ROGERS CORPORATION

An Overview of Glass-Weave Impact on Millimeter-Wave PCB Performance

John Coonrod

Technical Marketing Manager

ROGERS CORPORATION

Agenda

- Basic overview of different glass styles and laminate constructions
- Simple definitions of glass-weave effect
- Different circuit-glass configurations where glass weave patterns can impact RF performance
- Overview of recent studies evaluating glass weave effects at millimeter-wave frequencies

An Overview of Glass-Weave Impact on Millimeter-Wave PCB Performance

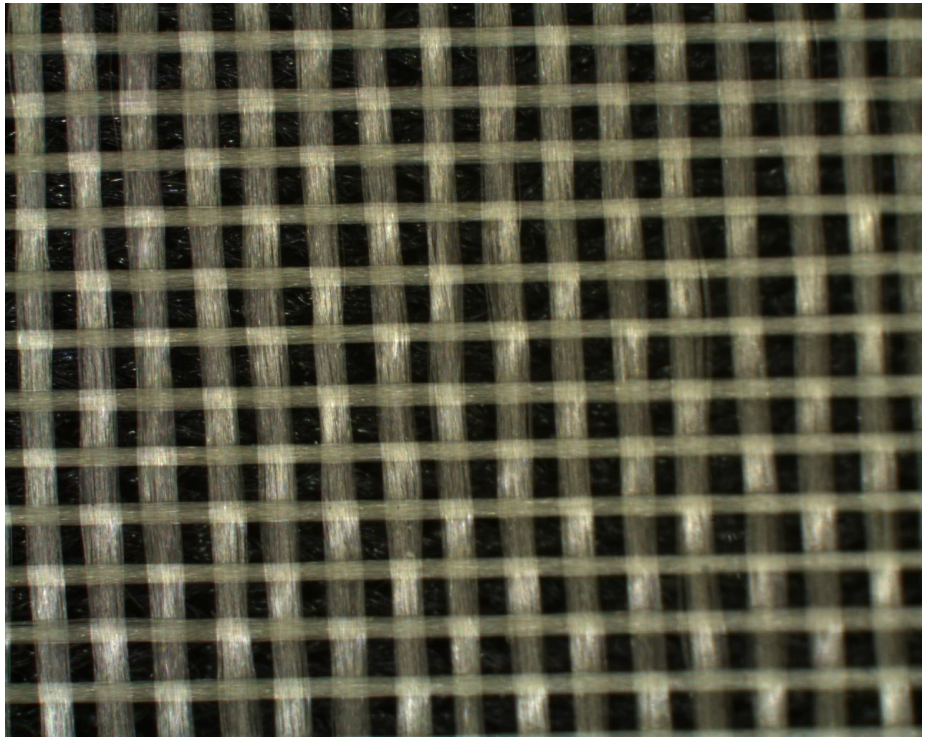
Basic overview of glass styles and laminate constructions

- Over the past several years and in response to the concern of glass-weave effect, there have been different glass fabrics brought to the market to address the issues
- A recent study, with results shown later, will be comparing results from three different types of glass
  - 106, open weave
  - 1080, open weave
  - 1078, spread glass
- All three of these glass styles are relatively thin and are often used in thin laminates made for millimeter-wave applications
- The laminate made with these different glass styles used PTFE only without filler

An Overview of Glass-Weave Impact on Millimeter-Wave PCB Performance

Basic overview of glass styles and laminate constructions

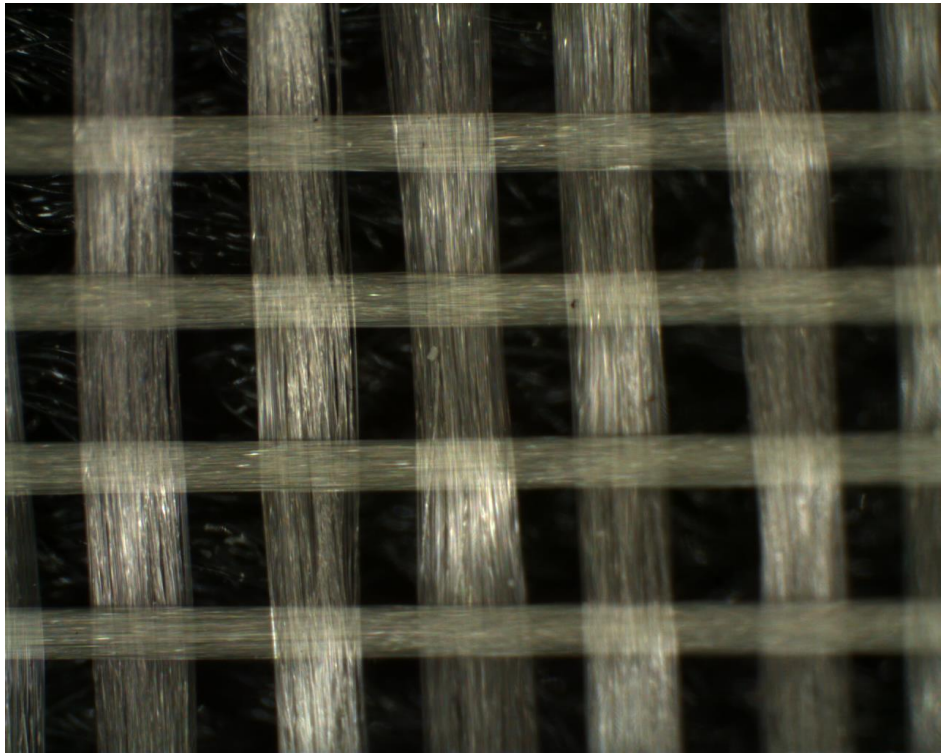
- 106 glass, standard weave
- Balanced glass cloth



4.8mil

- Even through the dimensions are different, there is the same amount of glass content on both axes

10.2mil



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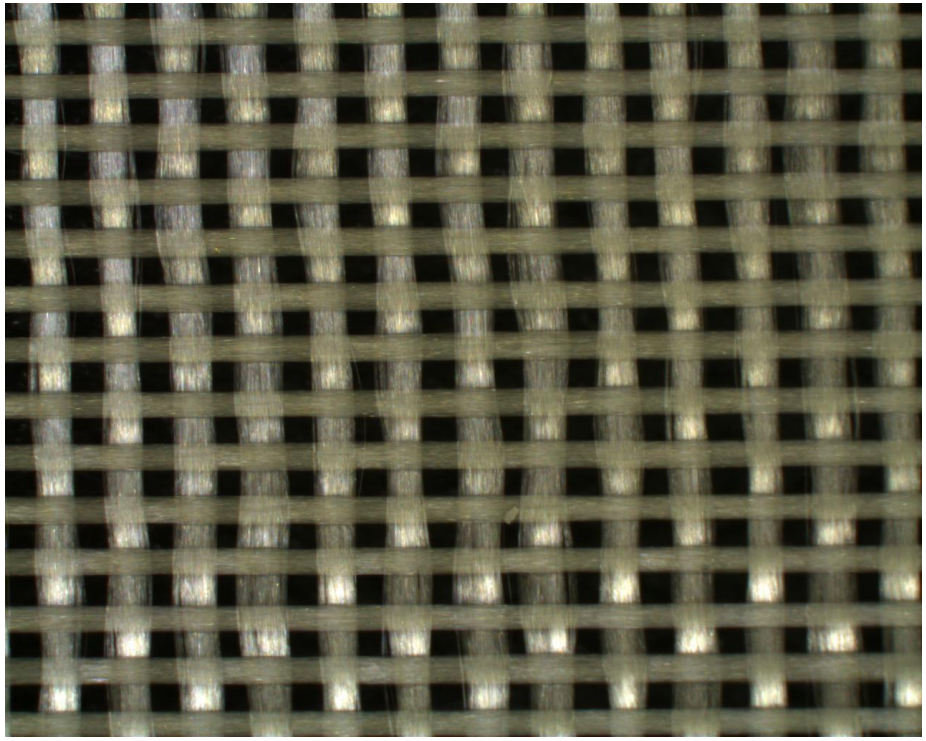
Basic overview of glass styles and laminate constructions

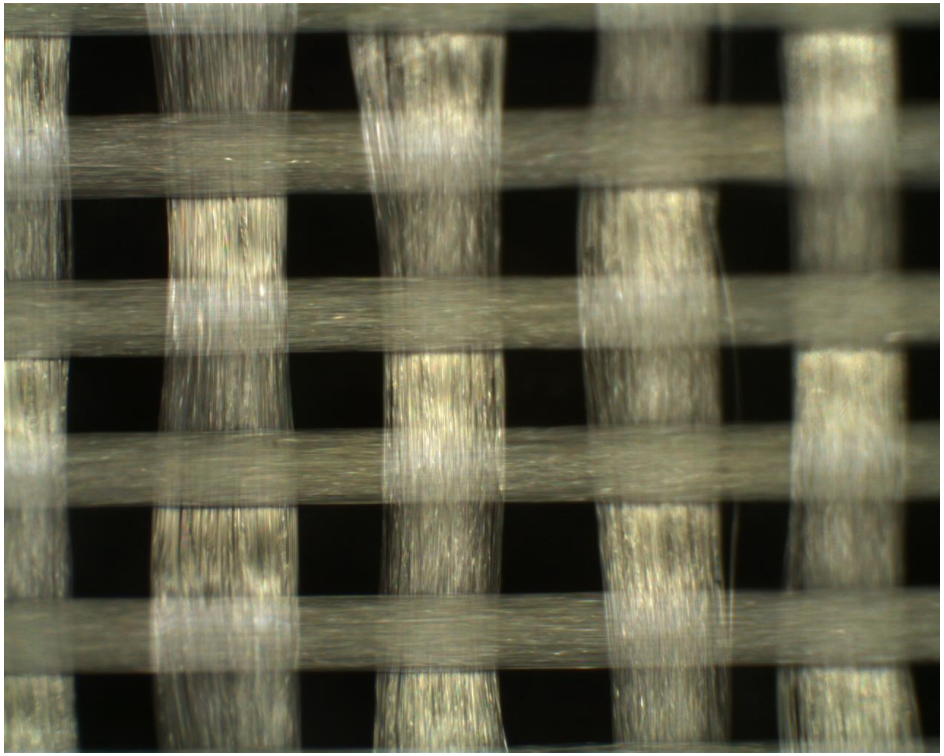
- 1080 glass, standard weave



8.2mil

- Unbalanced glass cloth
  - One axis has more glass content than the other axis

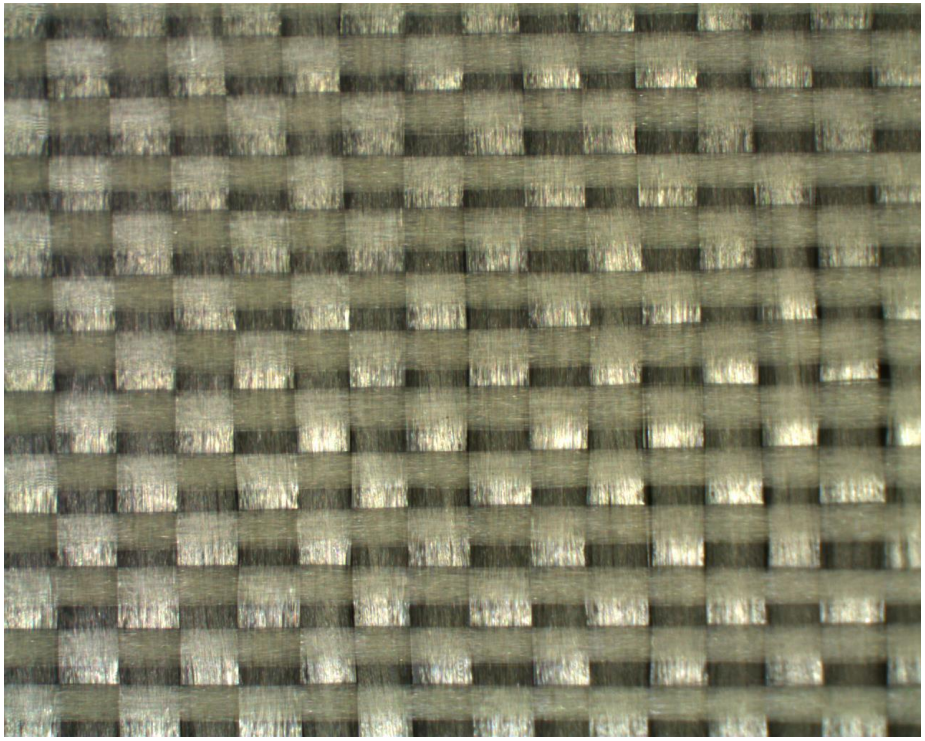
12.1mil



An Overview of Glass-Weave Impact on Millimeter-Wave PCB Performance

Basic overview of glass styles and laminate constructions

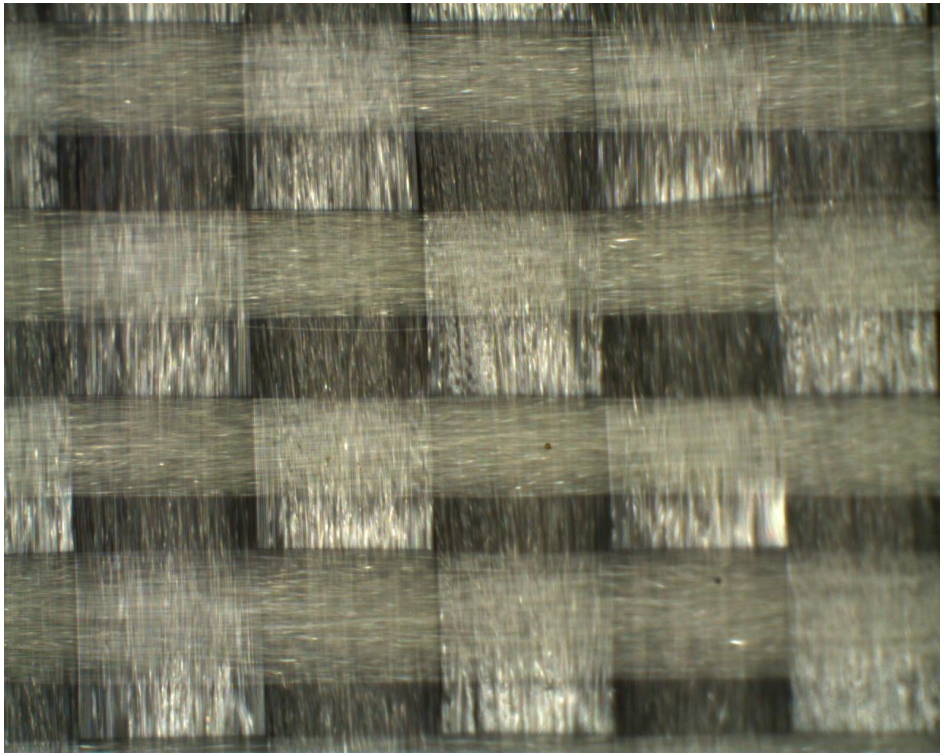
- 1078 glass, spread weave



This is considered a balanced glass weave

- This particular glass style is very similar to 1080 glass, but the glass bundles were spread on one axis

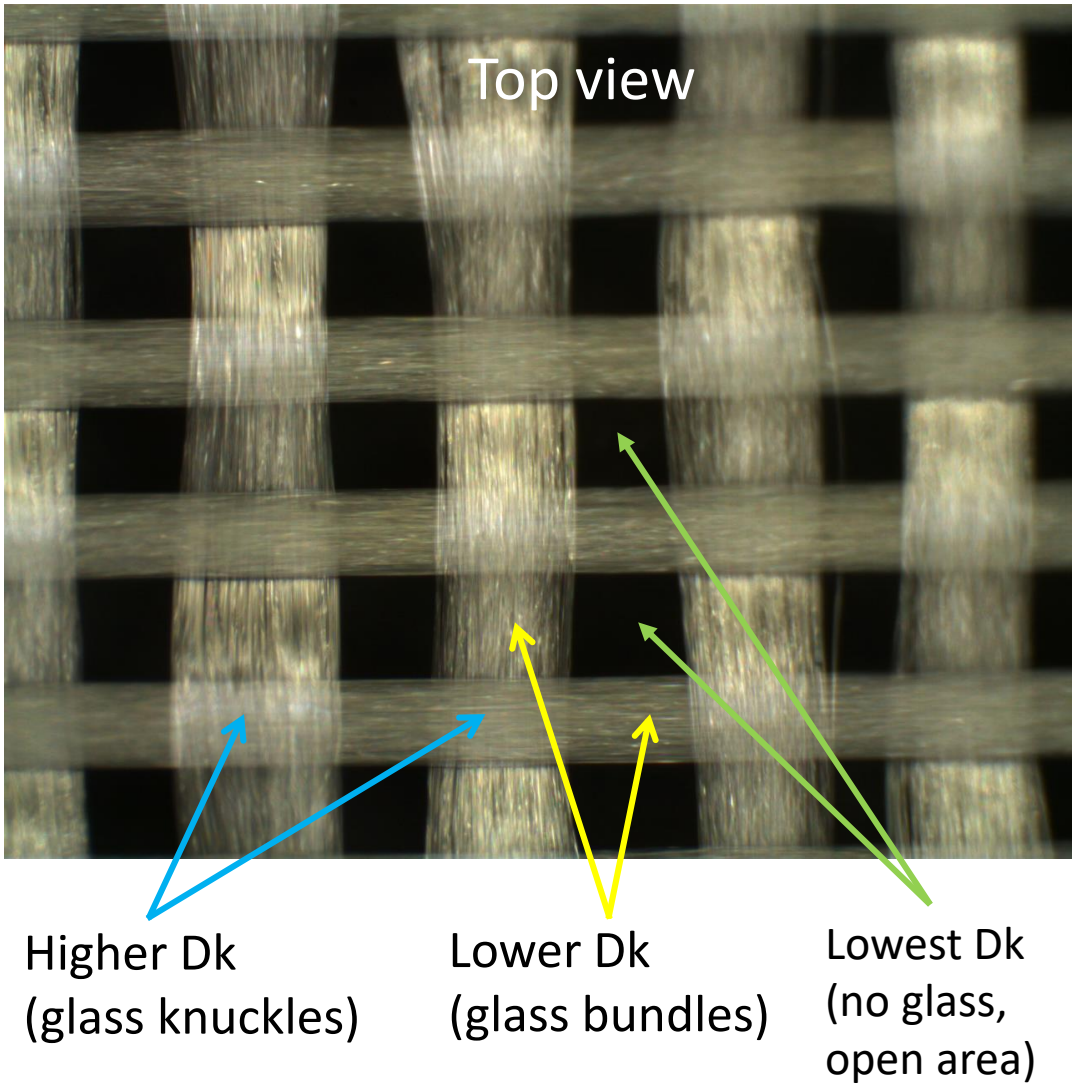
- This will behave more like a uniform plane of glass than will standard weave glass styles



An Overview of Glass-Weave Impact on Millimeter-Wave PCB Performance

Several potential circuit-glass configurations where glass-weave patterns can impact RF performance

- Top view to the right, with no copper planes, assume the resin system is clear, looking down and considering the isolated Dk differences of the different glass-weave configuration
- Glass has a Dk ~ 6
- Resin system can vary a lot, but for mmWave laminates it is usually ~ 2.1 to ~3.0



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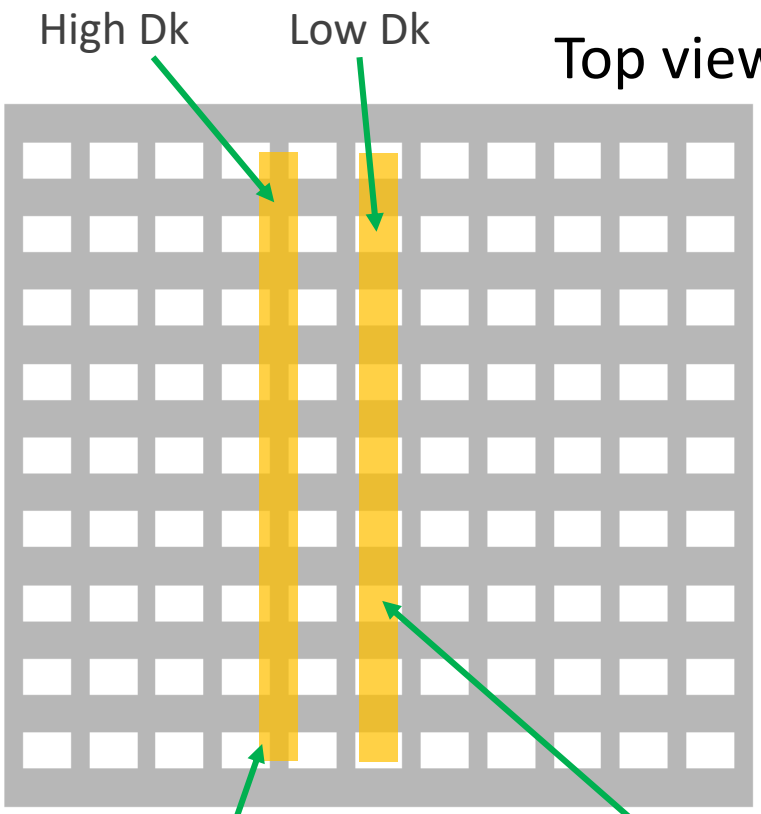

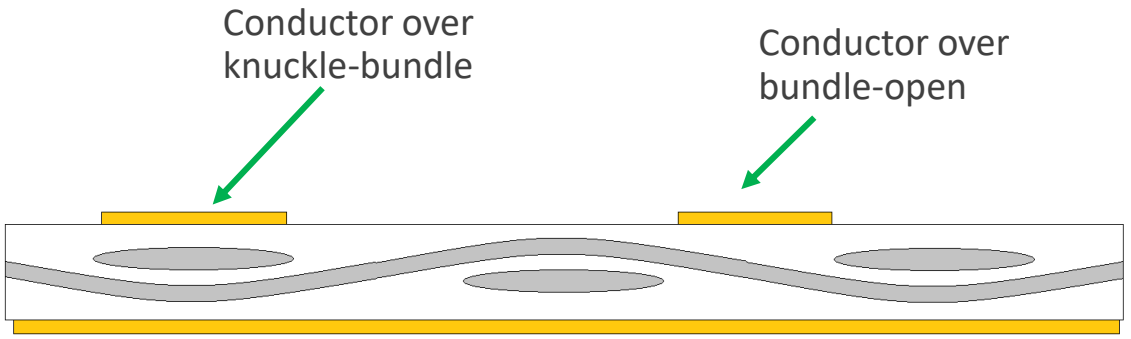

Conductor with overall **lower Dk** is aligned over the <u>bundle-open</u> orientation

Conductor with overall **higher Dk** is aligned over the <u>knuckle-bundle</u> orientation

Local trace environment

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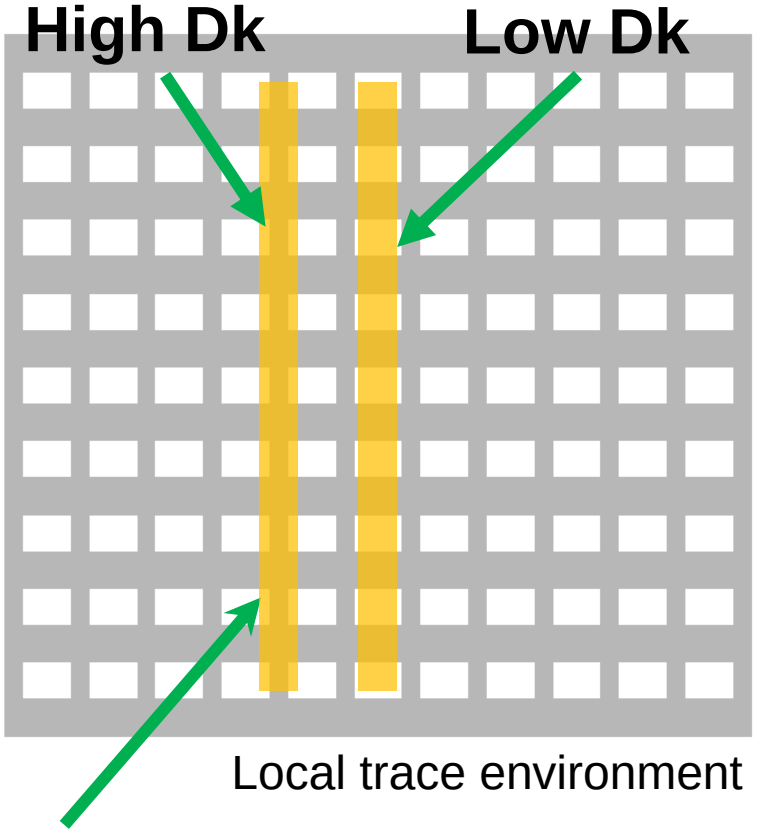
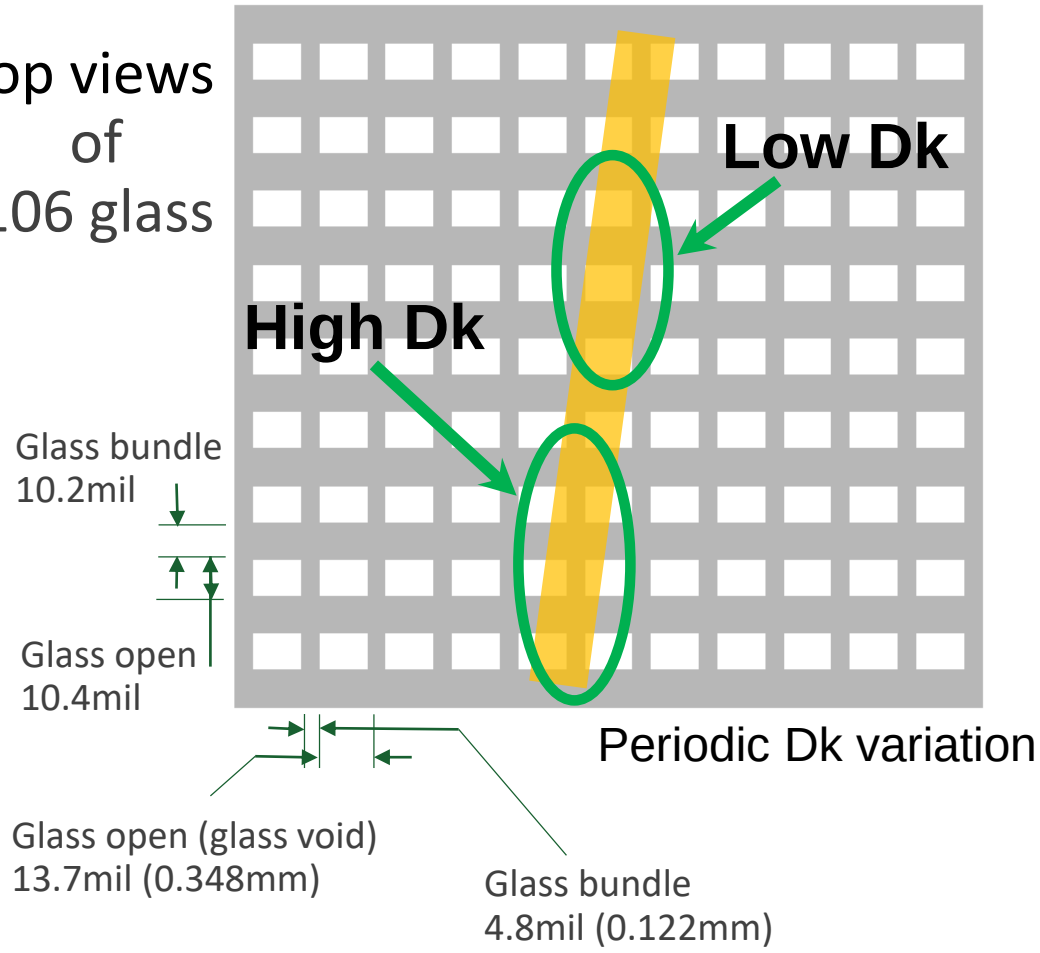
Several potential circuit-glass configurations where glass-weave patterns can impact RF performance



Top views of 106 glass



Sometimes periodic variation is due to the glass pattern shifting and not the conductor

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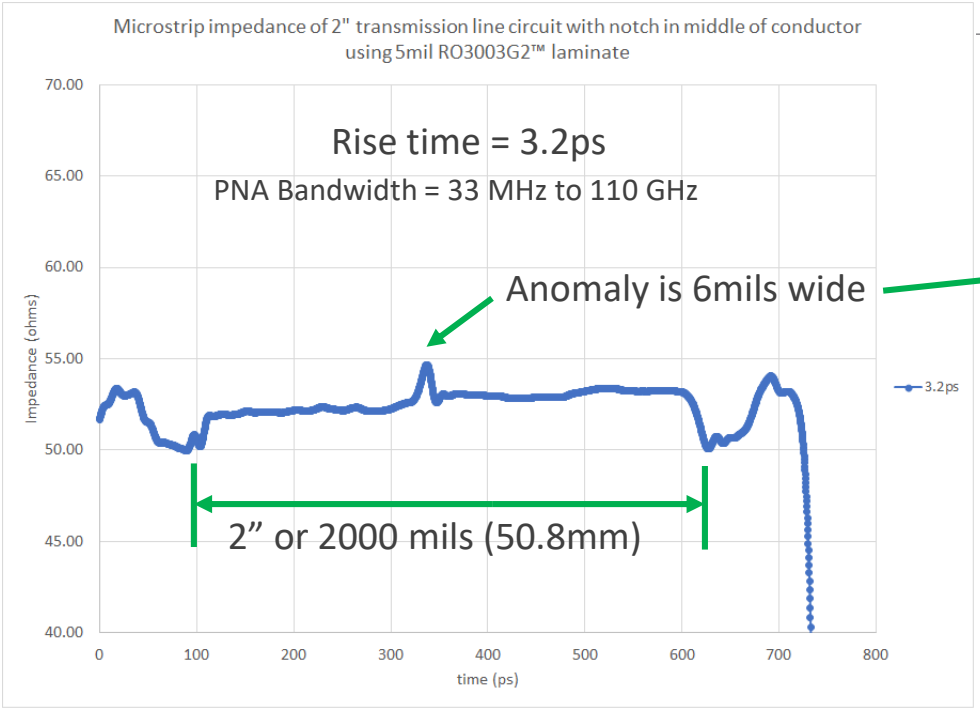
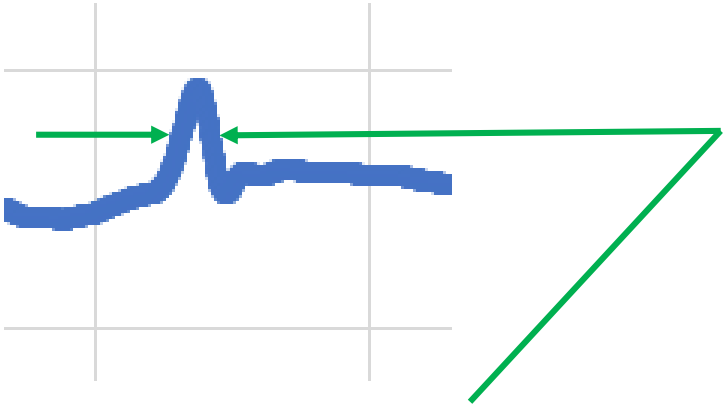
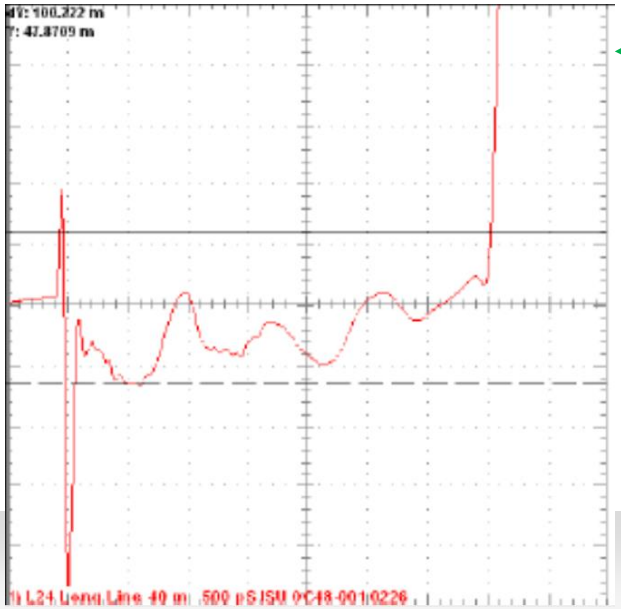
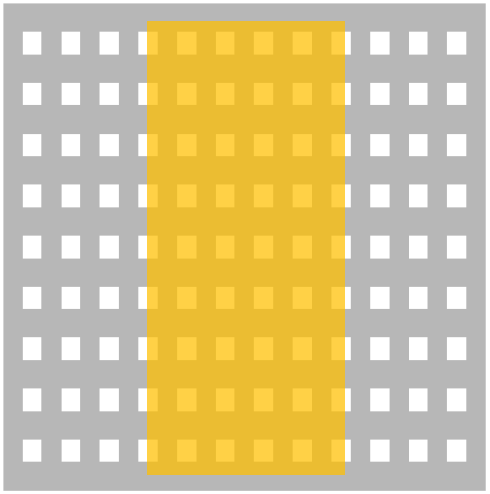




Middle of peak, measures 13ps wide and that is equivalent to 100mils, which is ~5 x pitch of 1080 glass



reported to be glass variation on FR-4 with 1080 glass, but on a scale of 500ps (circuit ~ 340ps) there should be about 95 bundle-open areas. This is probably showing a periodic glass-weave effect and not a local effect



1080 glass

It is not possible to see the bundle-open relationship in impedance measurements

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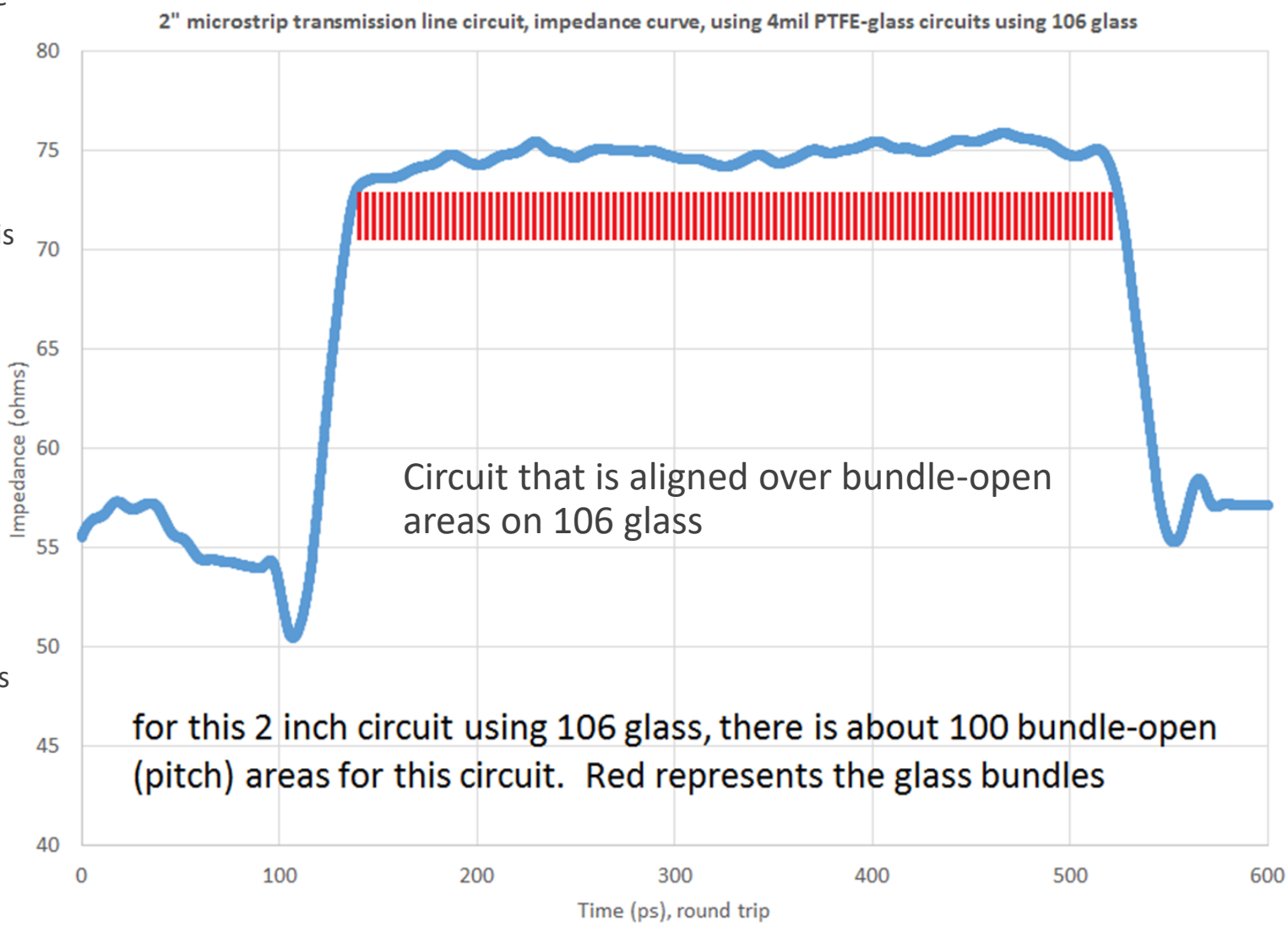
Impedance curve for one of the circuits in our study

We used a 5mil wide conductor to be more sensitive to the glass-weave pattern and that is why the impedance is higher than 50 ohms

The difference between the resin (Dk = 2.1) and the glass (Dk = 6.0) is blended together

The bumps on impedance curve is due to periodic glass weave effect and minor conductor width changes along the length of the conductor. A width difference of 0.3mil is 1 ohm impedance difference. This circuit had width variations of 0.5mil along the 2" length

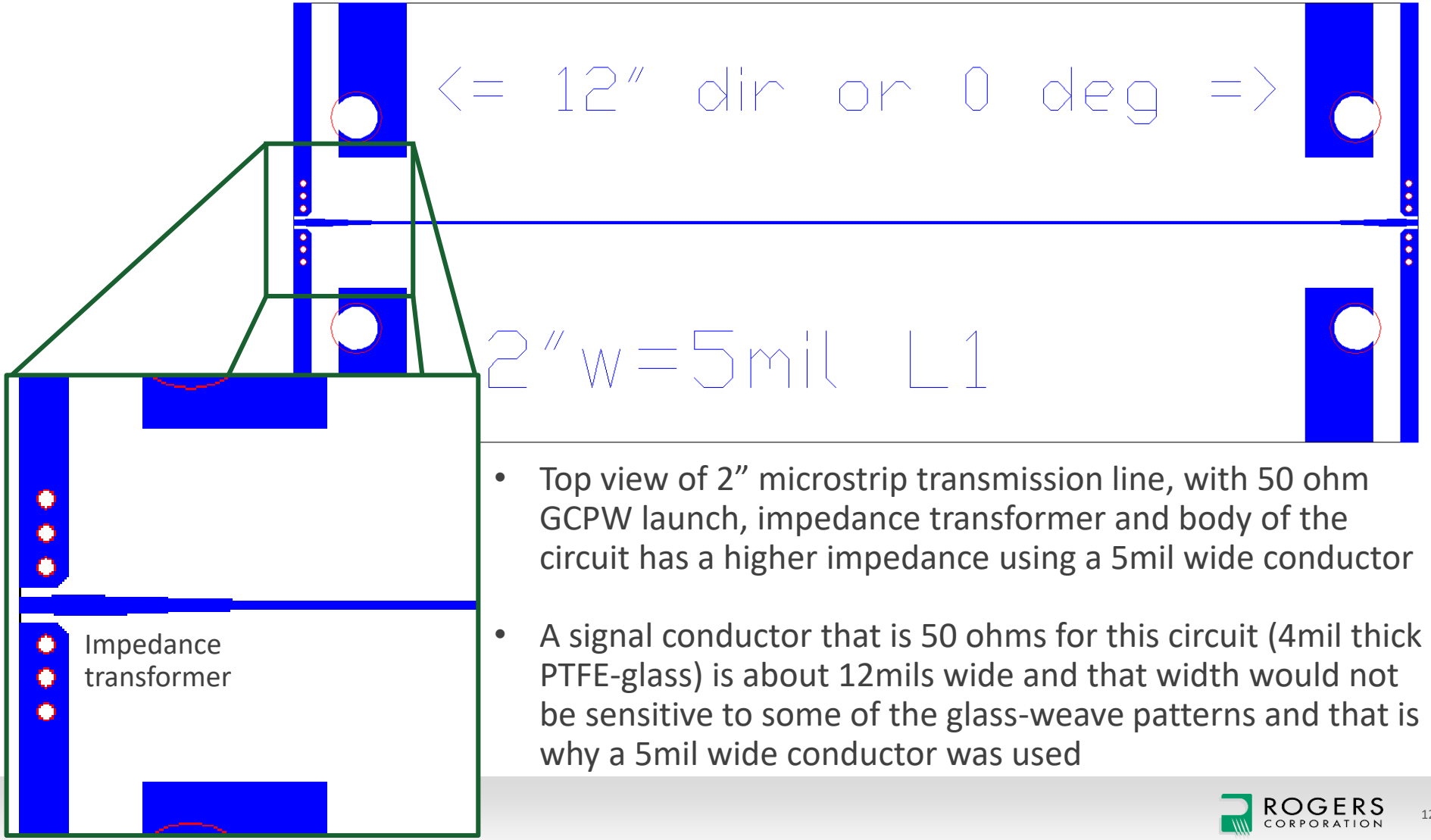


Measured with 3.2ps rise time. Impedance is a round trip measurement

An Overview of Glass-Weave Impact on Millimeter-Wave PCB Performance

Overview of recent studies evaluating glass weave effects at millimeter-wave frequencies

- Test vehicle and test method definition



- Top view of 2" microstrip transmission line, with 50 ohm GCPW launch, impedance transformer and body of the circuit has a higher impedance using a 5mil wide conductor
- A signal conductor that is 50 ohms for this circuit (4mil thick PTFE-glass) is about 12mils wide and that width would not be sensitive to some of the glass-weave patterns and that is why a 5mil wide conductor was used

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Overview of recent studies evaluating glass weave effects at millimeter-wave frequencies

- Test vehicle and test method definition
  - A network analyzer is designed to measure two properties extremely accurately
    - Magnitude
    - Phase angle
  - For this evaluation, the following properties were measured:
    - Phase angle (unwrapped)
    - Group delay (based on phase angle which varies with frequency)
    - Propagation delay, from effective_Dk measurements based on phase angle
    - Impedance from reflected S11 and S22
  - Comparisons of these properties were done with circuits using:
    - 4mil thick PTFE-woven-glass with 106 glass
    - 4mil thick PTFE-woven-glass with 1080 glass
    - 4mil thick PTFE-woven-glass with 1078 glass
    - 4mil thick RO4835™ LoPro® laminate with 1080 glass

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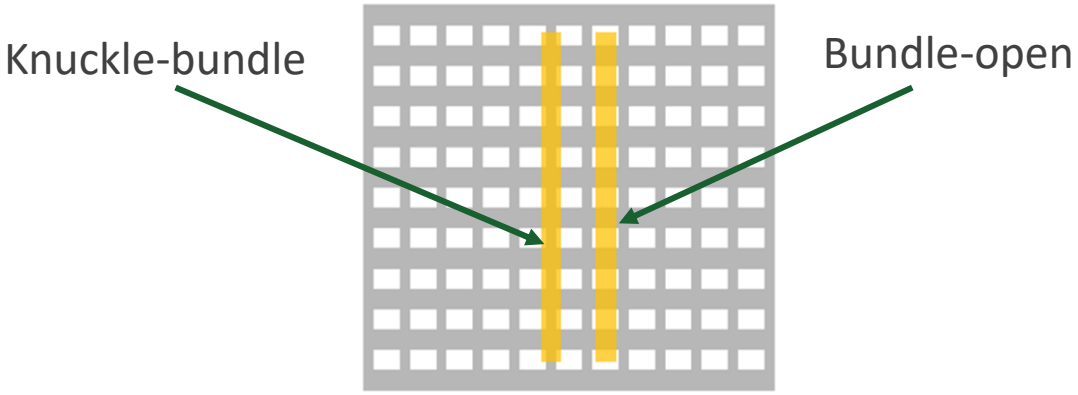
Overview of recent studies evaluating glass weave effects at millimeter-wave frequencies

- Overview of test results



		Average differences between knuckle-bundle and bundle-open		
		40 GHz to 80 GHz		77 GHz
Glass style	Type	group delay (ps)	Prop delay (ps)	phase angle (°)
106	open weave, balanced	4.7	6.9	100
1078	spread, balanced	1	1.3	20
1080	open weave, unbalanced	7.3	10.1	149

		Equivalent difference in Dk (ΔDk) between knuckle-bundle and bundle-open		
		40 GHz to 80 GHz		77 GHz
Glass style	Type	ΔDk from group delay	ΔDk from propagation delay	ΔDk from phase angle
106	open weave, balanced	0.11	0.15	0.09
1078	spread, balanced	0.02	0.03	0.02
1080	open weave, unbalanced	0.17	0.22	0.14

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