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Relative Permittivity Variation Surrounding PCB Via Hole Structures

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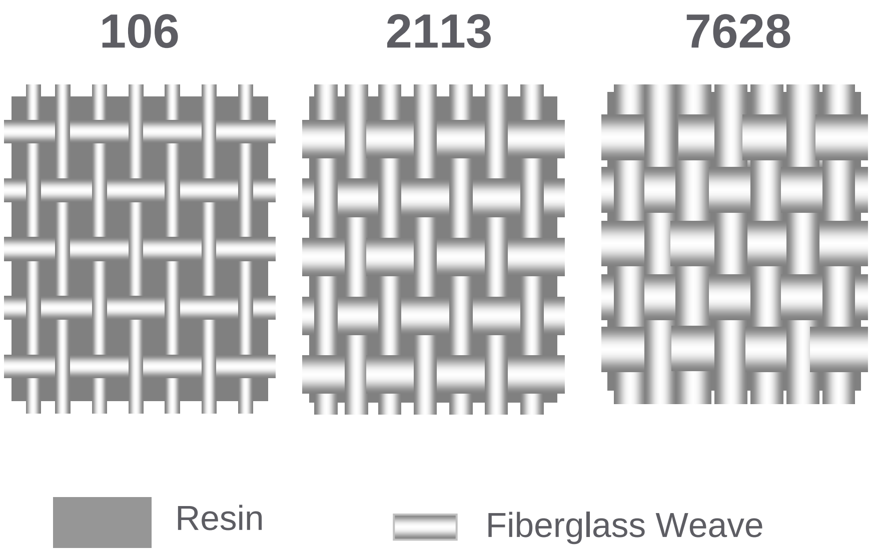
Introduction

- Present IC technology advancements are allowing data rates beyond 6 Gb/s
- PCB through hole via parasitics becoming more of a factor affecting BER performance
- Accurate via modeling and topology simulation are a must
- All models and methodologies require defining relative permittivity (ε_r) or dielectric constant (*Dk*) of material surrounding the via hole structure

PCB Fabrication Overview

- Conventional PCB laminates are fabricated with a weave of E-glass fiber yarns (*Dk 6.6 @ 1MHz*) and resin (*Dk 3.2 @ 1MHz*) [1]
- Effective *Dk* is a function of glass to resin ratio of laminates used in the PCB stackup
- For FR-4 PCBs an effective *Dk* of 4.3 is often used for trace etch impedance calculations

Fiberglass Weave vs Resin Content

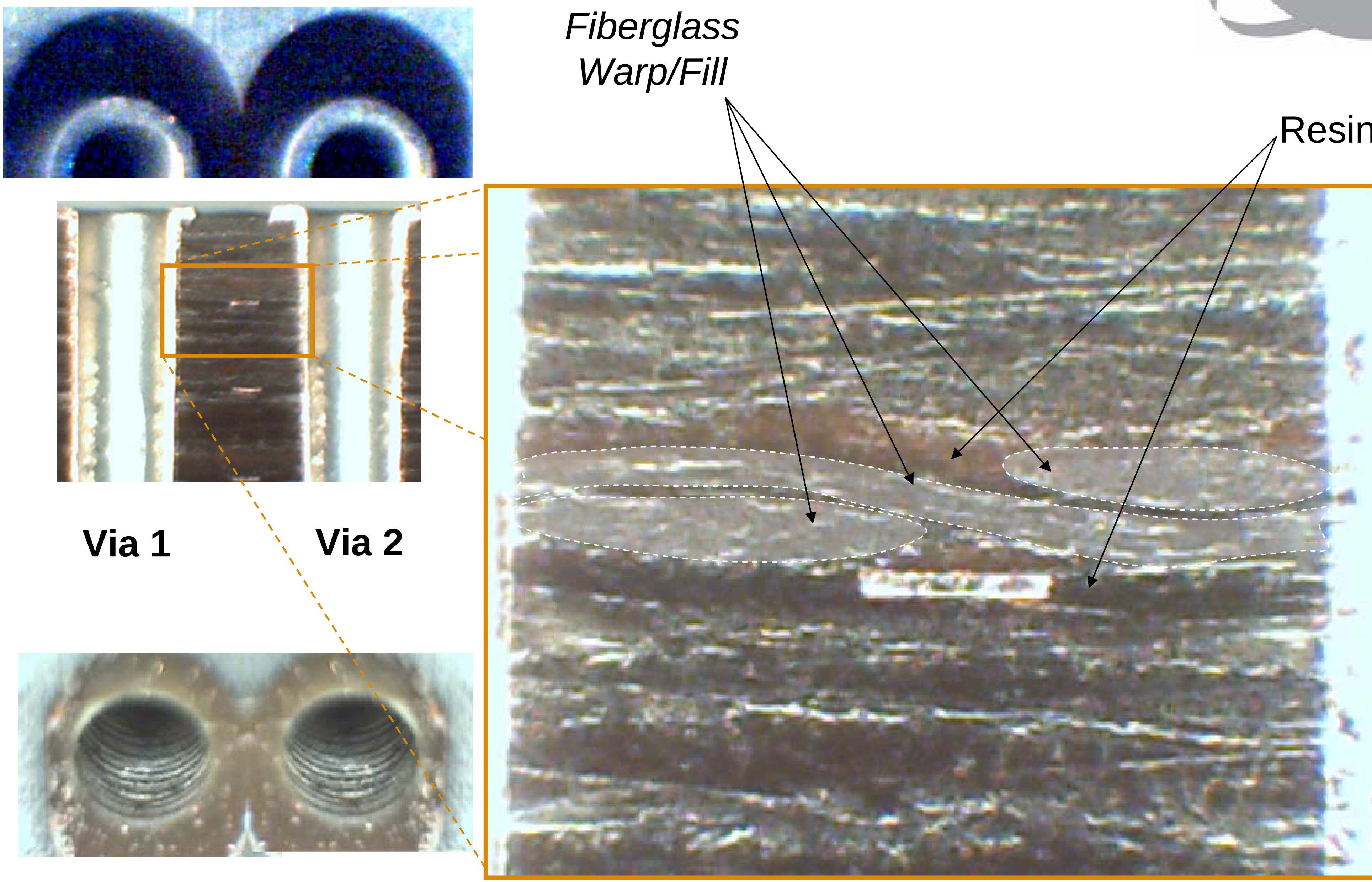


Fiberglass weaves vs. resin content illustration. Smaller glass diameter and thread count results in higher resin content, while larger glass diameter and thread count results in lower resin content.

N4000-6 TM Dielectric Properties Table [1], [2]

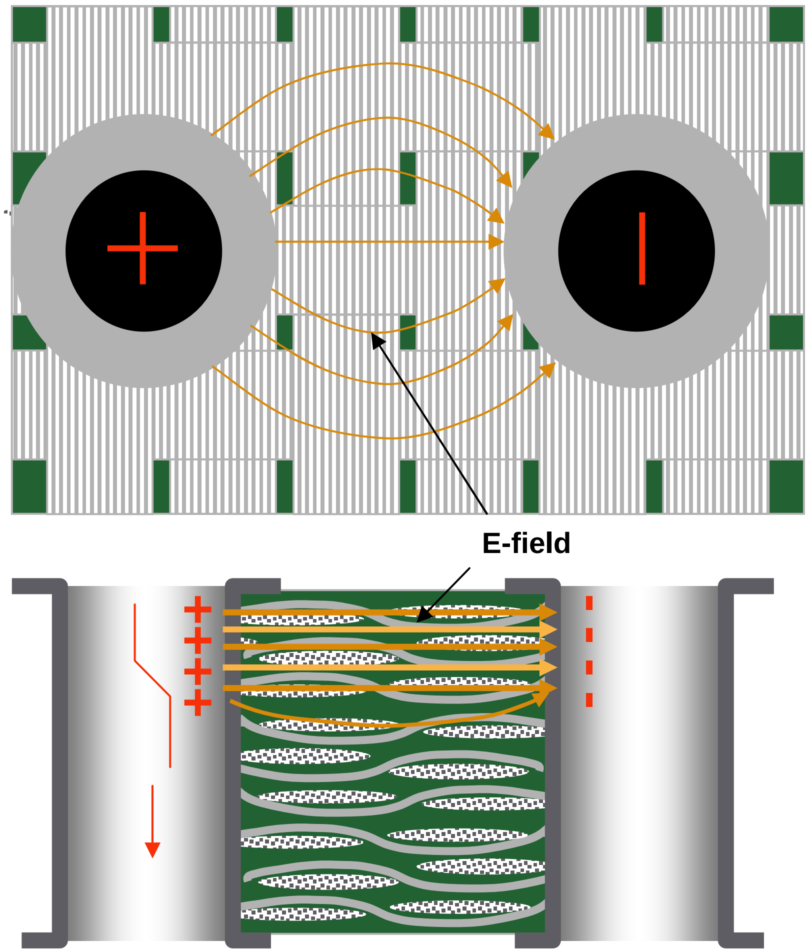
Style	Glass / Laminate Thickness Ratio (mils)	Resin Content (%)	Yarn Count (threads/inch)	Yarn Pitch (mils)
106	1.4/2.0	69.0	56x56	17.9x17.9
1080	2.3/3.0	62.0	60x40	16.7x21.3
2113	2.9/4.0	54.5	60x56	16.7x17.9
2116	3.8/4.0	43.0	60x58	16.7x17.2
7628	6.8/8.0	44.4	44x32	22.7x31.3

Dielectric Property Between Vias



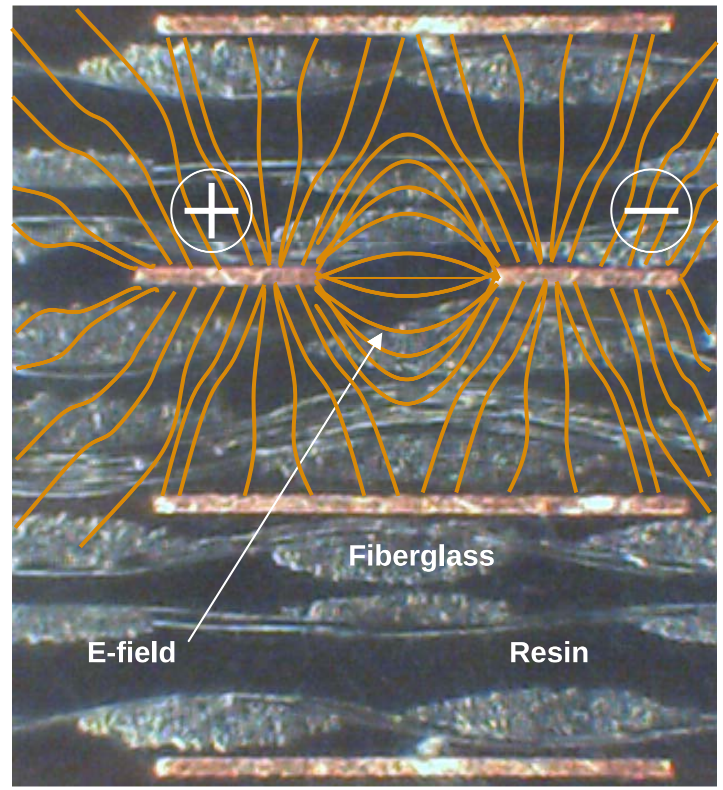
Laminate Weave Effect

Vias



VS

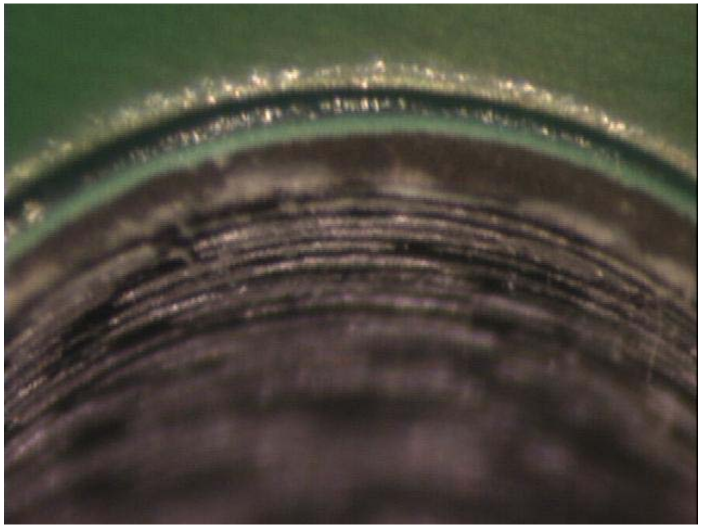
Etch

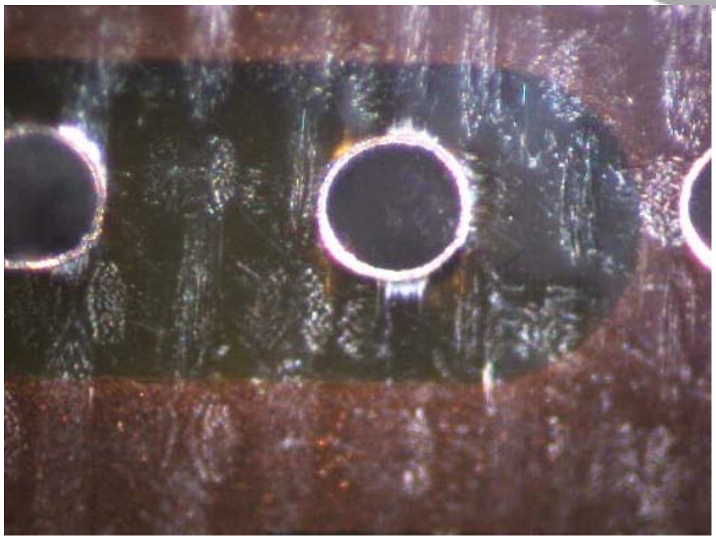


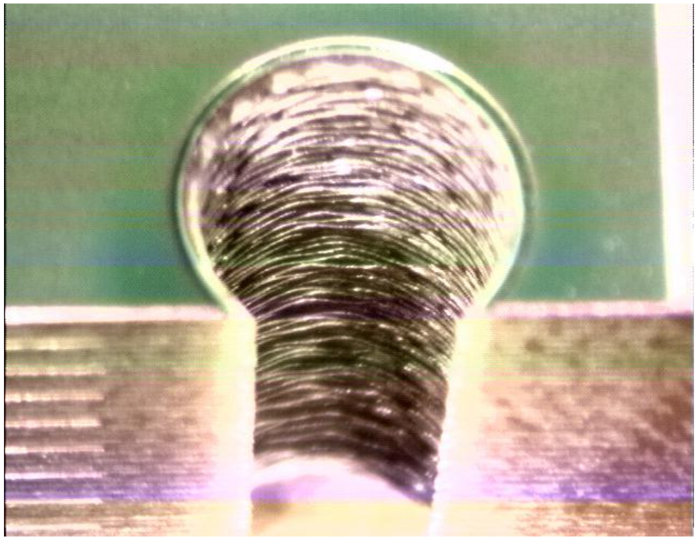
Higher glass to resin ratio between charges => Higher effective dielectric constant

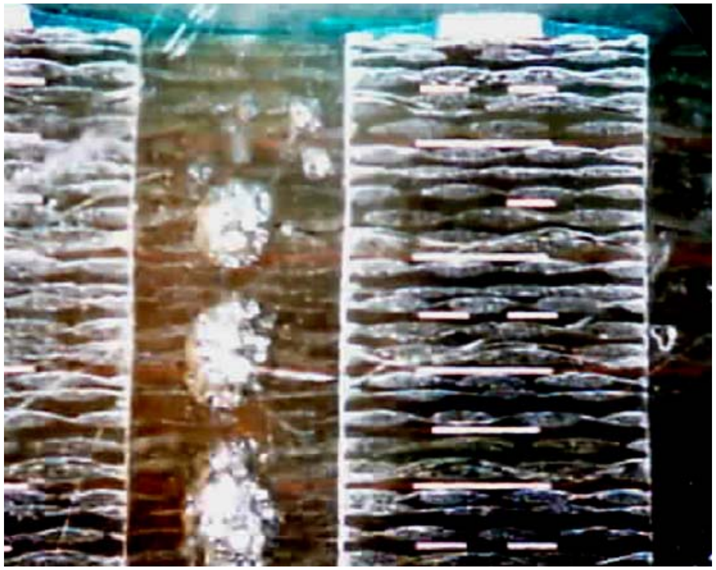
Lower glass to resin ratio between charges => Lower effective dielectric constant

Laminate Weave Effect of Via Hole Structure





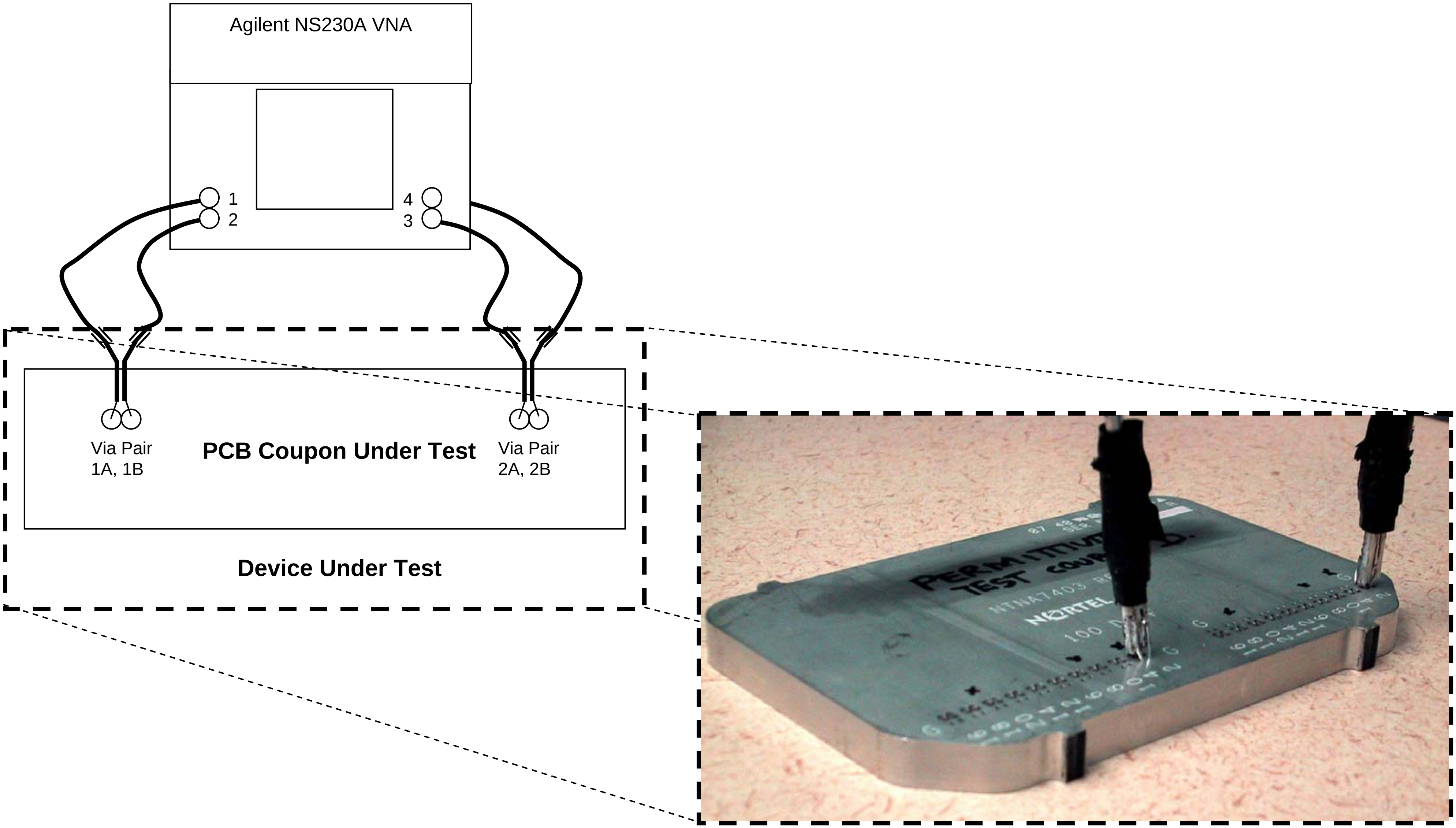




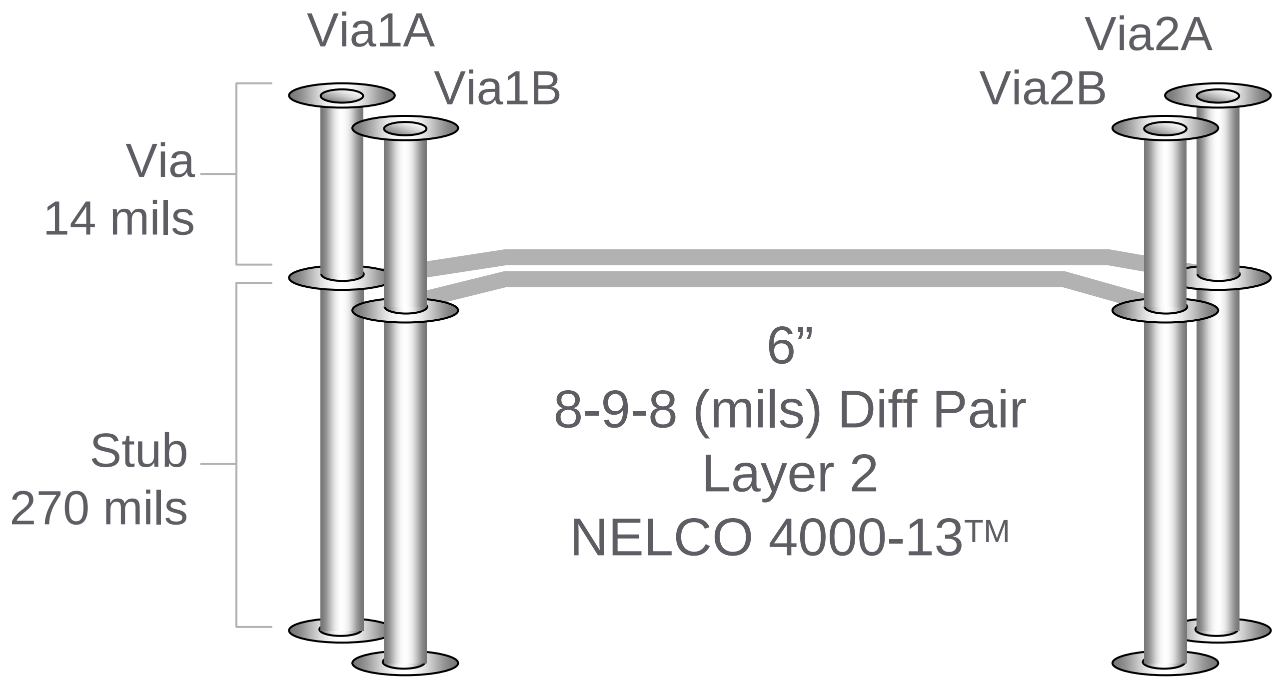
Case Study Objective

- To study the effect of relative permittivity surrounding a PCB via hole structure
- Validate transmission line via model correlation to measured results

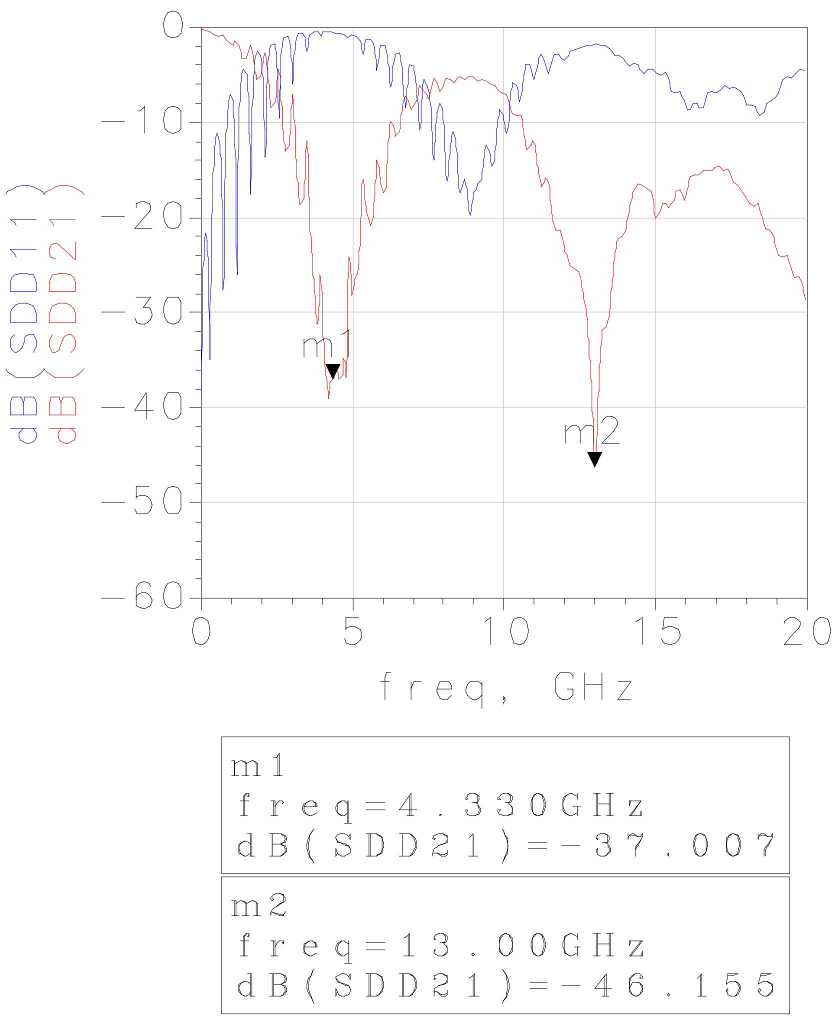
Test Setup


Agilent NS230A VNA
1
2
4
3
Via Pair
1A, 1B
PCB Coupon Under Test
Via Pair
2A, 2B
Device Under Test

Test Coupon Topology



Data and Results



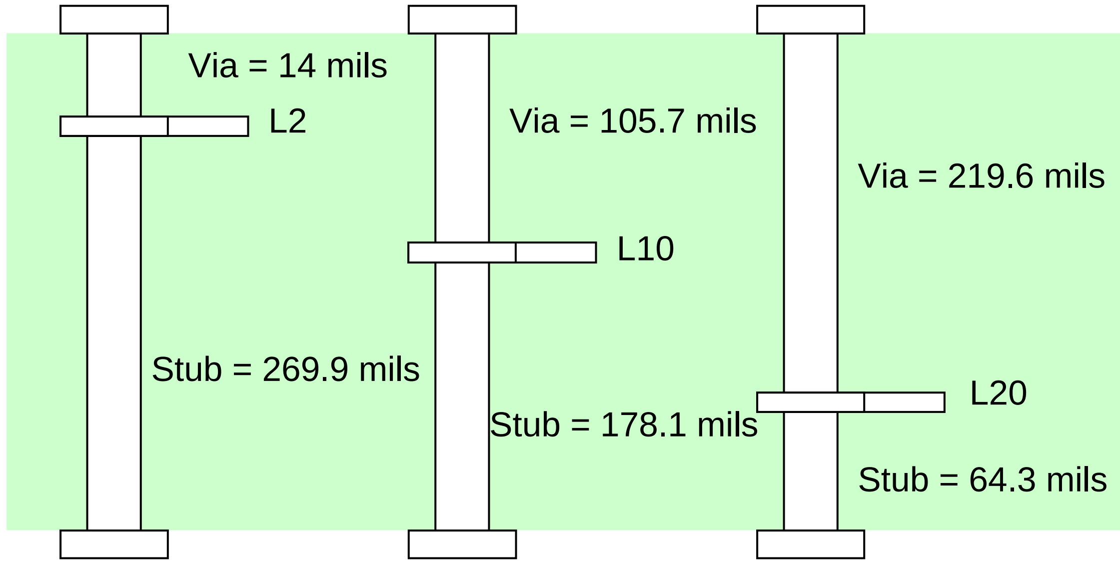
- Resonant frequency nulls due to the via stub length occur at odd harmonics of the ¼ wave frequency null
- Effective relative permittivity (a.k.a. dielectric constant Dk) can be calculated by [5];

$$Dk = \left[\frac{c}{4 * Stub\_length * f} \right]^2$$

= *6.46*

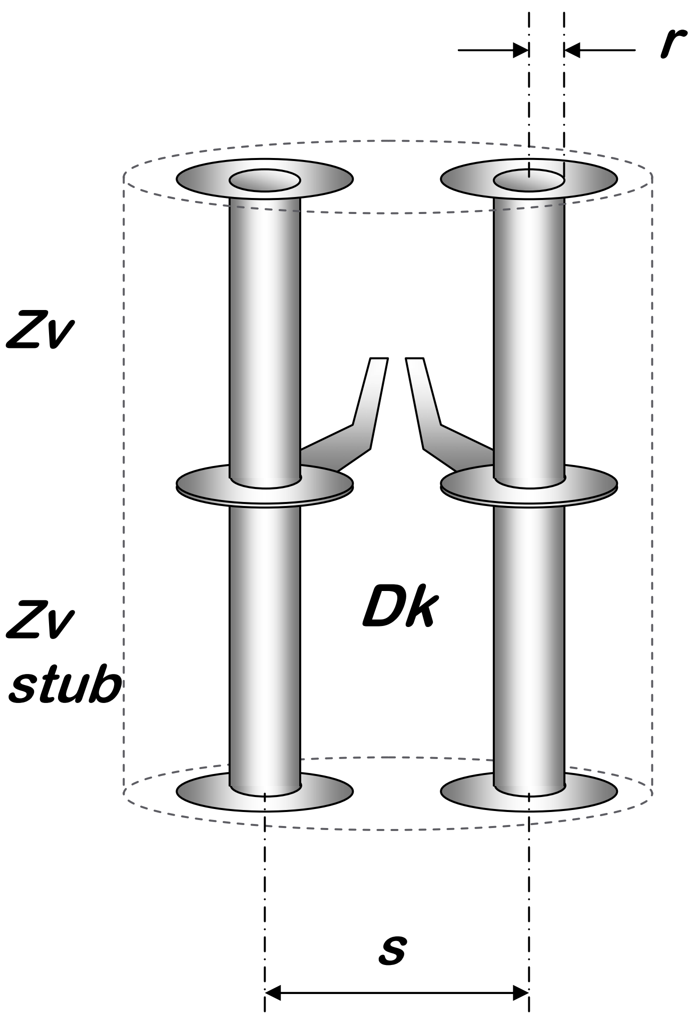
Where: c = Speed of light (1.18E10 inches/sec); Stub_Length (0.270) inches; f = ¼ wave frequency (13.00GHz/3)

Data and Results



Stripline Layer	¼ Wave Frequency (GHz)	3rd Harmonic Frequency (GHz)	Via/Stub Lengths (Mils)	Calculated Dk
02	4.3	13.0	14/269.9	6.46
10	6.3	18.9	105.7/178.1	6.90
20	18.4	N/A	219.6/64.3	6.20

Differential Pair Via Model



- Modeled as differential pair transmission lines
- Analogous to a twin-round-wire wire structure

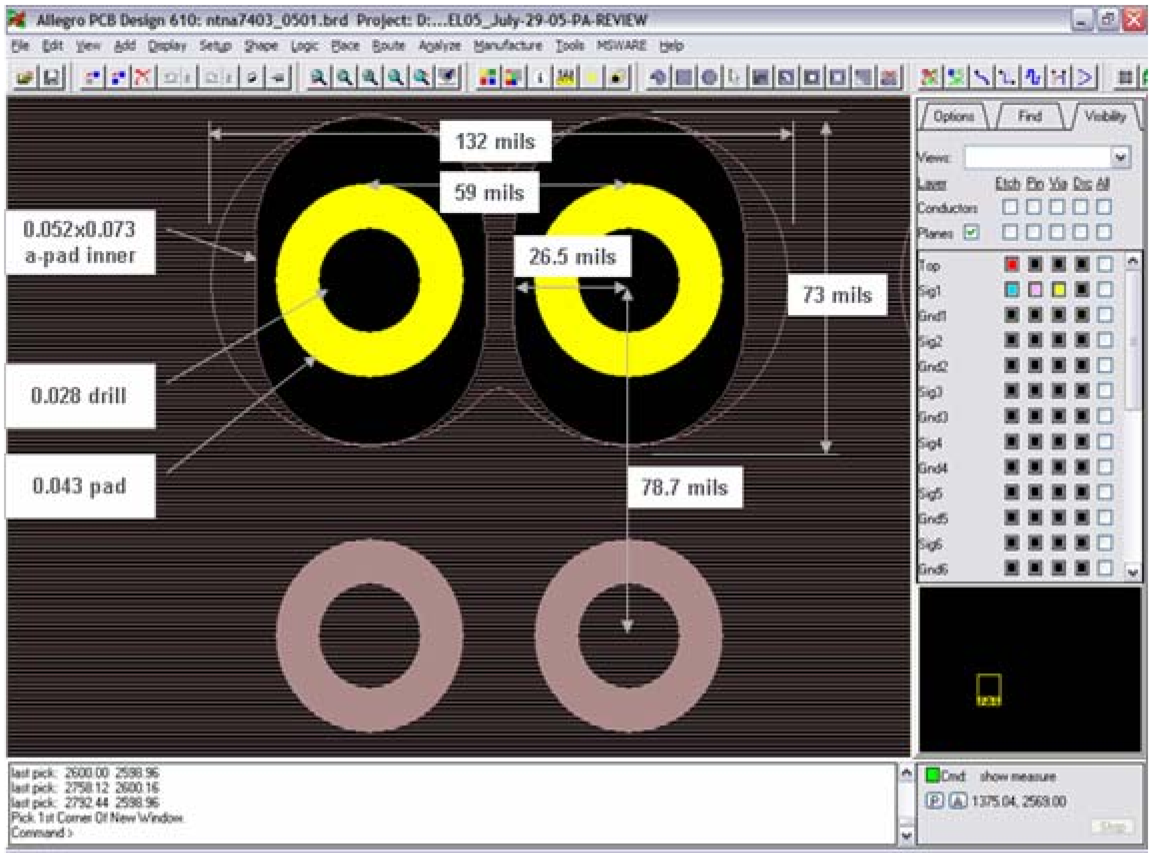
$$Zdiff = \frac{120\Omega}{\sqrt{Dk}} \ln\left(\frac{s}{2r} + \sqrt{\left(\frac{s}{2r}\right)^2 - 1} \right)$$

Where: Zdiff = Differential impedance; Dk = Dielectric constant; s = center-to-center space of vias; r = radius of drill [6]

- Odd mode via impedance (Zv)

$$Zv = \frac{Zdiff}{2}$$

Via Impedance Calculation



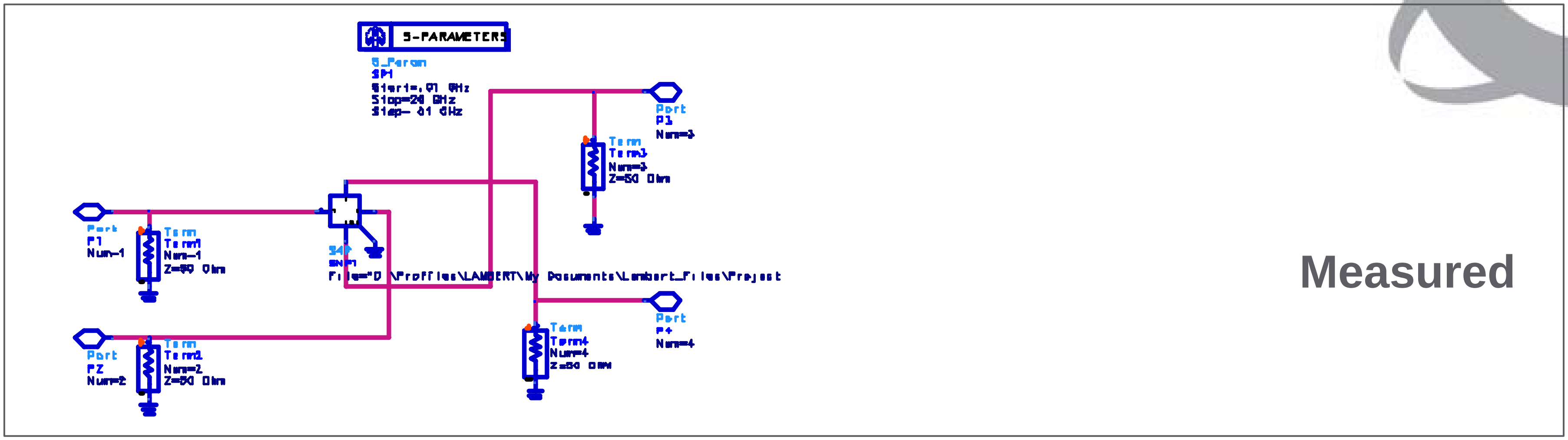
$$Zdiff = \frac{120\Omega}{\sqrt{Dk}} \ln\left(\frac{s}{2r} + \sqrt{\left(\frac{s}{2r}\right)^2 - 1}\right)$$

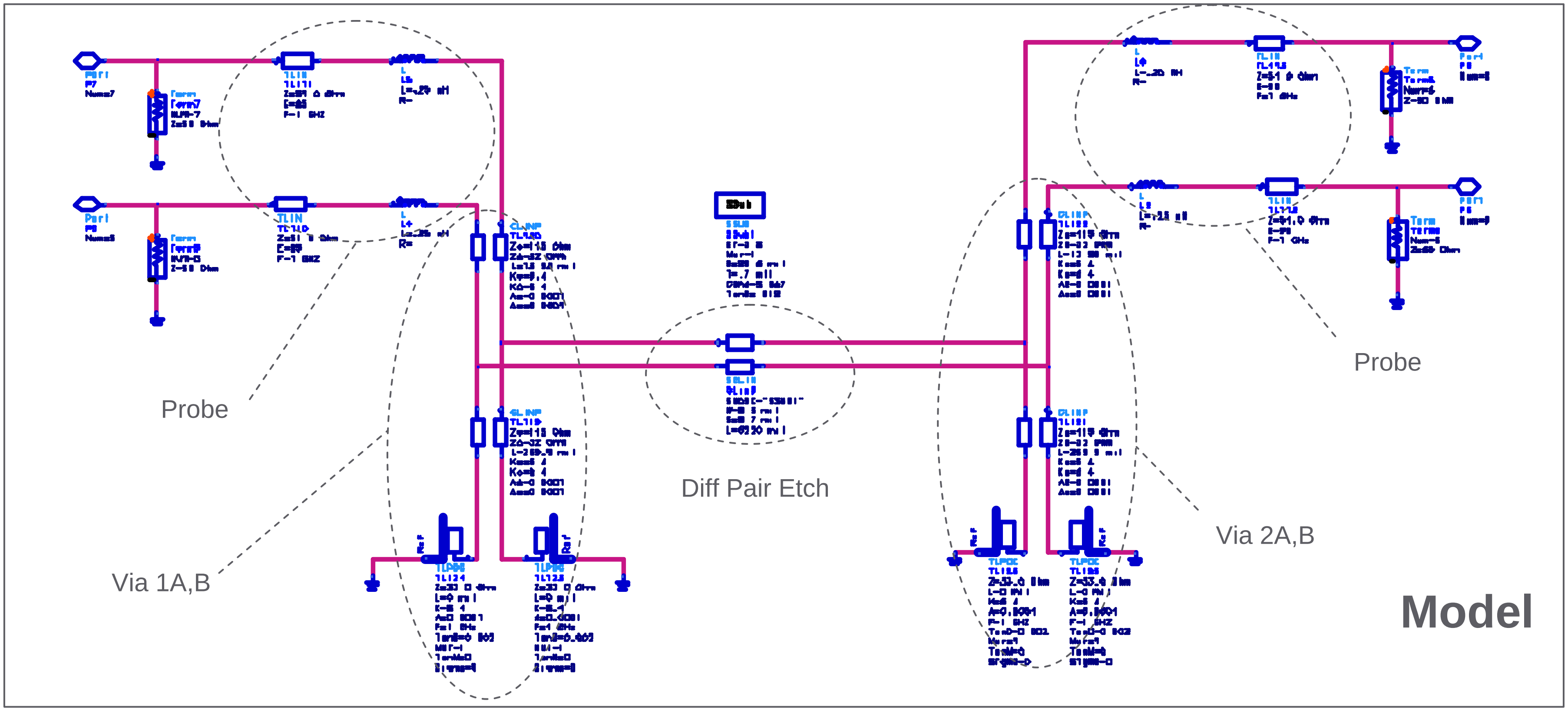
$$= \frac{120\Omega}{\sqrt{6.4}} \ln\left(\frac{59}{28} + \sqrt{\left(\frac{59}{28}\right)^2 - 1}\right)$$

$$= 65\Omega$$

$$Zv = Zodd = \frac{Zdiff}{2} = \frac{65}{2} = 32.5\Omega$$

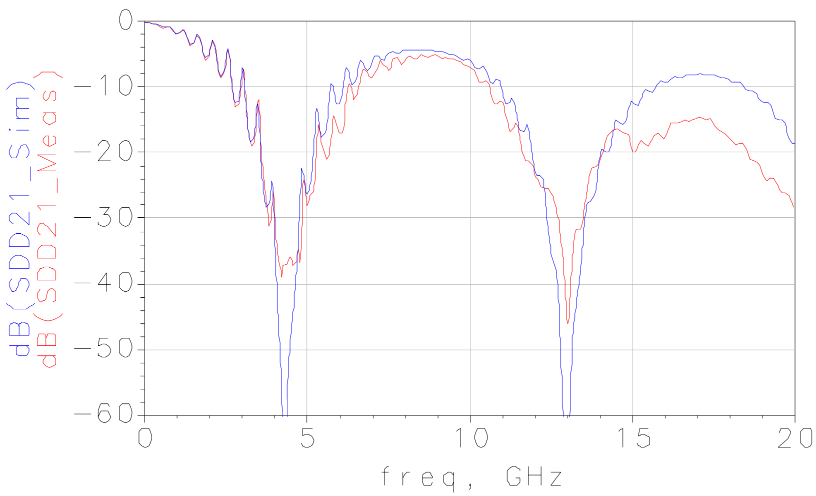
ADS Simulation Correlation Topology

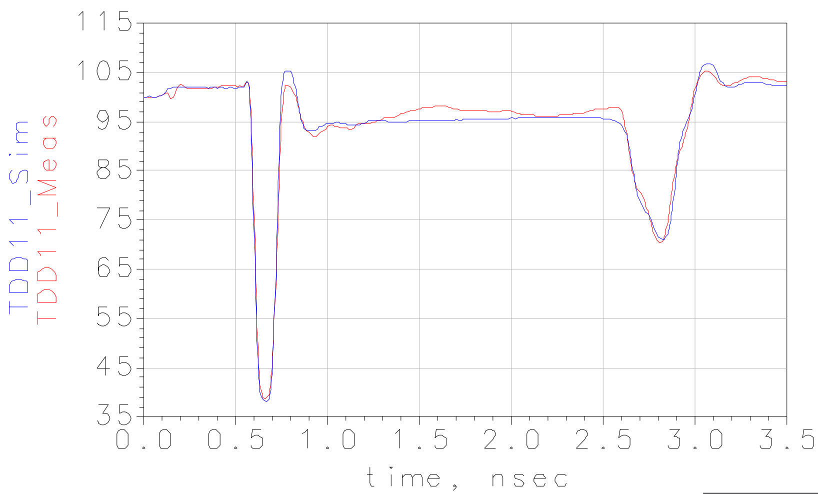




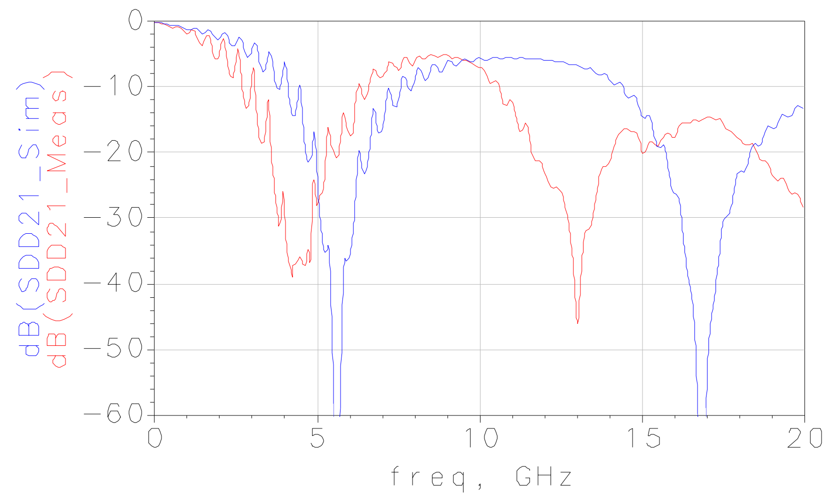
ADS Simulation Correlation Results

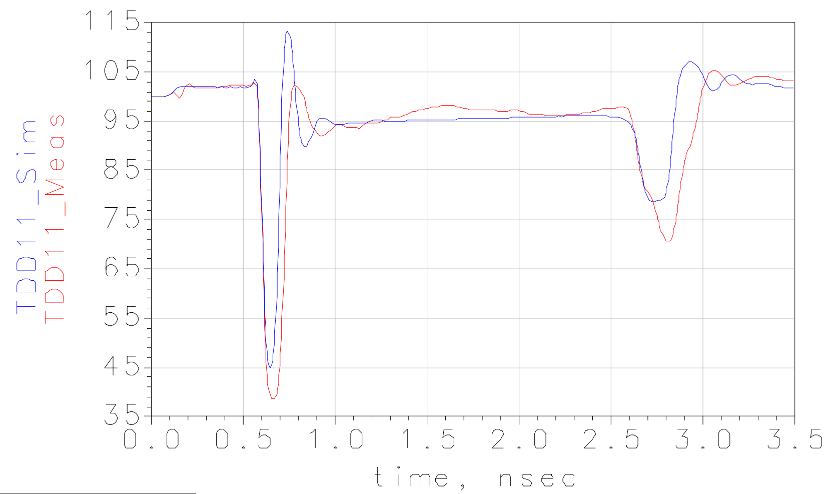
Dk = 6.4





Dk = 3.8





-- Measured -- Simulated

Conclusions

- Due to the fiberglass weave effect surrounding differential pair vias, the relative permittivity is higher than the dielectric surrounding wiring etch within the same PCB stackup

- Using the correct value of dielectric constant has shown better accuracy for via modeling during topology simulations

References

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