P-N @ 14GHz



1035 Grain Direction Insertion Loss

$$Delay = \frac{2 * UI}{\pi} cos^{-1}\left(10^{\frac{-dB}{20}}\right)$$

Skew at 21GHz NULL ~ 23ps



TAKE AWAYS

Skew observed on differential geometry

- Half width pitch intentionally has more narrow traces
- 1035: 23 ps of skew over 7.5 in. (3 ps/in)
- 1078: 45 ps of skew over 7.5 in. (6 ps/in)

Significantly decrease skew

- Fill Direction fabric wander is a natural skew mitigation.
- Rotation of artwork (beware of periodic structure resonance)
- Match trace pitch to the glass fabric pitch

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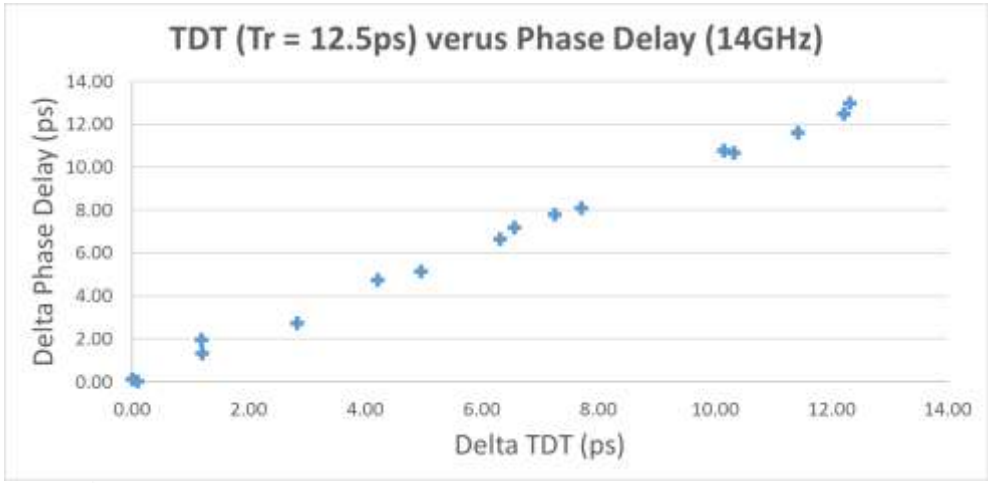
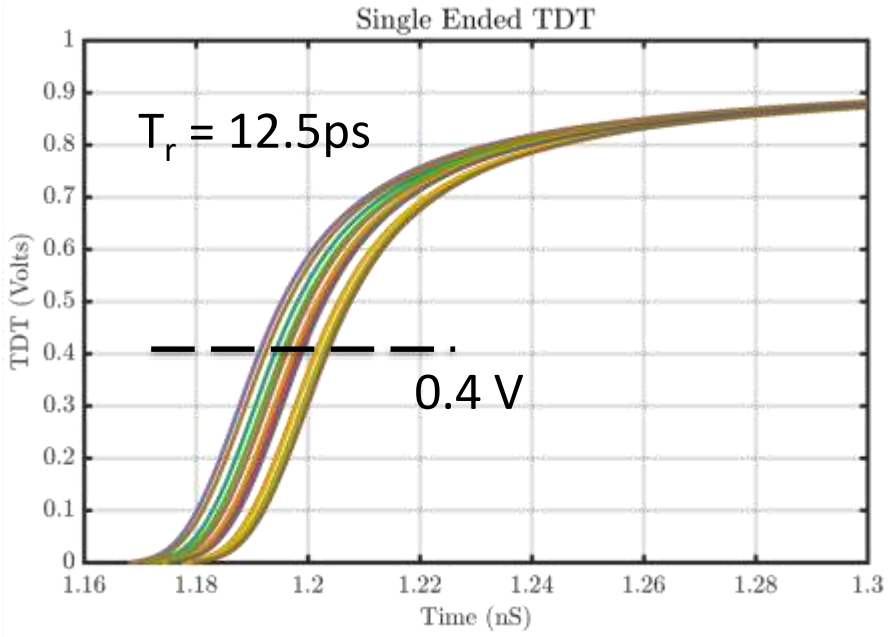
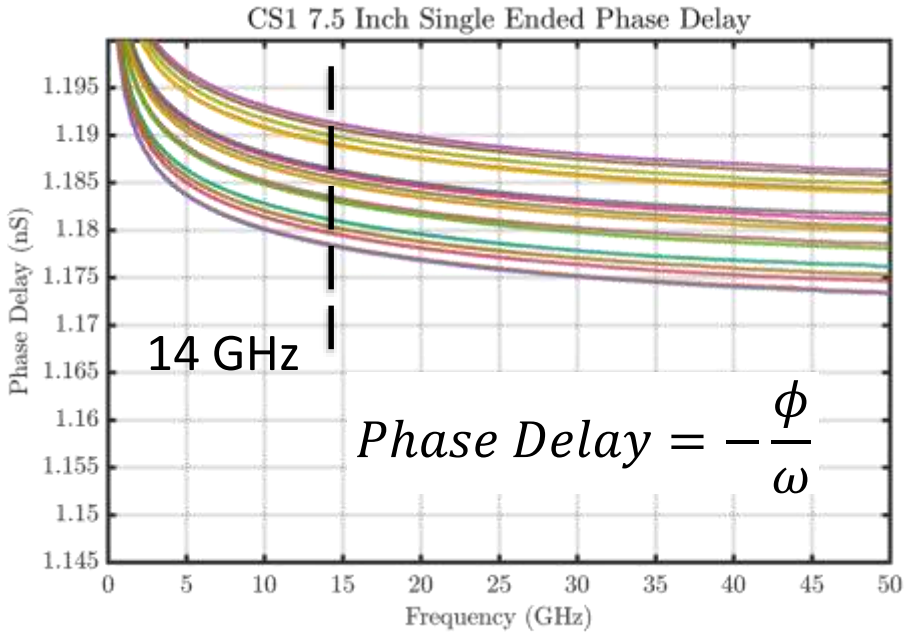
Method of Quantifying Skew

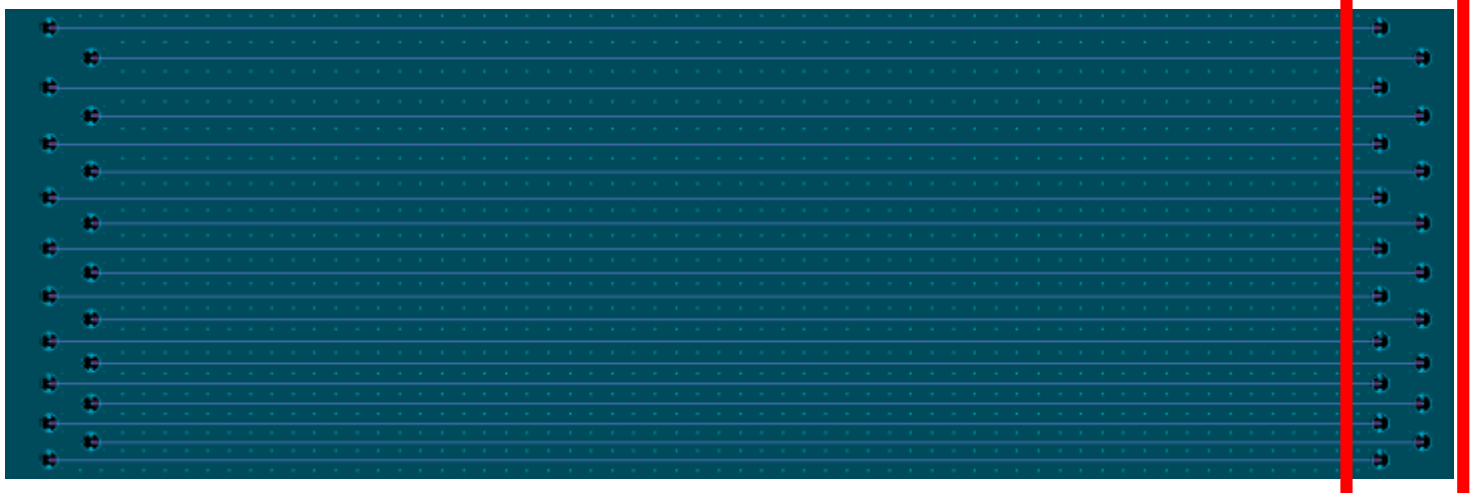
- TDT and Phase Delay trend well
- < 0.8ps observed

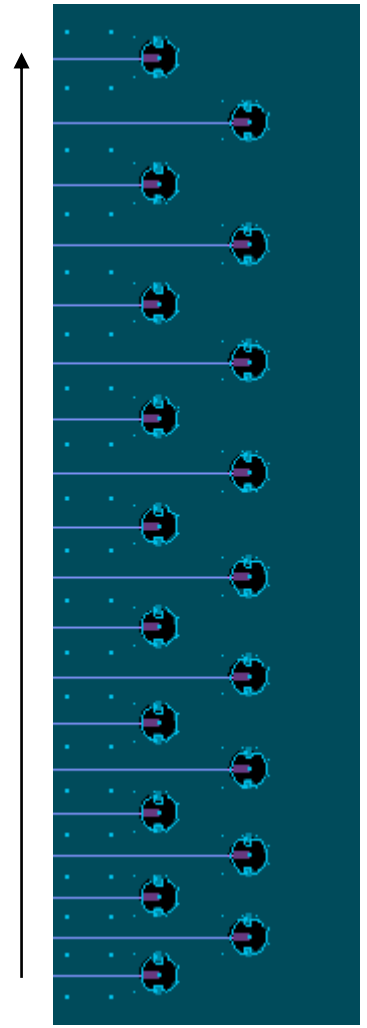






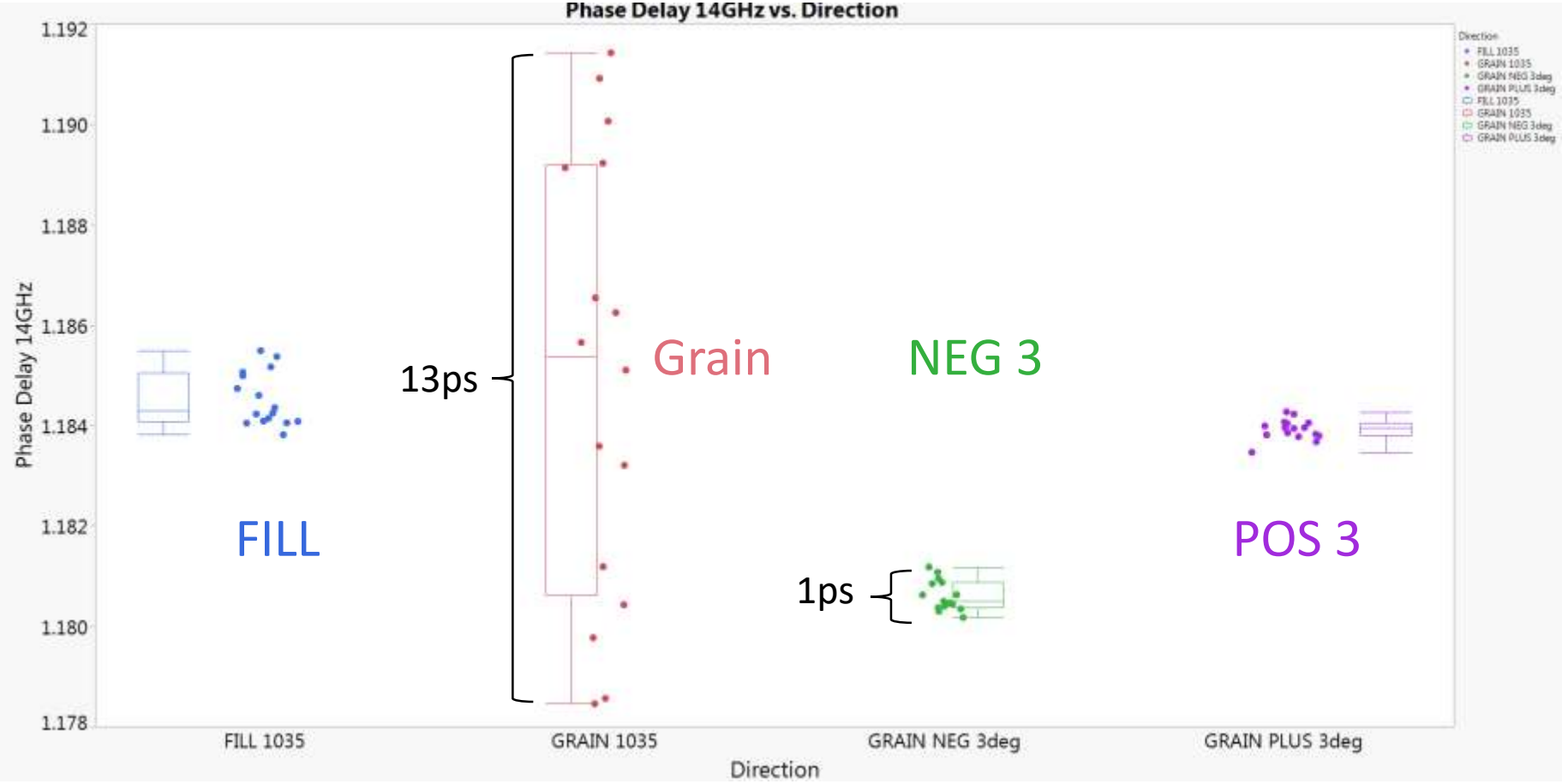
Single Ended Experiments



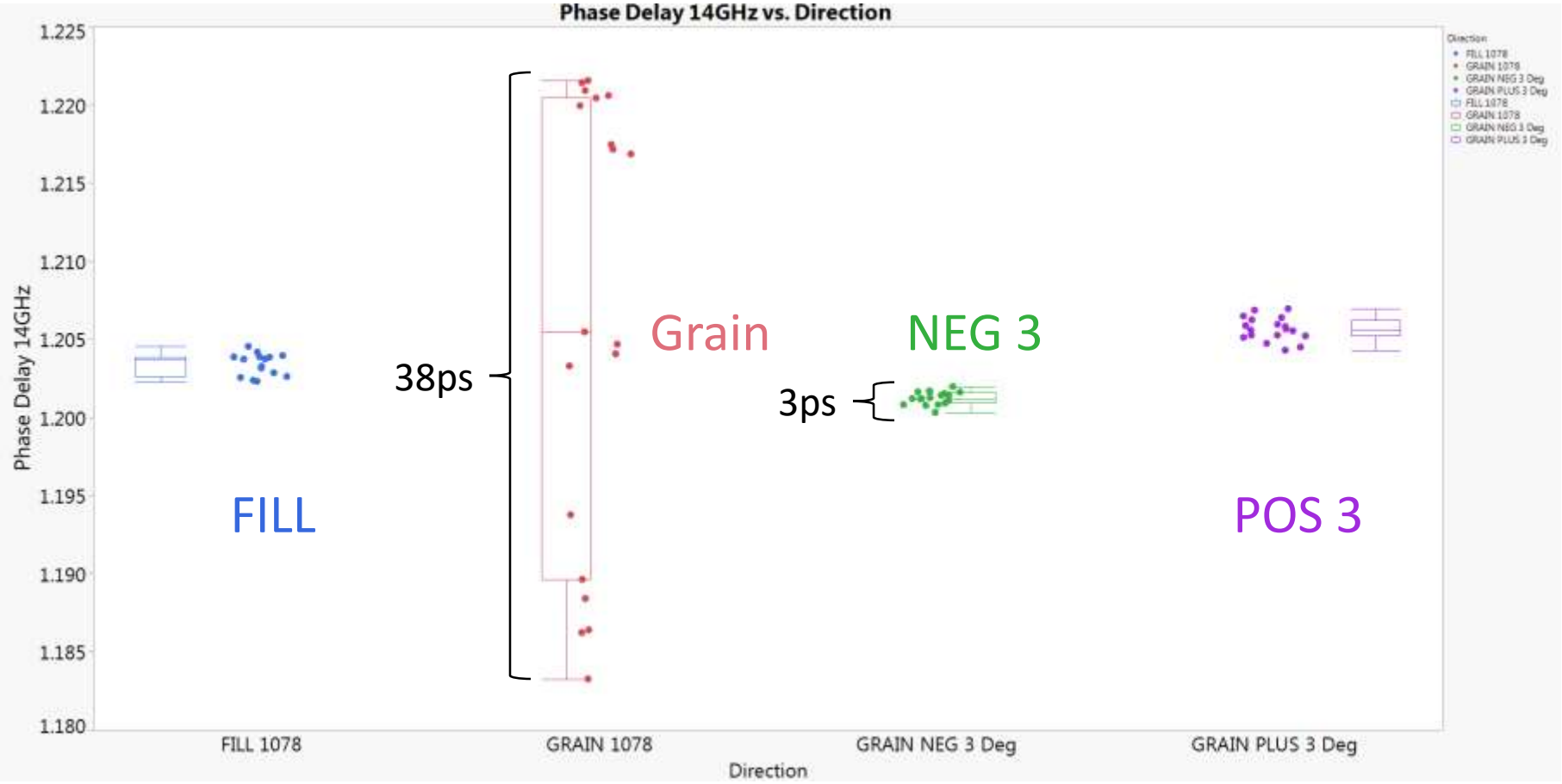


+ 1 mil increment

Phase Delay 1035 @ 14 GHz



Phase Delay 1078



TAKE AWAYS (Single Ended)

- Routing on Grain Direction potentially accumulates
  - 1035: 13 ps of skew over 7.5 in. (1.7 ps/in)
  - 1078: 38 ps of skew over 7.5 in. (5.0 ps/in)
  - May not capture maximum. Trace width versus bundle width
- Fill Direction or rotation (3º) significantly decreases potential skew
  - Fill Direction fabric wander is a natural skew mitigation.

1078 P-N @ 14GHz (Differential)