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Sources and Compensation of Skew in Single-Ended and Differential Interconnects

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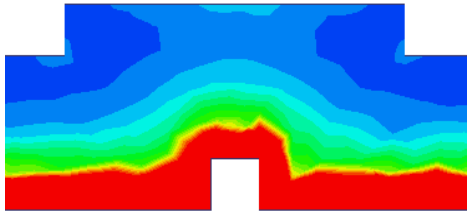
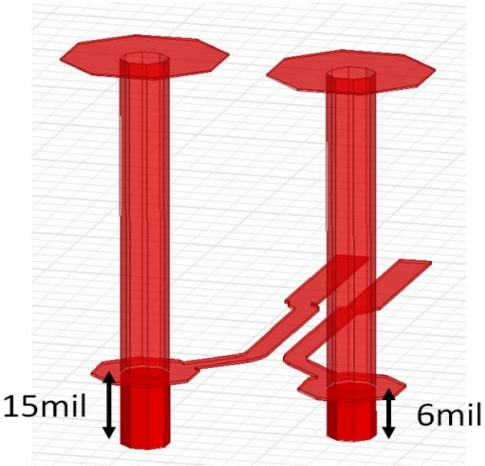
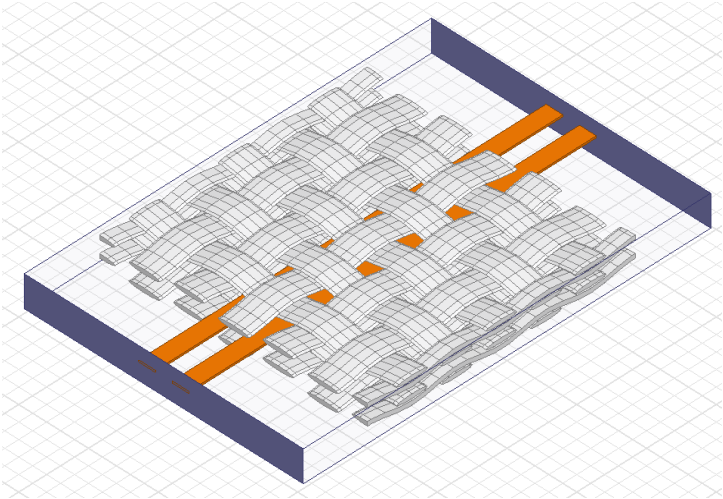
UBM Tech

Sources of Skew

- Layout dependent
  - Current redistribution
  - Via stub asymmetry
- Material dependent
  - Glass weave



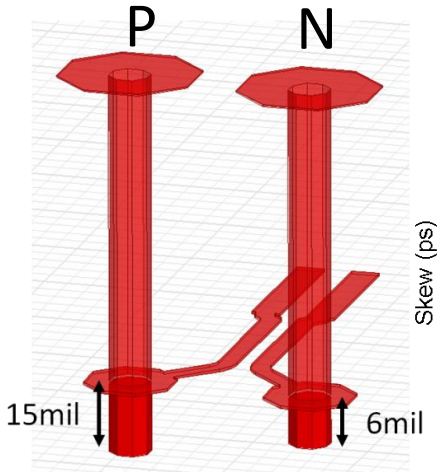


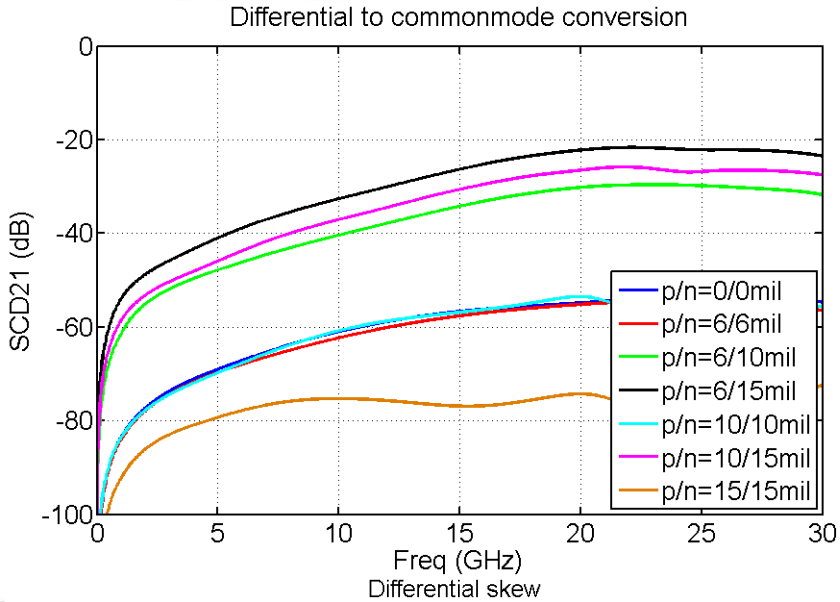


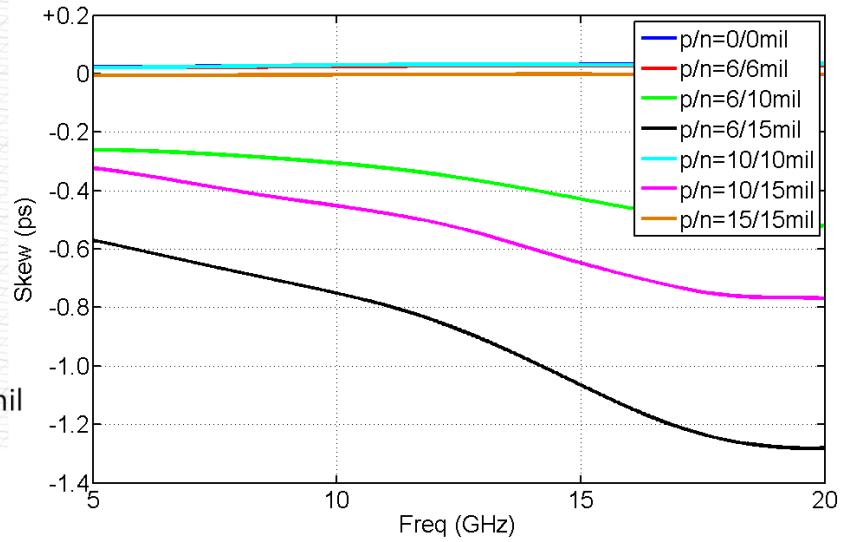
Skew by Via Stub Asymmetry

Skew is caused by asymmetric reflections from mismatched via stubs

Case	P stub (mil)	N stub (mil)
1	0	0
2	6	6
3	6	10
4	6	15
5	10	10
6	10	15
7	15	15

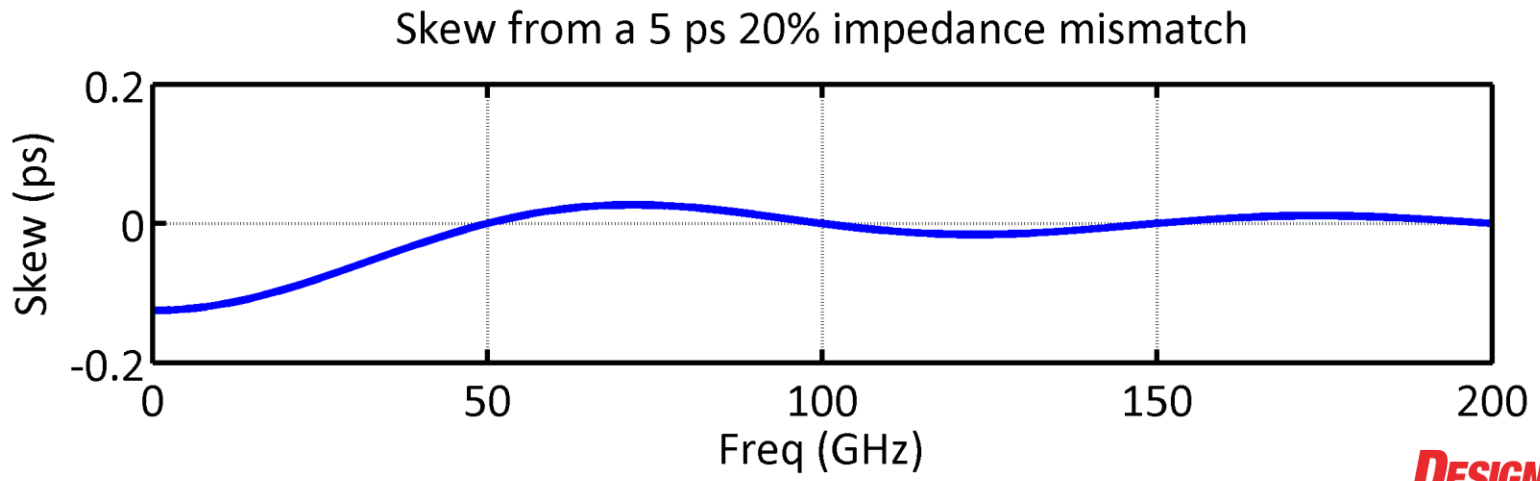






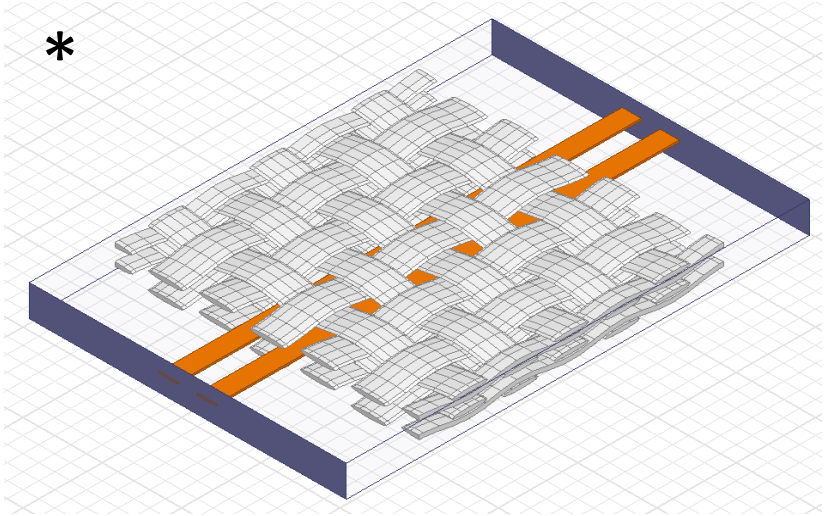
Skew by Reflection

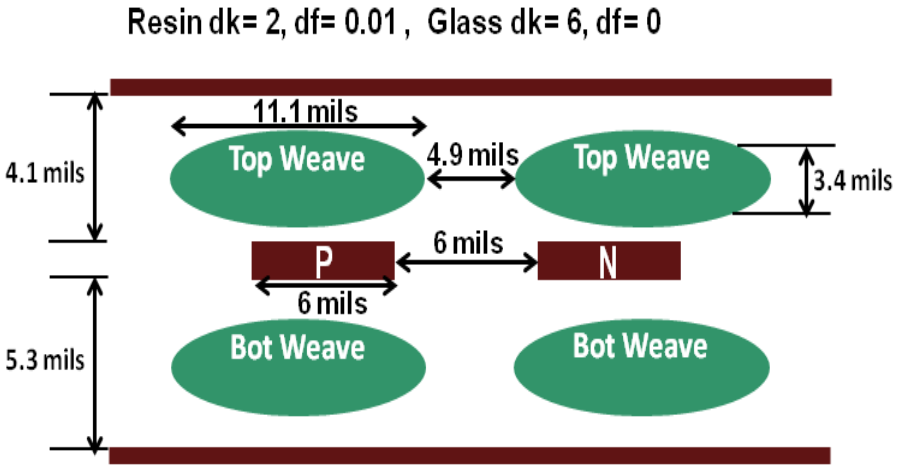
- Skew can be generated by reflections due to impedance, even when propagation delay is equal
- Even a small impedance mismatch can create skew that is hard to diagnose



Skew by Glass Weave

- Glass weave bundles may not align symmetrically with etch
- Asymmetrical alignment of weave bundles causes skew

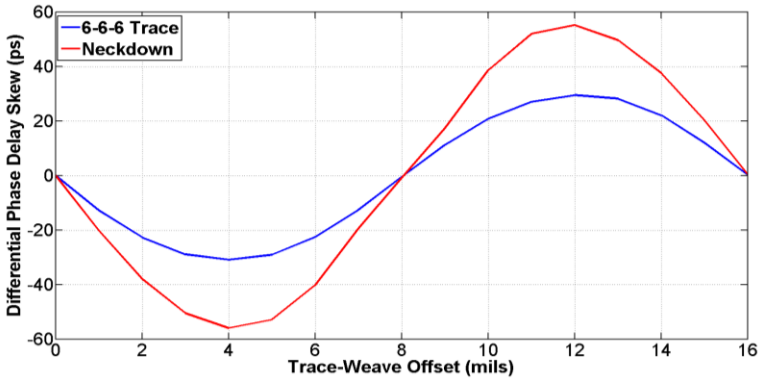


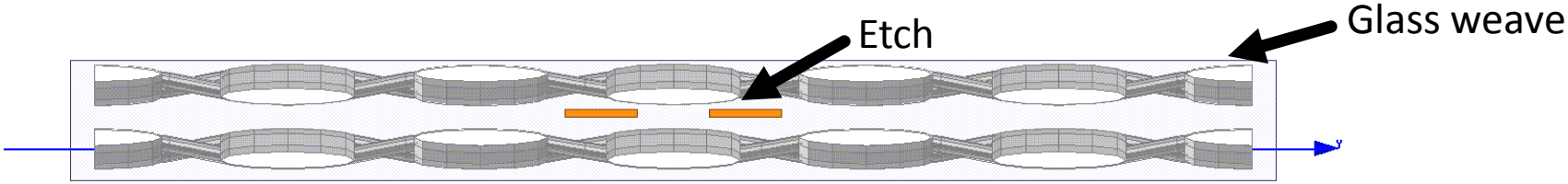


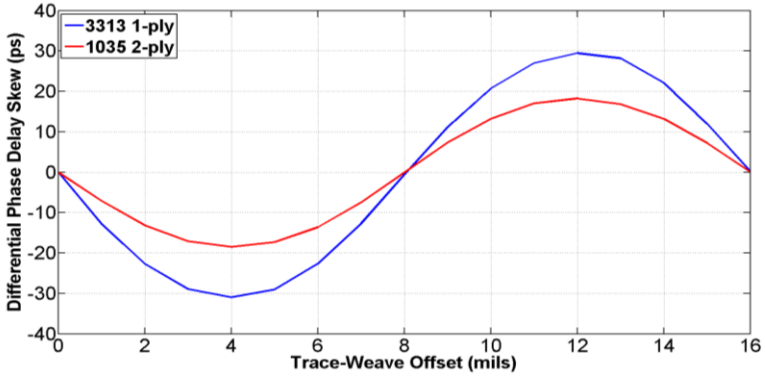
*Chris Herrick, Thomas Buck, and Ruihua Ding. "Simulation Fiber Weave Effect". (http://pcdandf.com/cms/magazine/95/6187), Printed Circuit Design and Fab, May 2009.

Skew by Glass Weave – Etch Offset

- Larger etch dimensions are less sensitive to weave offset
- 90% more skew from 6-6-6 mil pair to 4.2-3.2-4.2 mil pair



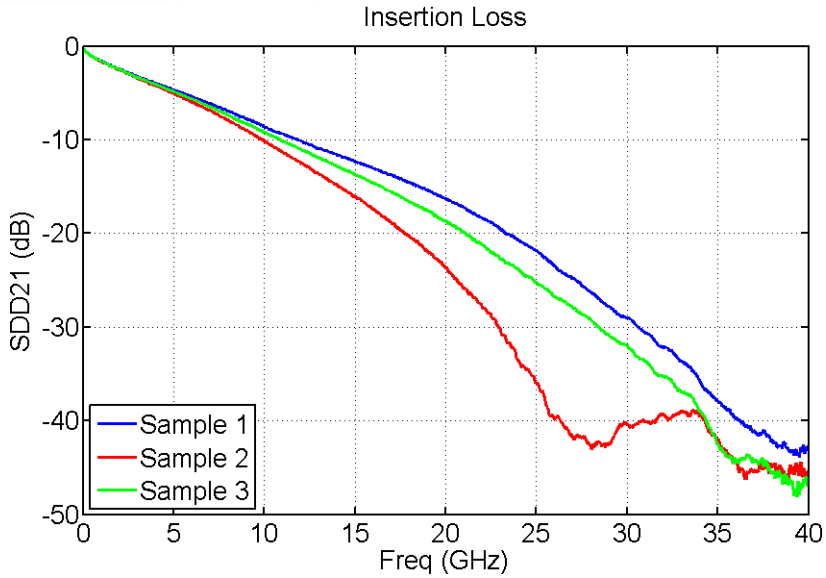


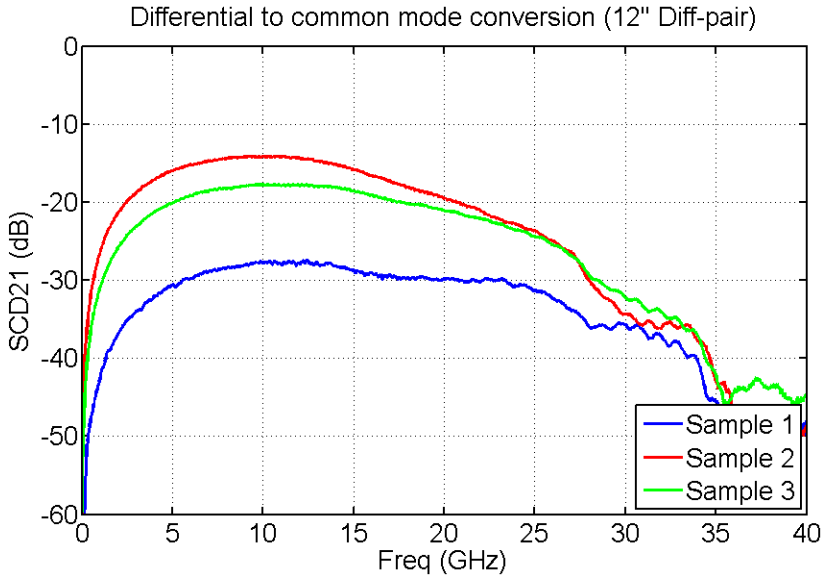


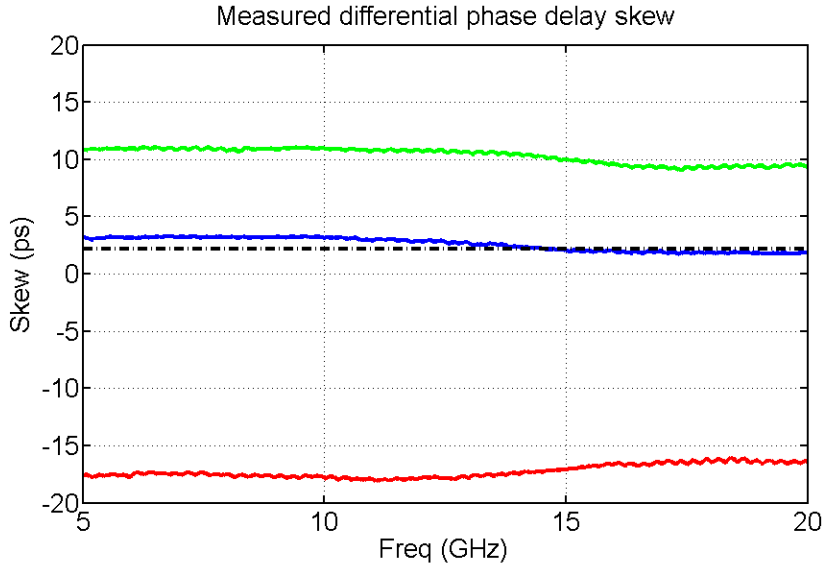
- Coarse glass weave (3313) produces 50% more skew than finer tighter glass weave (2x 1035)

Skew by Glass Weave – Measurement

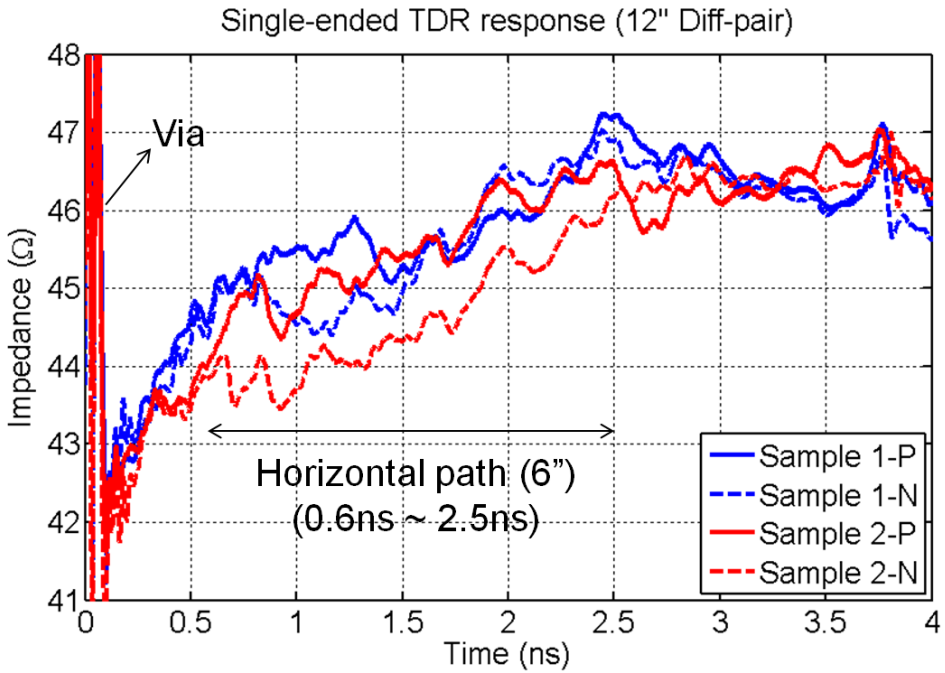
- VNA measurement of 12” long diff-pair stripline with 3313 prepreg
- Identical PCB layout
- Large variation in skew







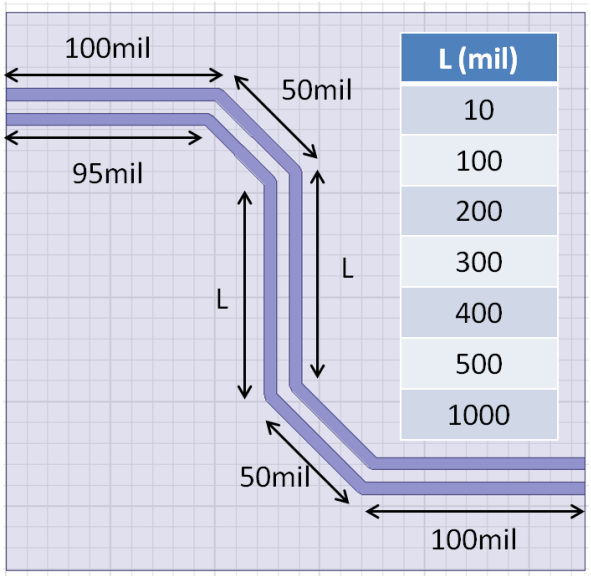
Skew by Glass Weave – Measurement



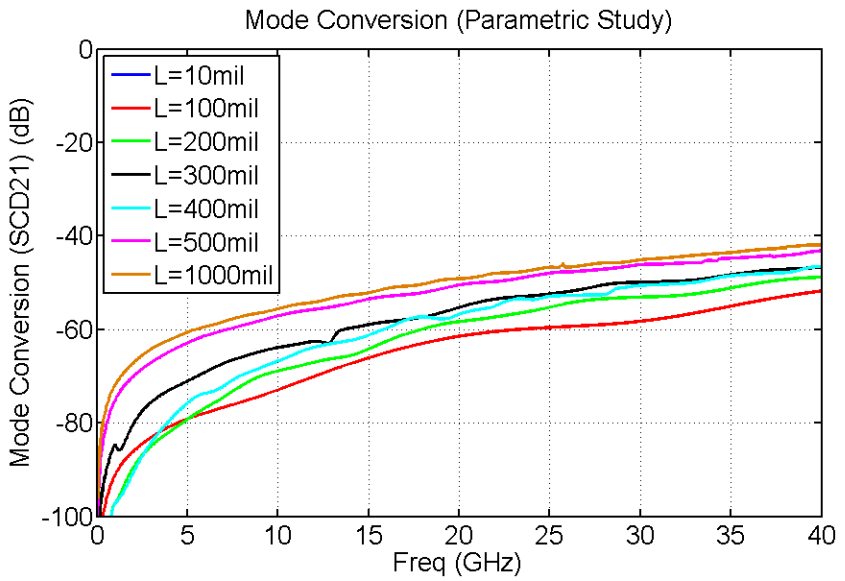
- Sample 2 shows large discrepancy between P and N impedances, indicating much more glass under N
- Location for 0.6~2.5ns corresponds to 6”-long straight path in etch

Compensation of Skew – Opposite Turns

- Typical and simple way of compensating lengths difference between two legs
- Location of opposite turns does not affect compensation efficiency for stripline



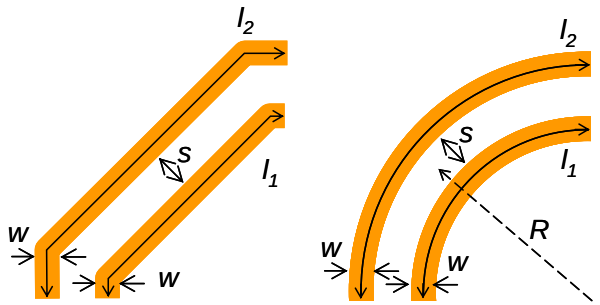
L (mil)
10
100
200
300
400
500
1000

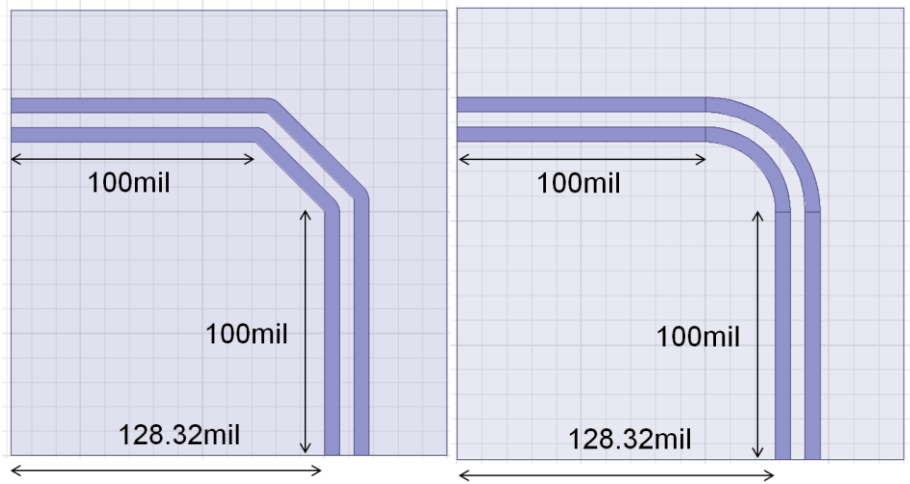


Arc or 45-Degree Bends?

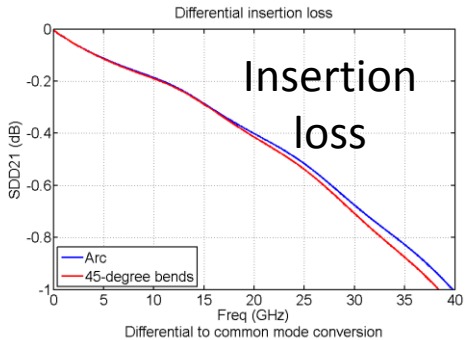
$l_2 - l_1 = 4*(s + w)*\tan(22.5^o)$
$= 1.66*(s + w)$

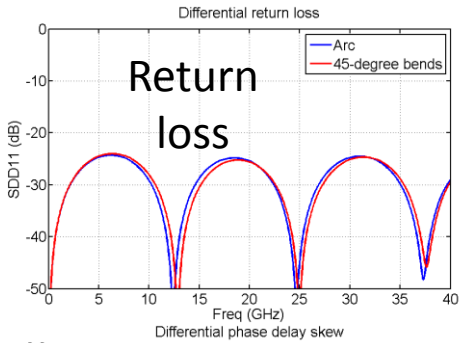
$l_2 - l_1 = 0.5*s*\pi$
$= 1.57*(s + w)$

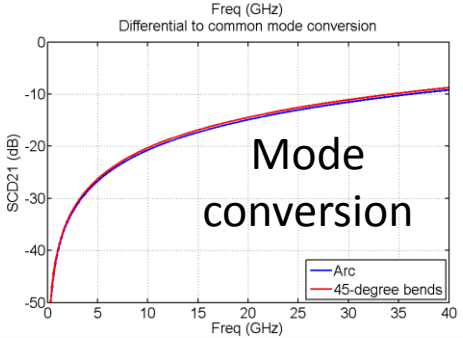


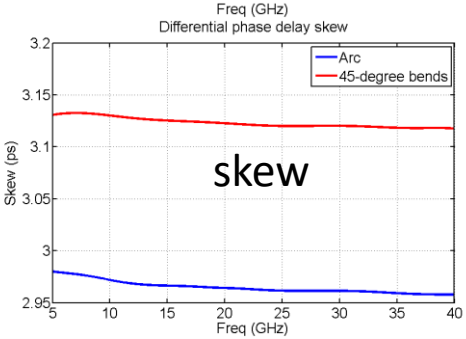


- Arc has 5% less center line length difference (l_2-l_1)
- Arc produces 5% less skew by simulation
- Negligible performance difference up to 20GHz

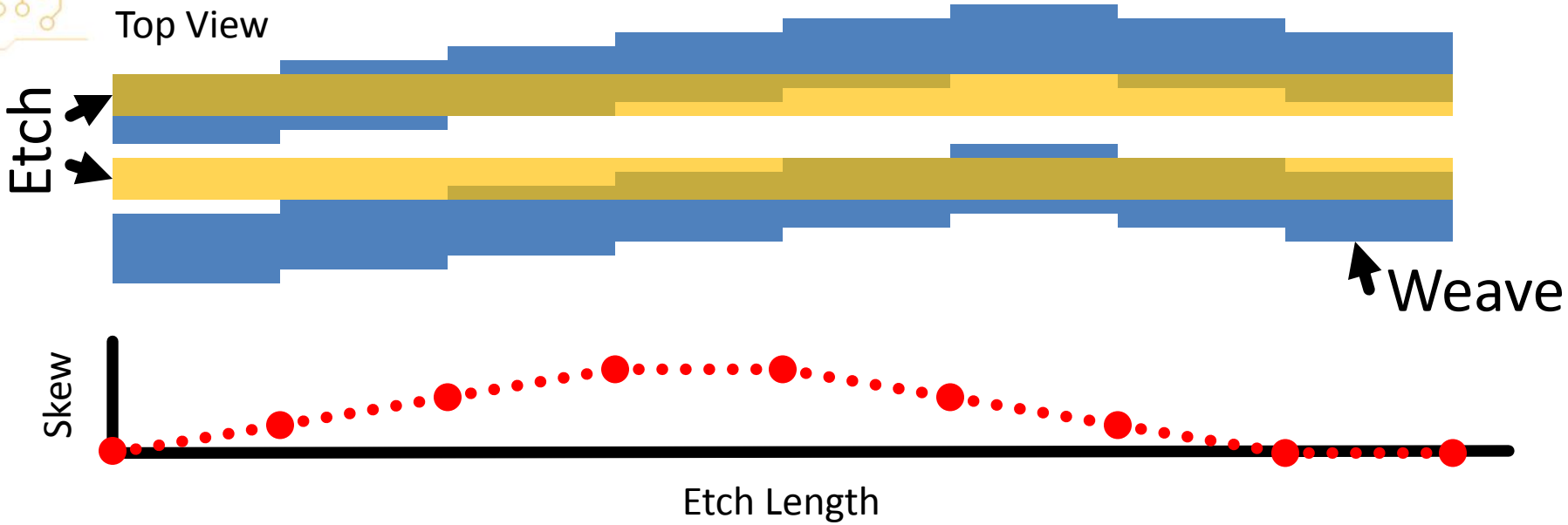






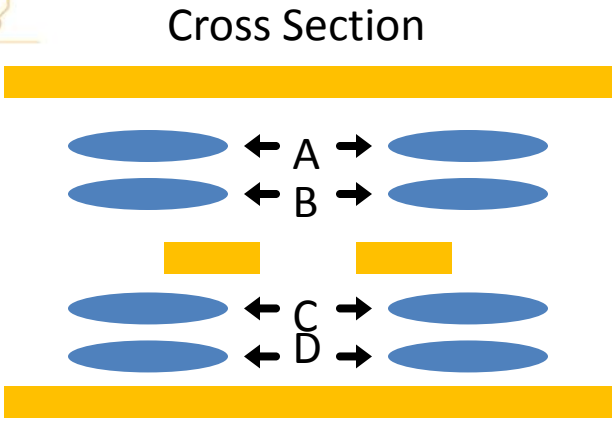


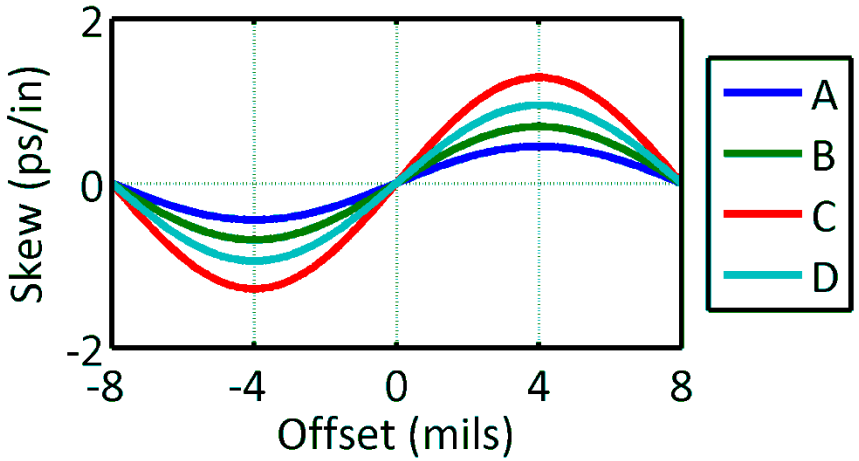
Single Ply Weave



- Weave wanders across etch
- As weave crosses etch, skew can be corrected
- How can we treat this systematically?
- What about multi-ply weave?

Multi-Ply Weave

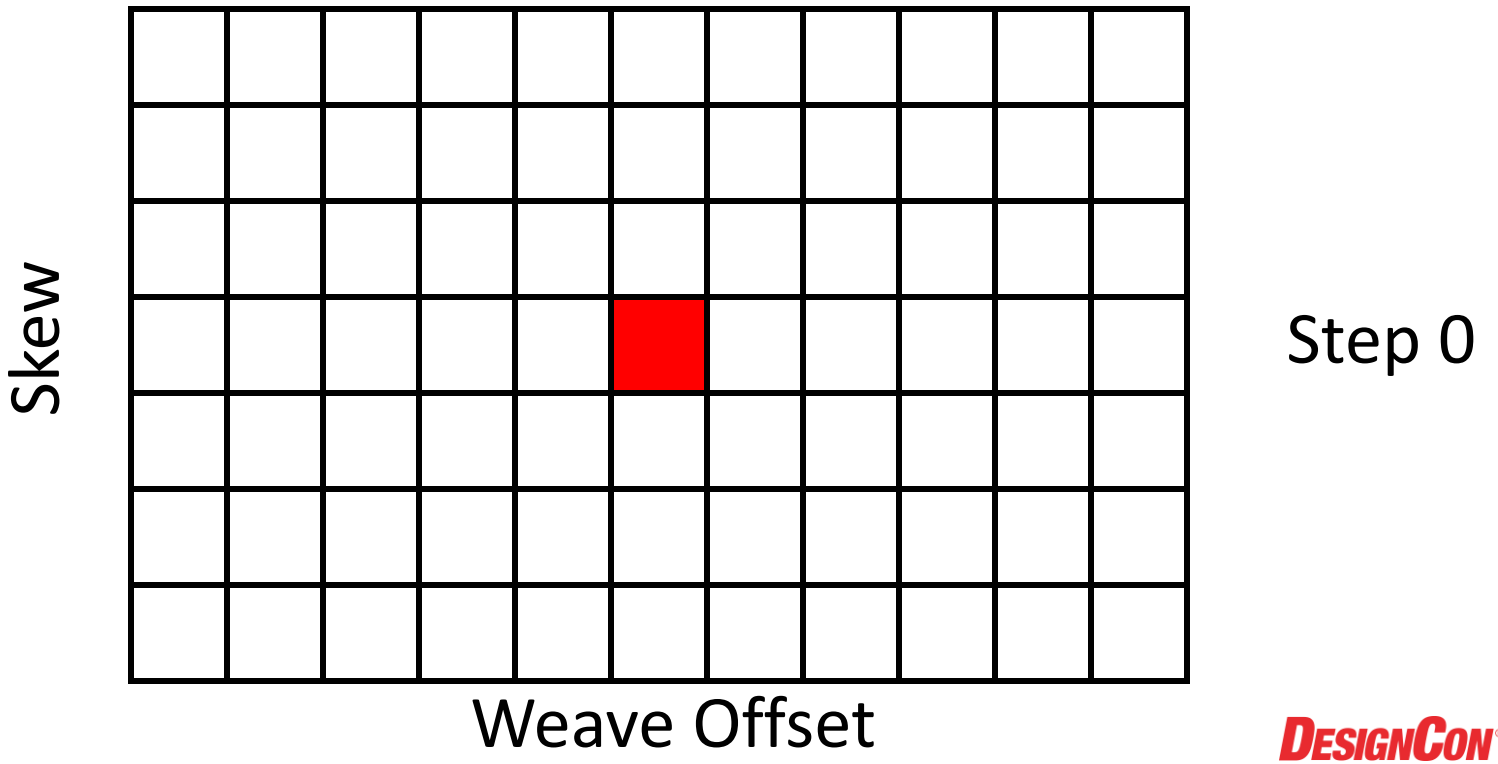




- Weakly coupled etch so weave skew is additive
- 3D EM Simulation shows skew from each ply is independent based on offset
- Weave plies can be treated independently

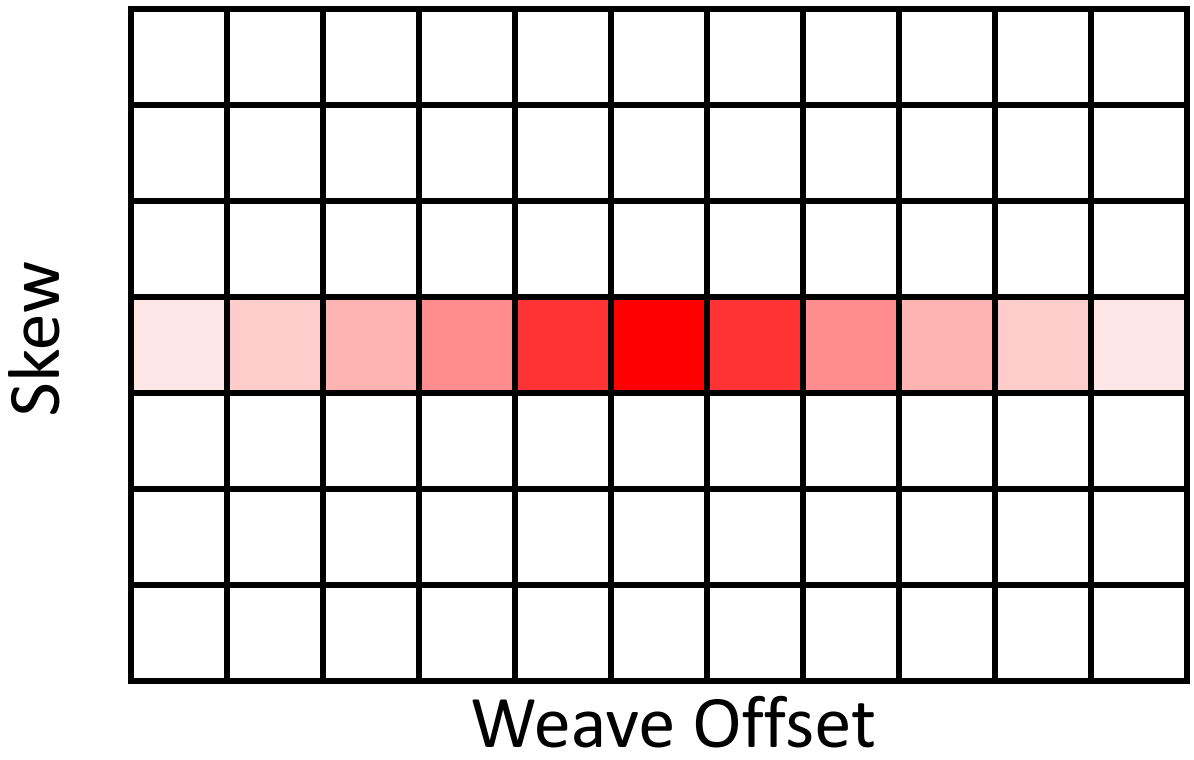
Weave Simulation

- Discrete PDF of skew and weave offset at each discrete step in etch length
- To start, skew is zero



Weave Simulation

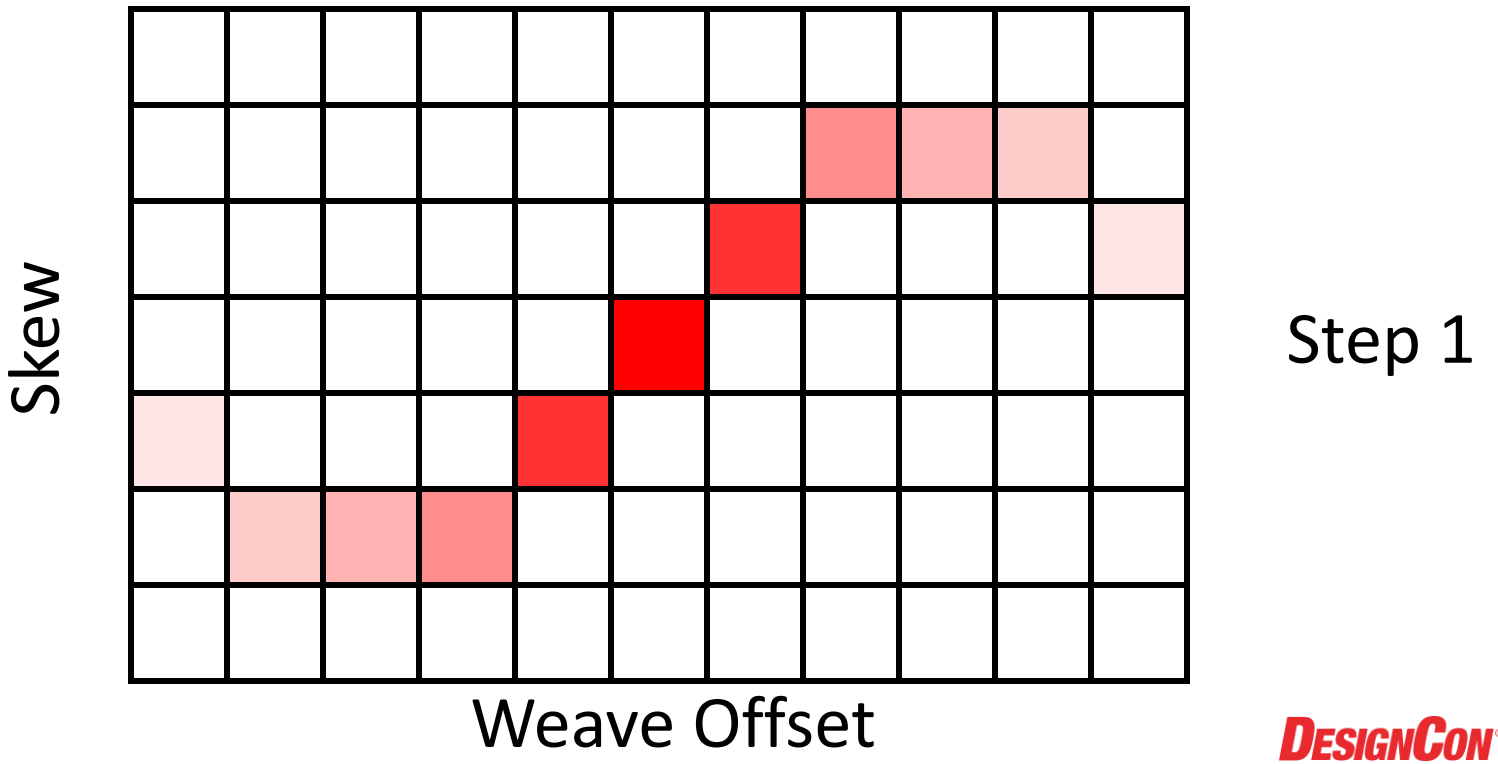
- For the next length step, first weave offset is modified by a Gaussian weave angle PDF (μ,σ)
- Other PDF shapes can be used easily



Step 0.5

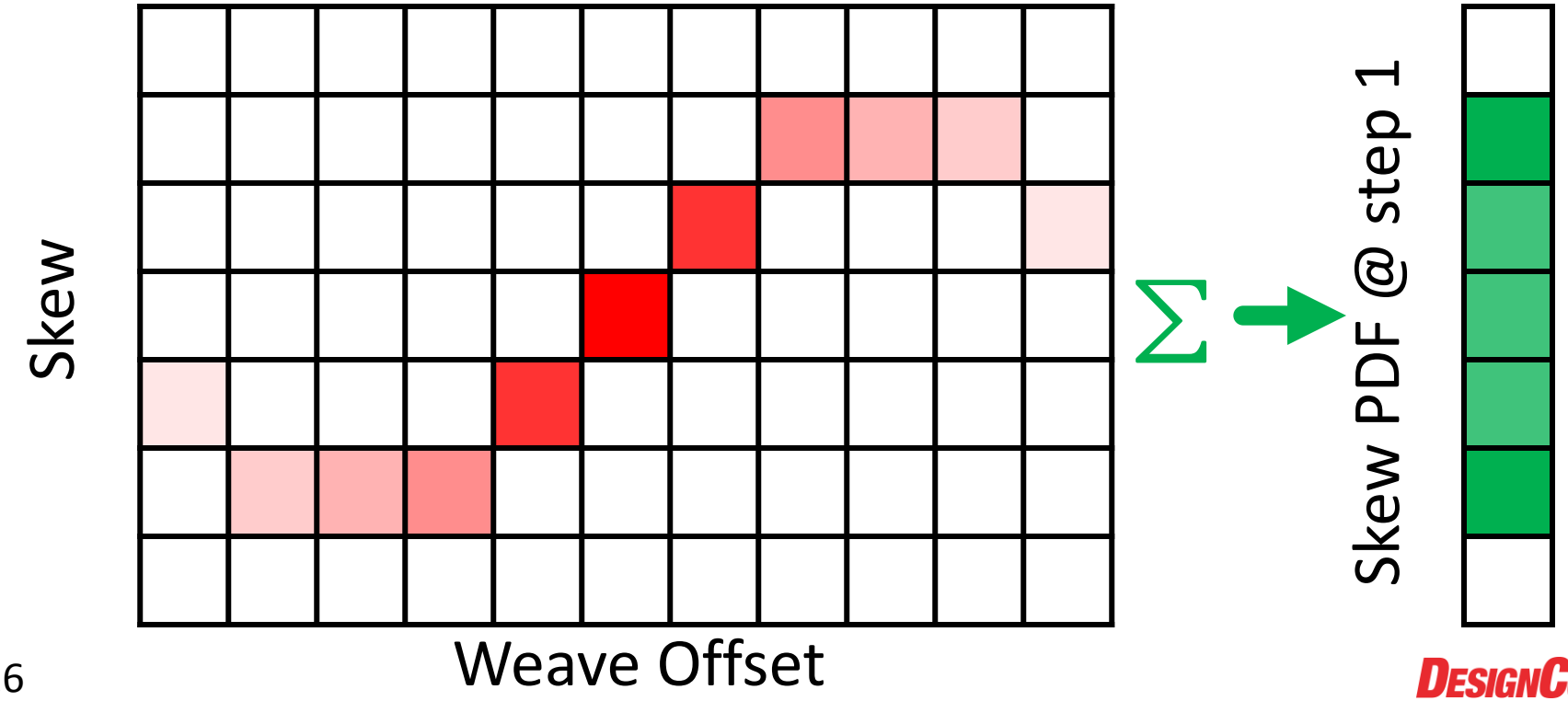
Weave Simulation

- Skew is then applied based on weave offset
- In the actual calculations, initial weave offset is distributed evenly

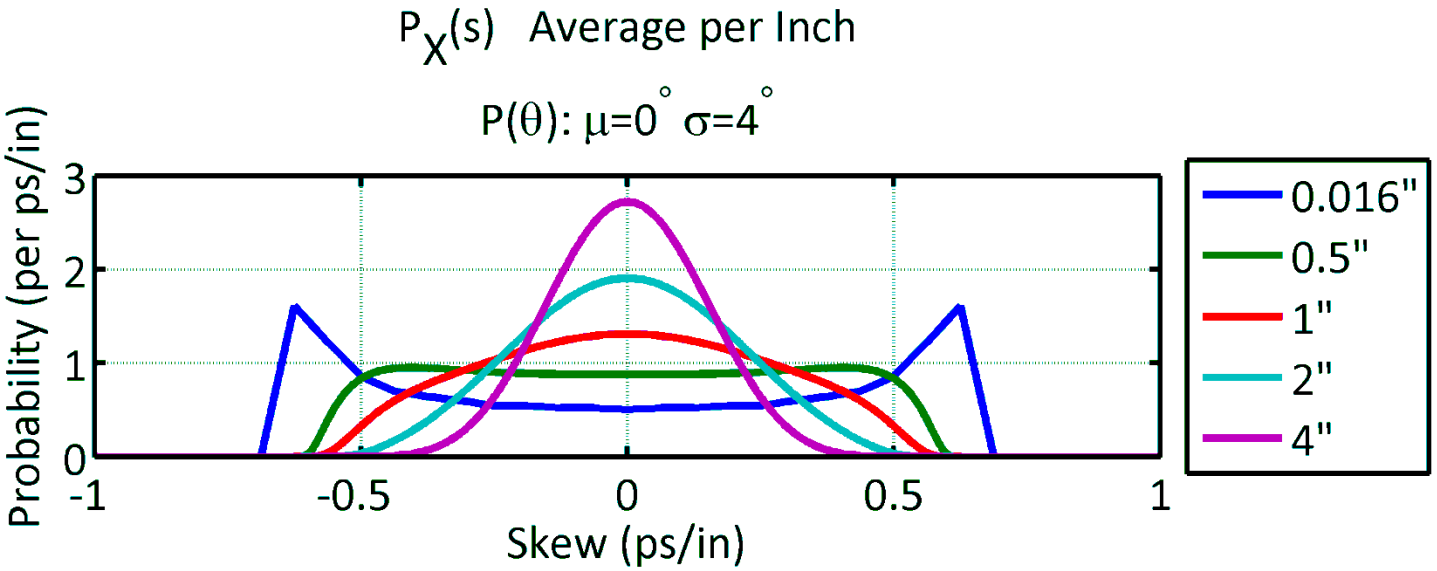


Weave Simulation

- Finally, a skew PDF is generated from the sum of each row
- Skew PDFs for multiple layers can be convolved

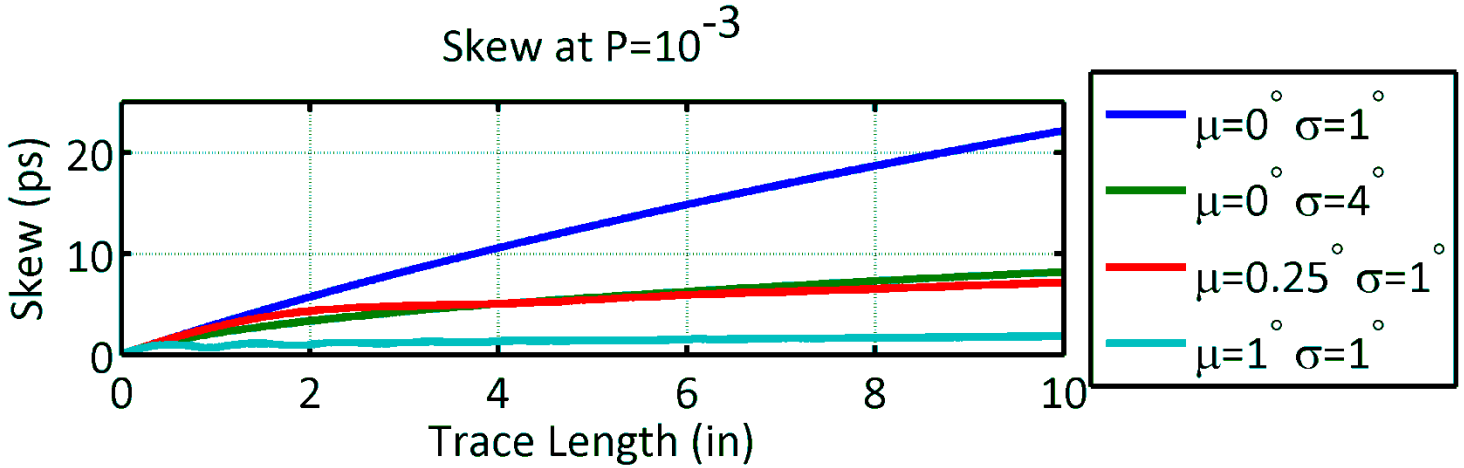


Model Implications



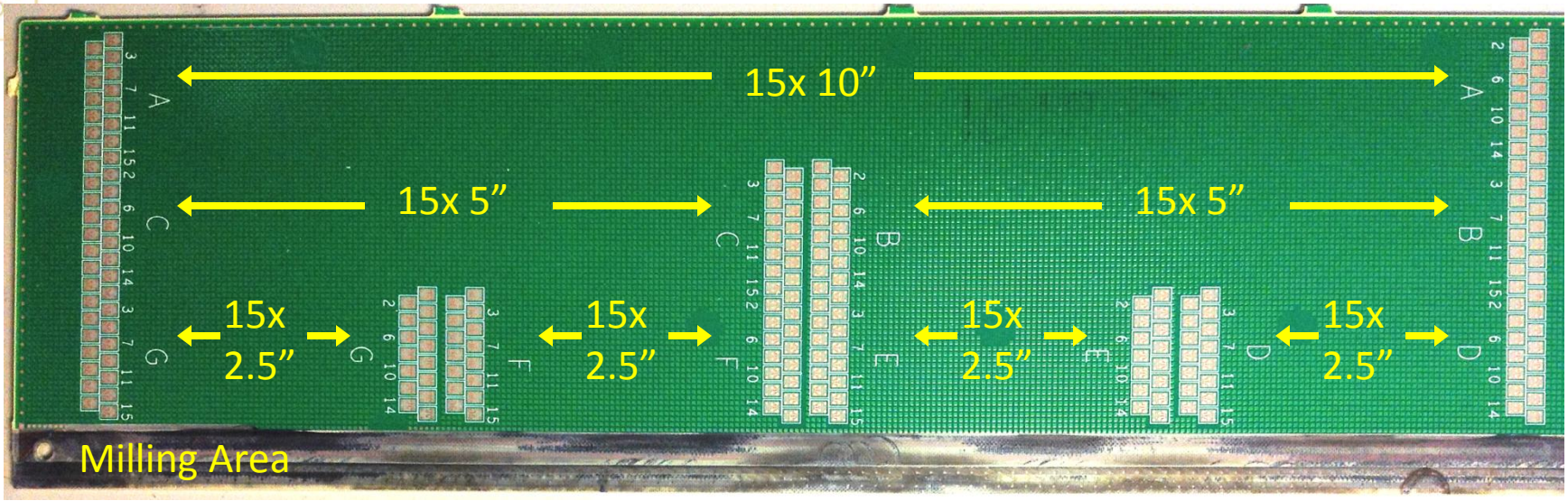
- Skew distributions are not Gaussian
- Worst case skew is very likely for short etch, and very unlikely for long etch
- Worst case skew is always possible unless minimum weave angle is guaranteed

Model Implications

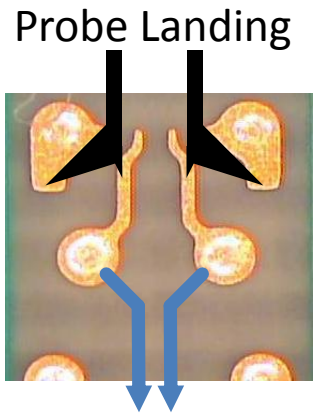


- "ps/in" are not always good units for skew
- A more useful metric: skew at a chosen failure rate, similar to eye diagrams
- It does not take much weave angle variability to significantly reduce skew

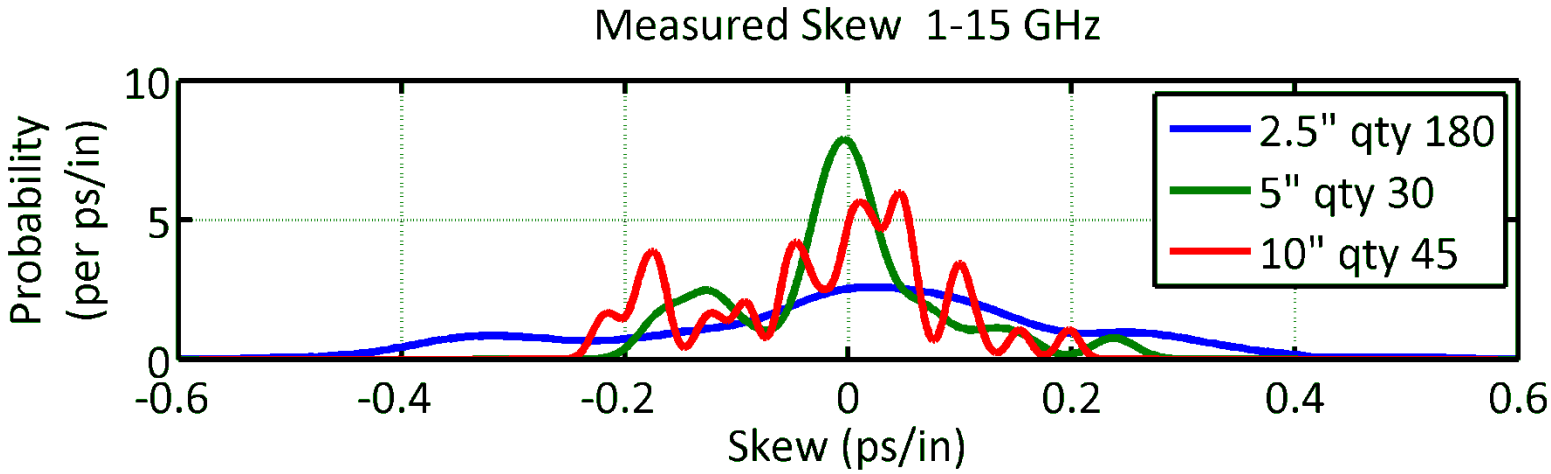
Skew / Weave Coupon



- Two ply core and prepreg
- Blind vias to etch on layer 3
- Dual 250/500 µm probe landing
- Milling area for weave measurement
- Other skew structures (not shown)



Coupon Results



- Skew per inch not decreasing from 5” to 10”
- Etch vs. weave periodicity?
- Limited sample set?
- Weave alignment?
- Weave history?

Conclusions

- Weave skew does behave as predicted between 2.5” and 5” etch
- Weave skew does not behave as predicted between 5” and 10” etch
- More work is needed to determine what causes this inconsistency
- More data is needed on weave angle
- This model seems to be a good starting point for examining weave skew statistics

THANK YOU

ANY QUESTIONS?