Base Material Consideration for High Speed Printed Circuit boards

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EXECUTIVE SUMMARY

Over these years, EU RoHS restriction and lead-free capability is the hottest environmental protection subject. In technology trend, signal integrity performance gets more critical upon today's higher signal transmission speed demand in every field of applications such as computer CPU and GPU chipset levels, system operation frequency and a variety of communication bus and cable like PCI express, SATA II and AGP bus for computer system. Signal communication speed will shift from 1-5 Gbps range up to 5-10Gbps depending on applications. In order to meet lead-free ingredients and severe processes conditions with capable signal integrity performance, laminate material will play a more and more critical and sensitive role in the system.

From consumer products to high-end applications, they all need certain electrical and thermal performances; it is therefore essential to meet those requirements with cost effectiveness. As a base material supplier, we will hereby discuss material design and factors that influence signal integrity, including epoxy and hardener, resin chemical construction, laminate ply-up construction, amount of resin content, fabric weaving density, moisture pick-up and environment factors etc. for a massive mainstream application and low loss application under the hypothesis of lead-free capability.

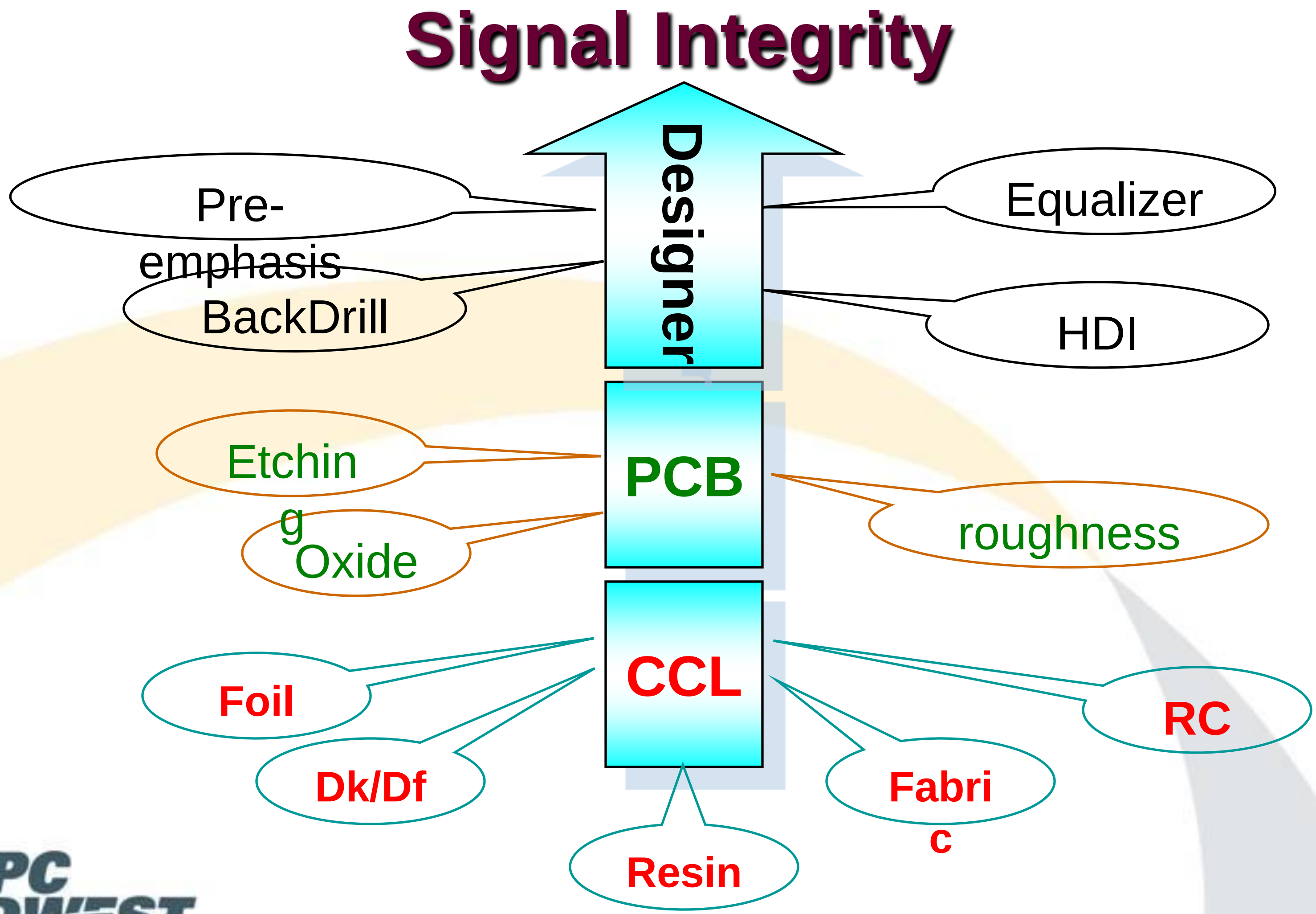
Base Material Consideration for High Speed Printed Circuit Boards

IPC Roadmap : Board Clock Frequency

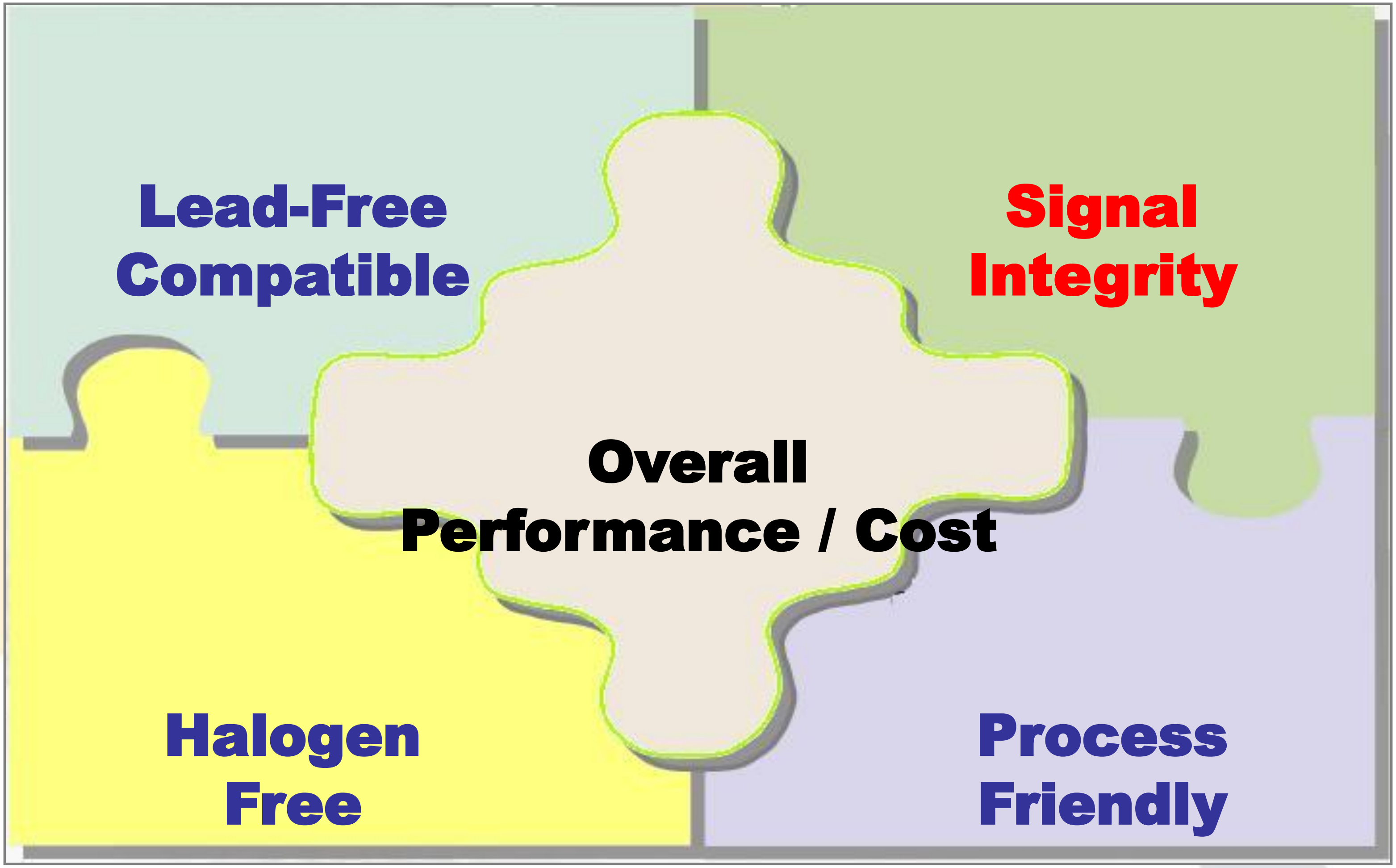
EMULATORS	CURRENT 2006-2007		NEAR TERM 2008-2009		MID TERM 2010-2011		LONG TERM 2012-2016	
	RCG	SoA	RCG	SoA	RCG	SoA	RCG	SoA
E1 Electronic Games	400	500	650	800	650	950	800	1200
E2 Consumer Products	130	150	250	350	700	800	1000	1500
E3 Hand-held / Wireless	130	180	250	300	700	900	1000	2000
E4 Mid Range Performace	1000	2000	1500	3000	2000	4000	3500	5000
E5 High Performace System	750	1250	1250	2500	2500	5000	5000	10,000
E6 RF and Microwave	450	600	550	700	700	800	1000	1200
E7 Harsh Environment: Aero	700	900	1000	1200	1600	1900	1900	2200
E8 Harsh Environment: Auto	56	100	80	150	150	200	200	500

IPC Technical roadmap 2006-2007

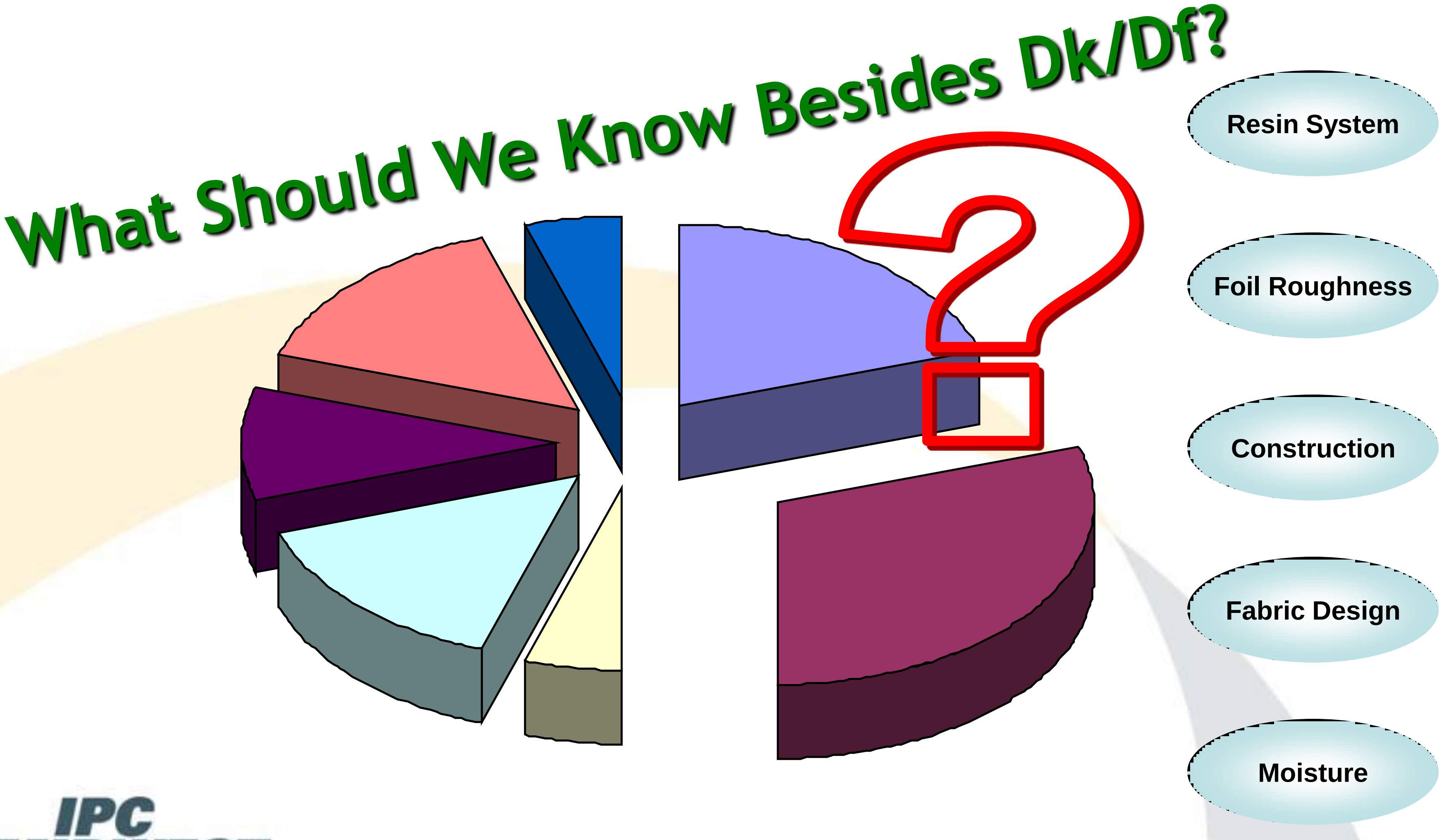
Signal Integrity



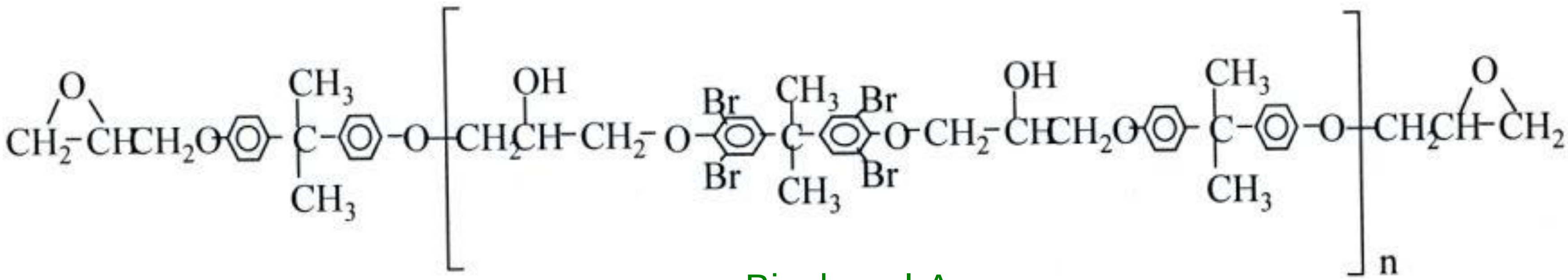
Signal Integrity – Overall Consideration



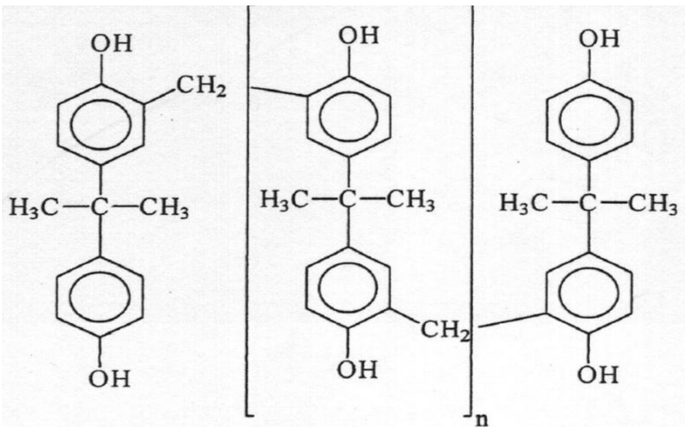
Signal Integrity – Base Material



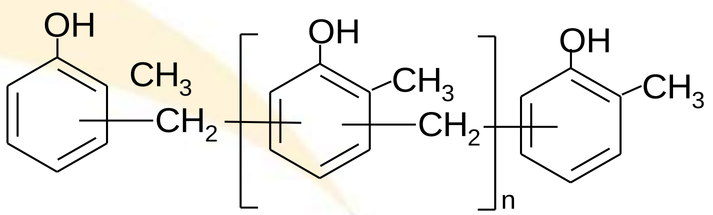
Signal Integrity – Resin System



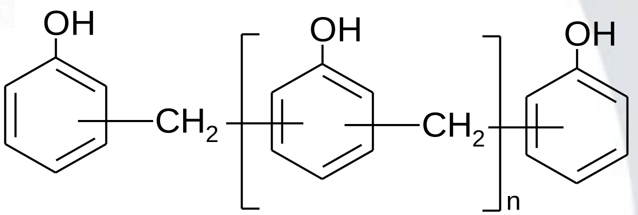
Bisphenol-A



Bisphenol-A Novolac

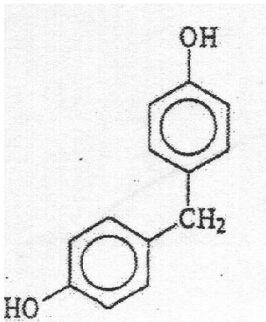


Phenol Novolac

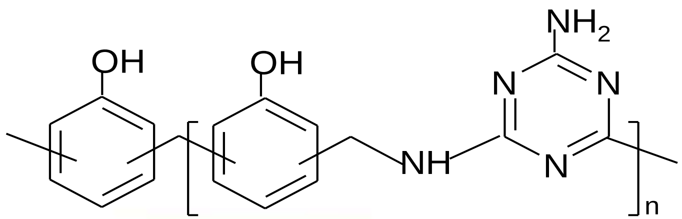


Cresol Novolac

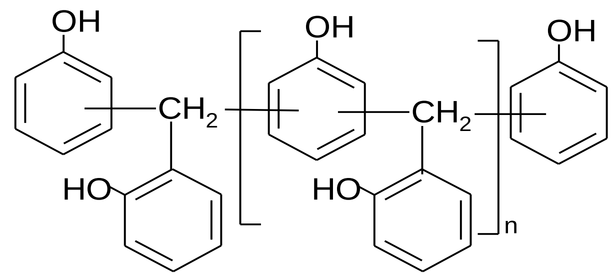
Signal Integrity – Resin System



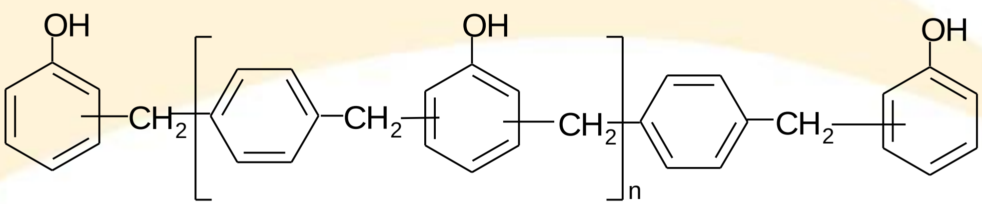
Bisphenol-F



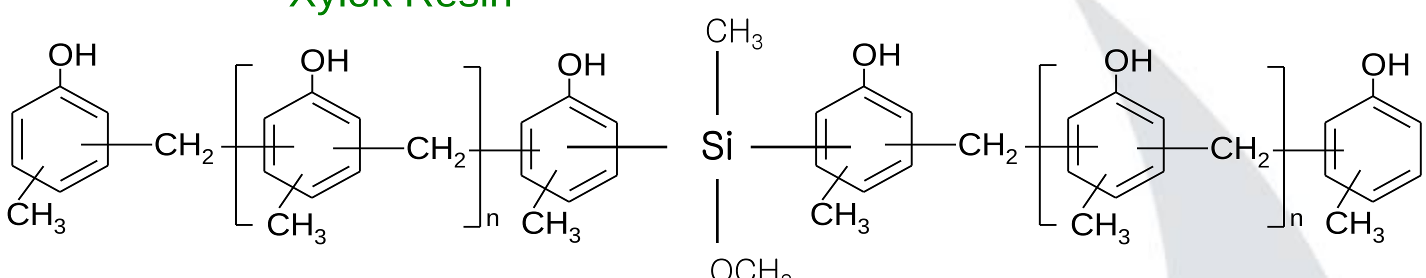
Amino Triazine



Multi-functional Resin

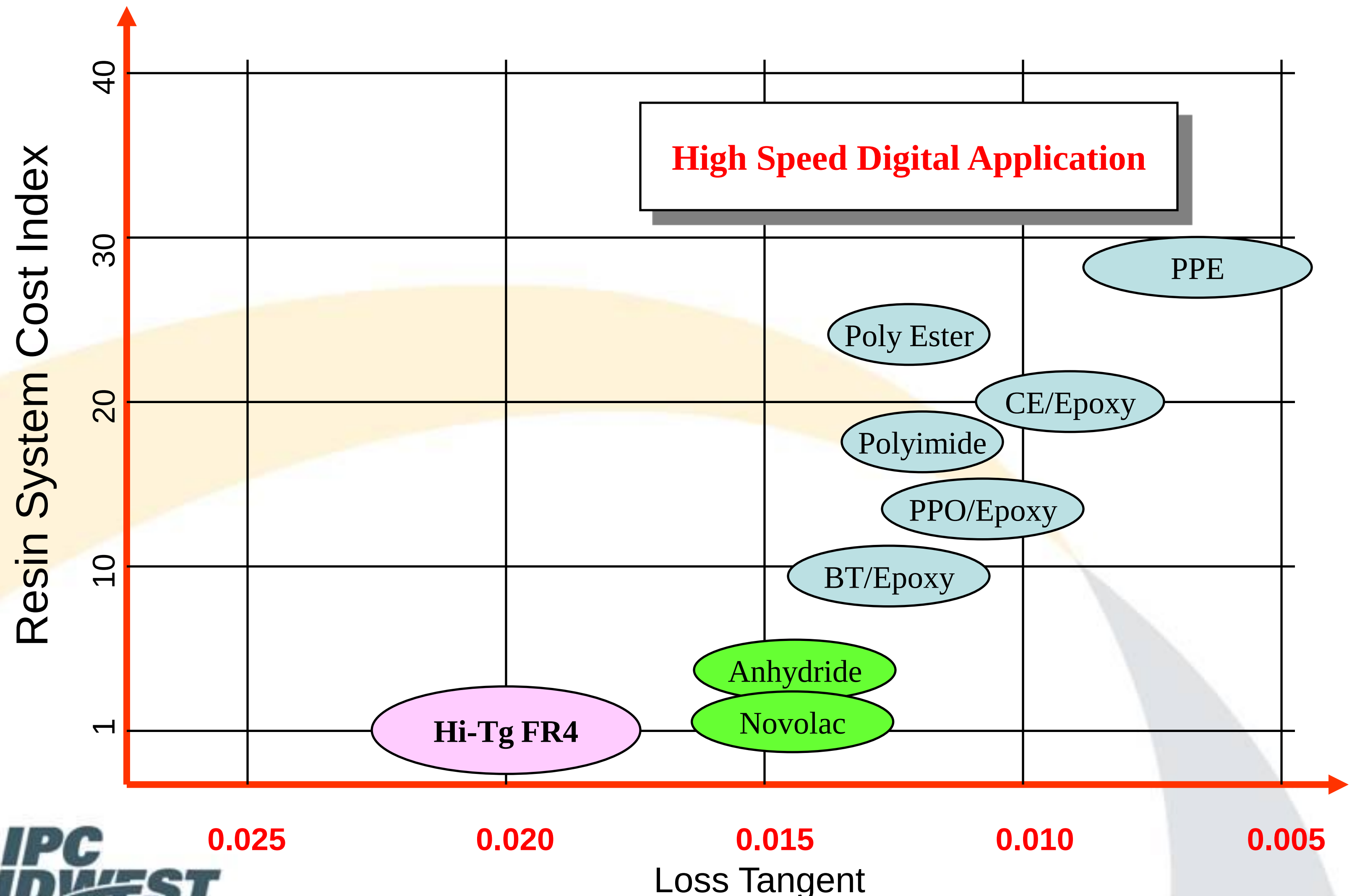


Xylok Resin



Silicone Modified Resin

Signal Integrity – Resin System



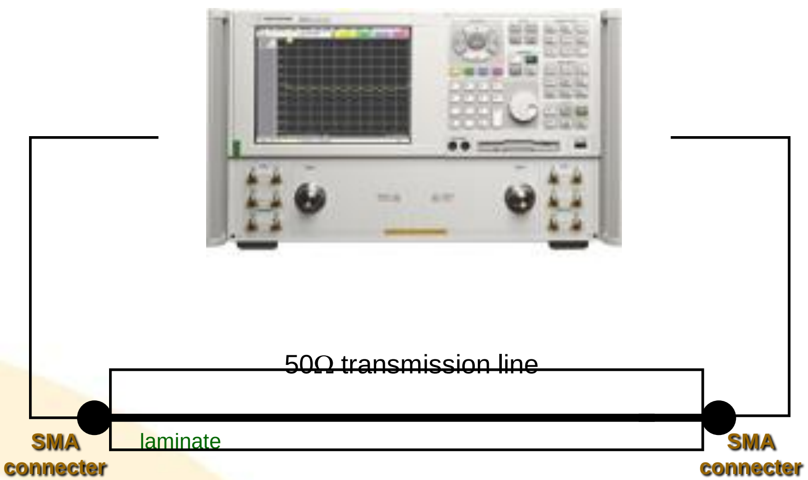
Signal Integrity

Specimen :

- 4” / 16” length
- 4L / stripeline
- 50 ohms
- RTF Foil

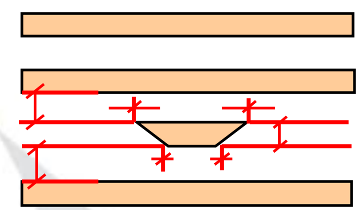
Monitor Items :

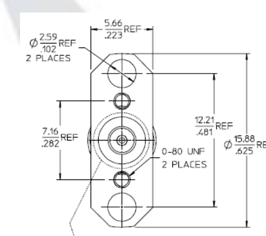
- SPC Dk/Df
- Effective Dk/Df
- (IBM SPP)
- Loss $|S_{21}|$



Test equipment :

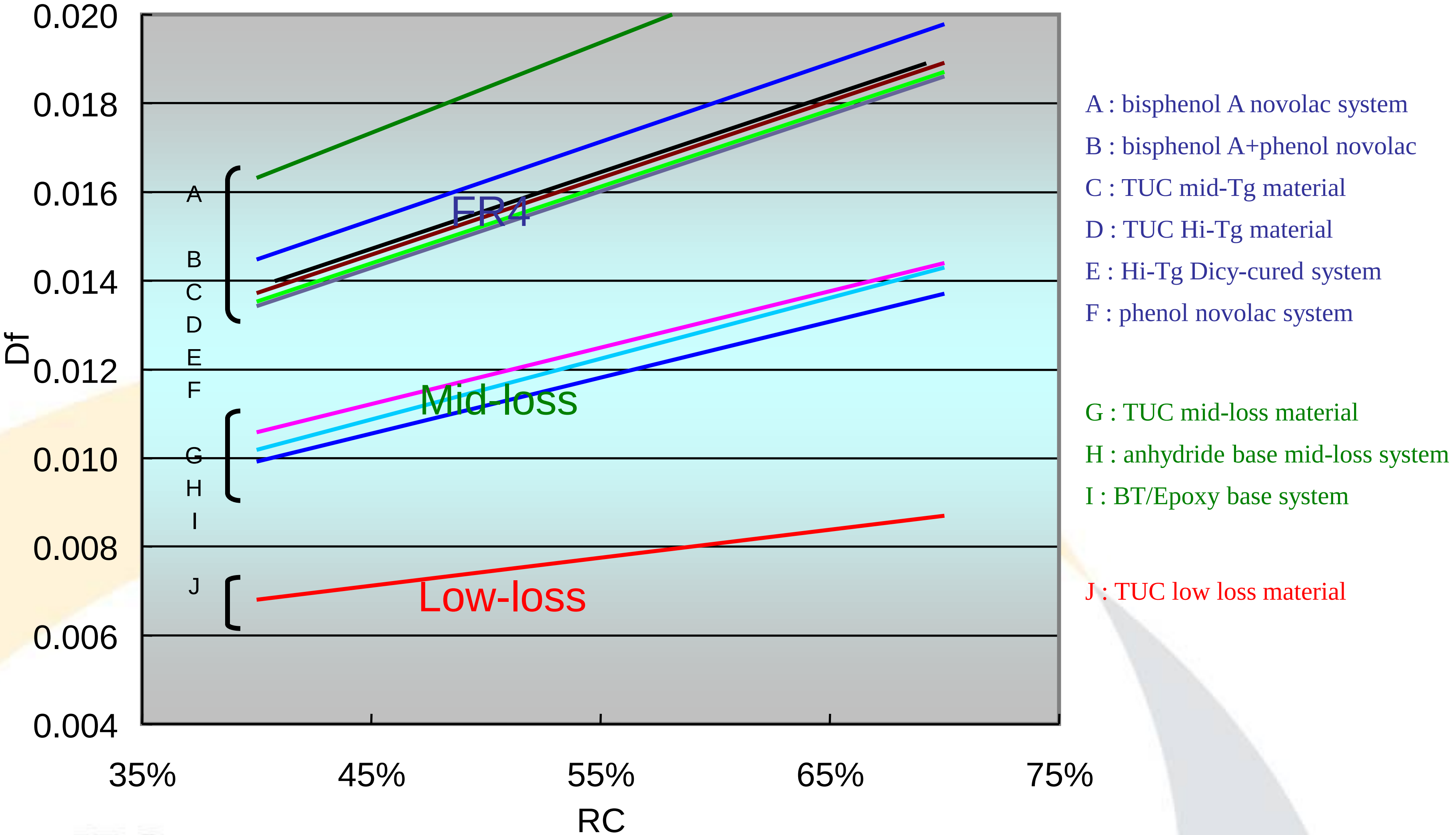
- Tektronix TDR (Time Domain Reflector)
- PNA Network Analyzer (Signal Attenuation)
- Pulse Pattern Generator (Eye Diagram)
- Oscilloscope (Eye Diagram)
- Test Fixture: 26 GHz bandwidth SMA connector



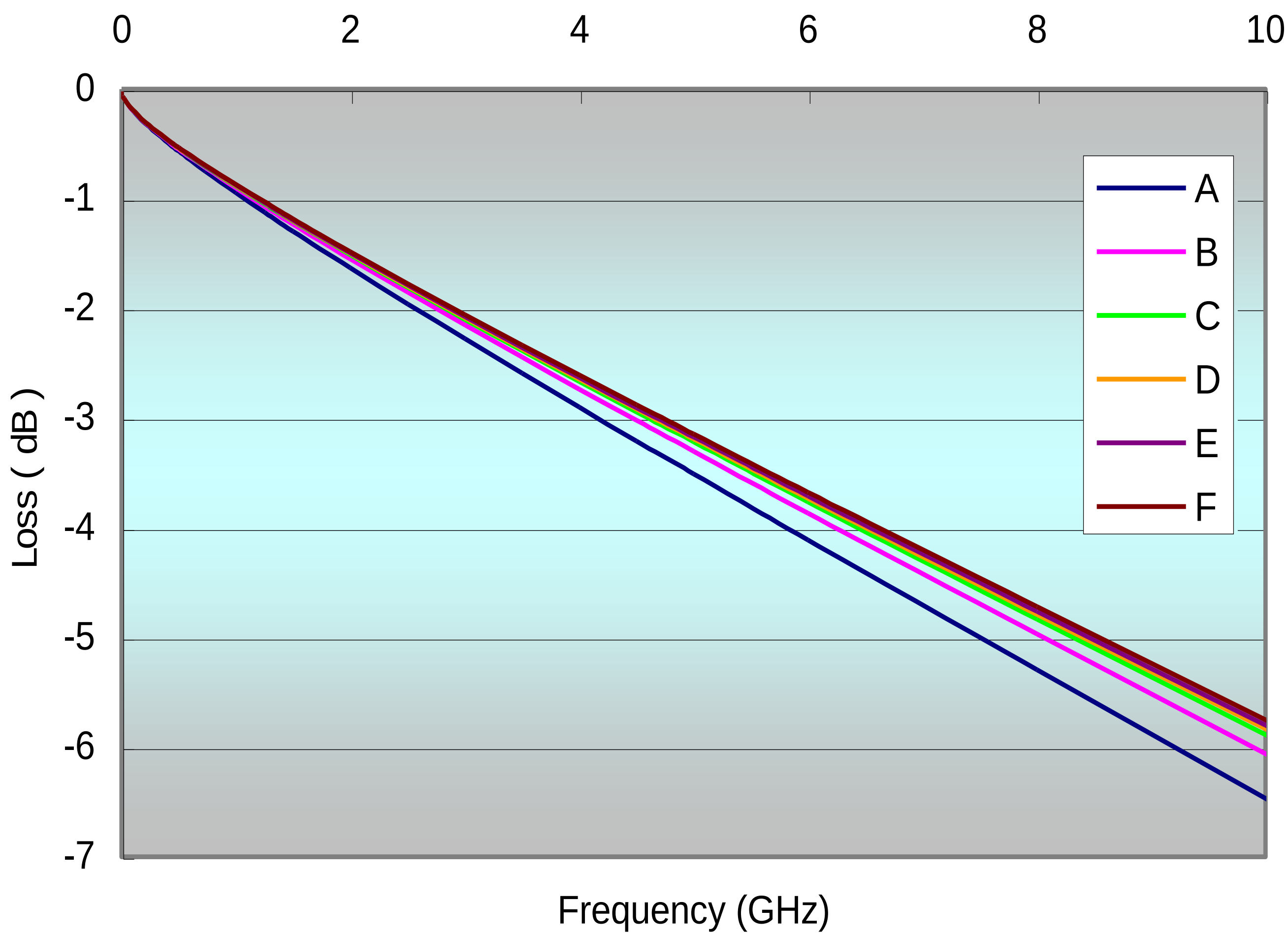


IPC MIDWEST CONFERENCE & EXHIBITION

Df (Resin System, RC)



FR4 Grade Materials



A : bisphenol A novolac system

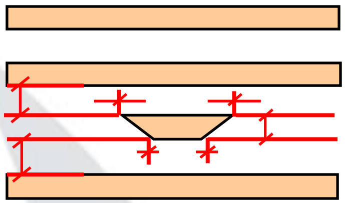
B : bisphenol A + phenol novolac

C : TUC mid-Tg material system

D : TUC Hi-Tg material

E : Hi-Tg dicy-cured

F : phenol novolac system



Specimen :
4L stripeline
4” length

FR4 Grade Materials

Loss	A	B	C	D	E	F
1.0 GHz	108.6%	103.7%	101.6%	101.0%	100.6%	100%
3.0 GHz	110.7%	104.6%	102.0%	101.3%	100.8%	100%
5.0 GHz	111.6%	105.0%	102.2%	101.4%	100.8%	100%
BW : -3dB	~4.2GHz	~4.5GHz	~5.1GHz	~5.2GHz	~5.2GHz	~5.2GHz

A : bisphenol A novolac system

B : bisphenol A + phenol novolac

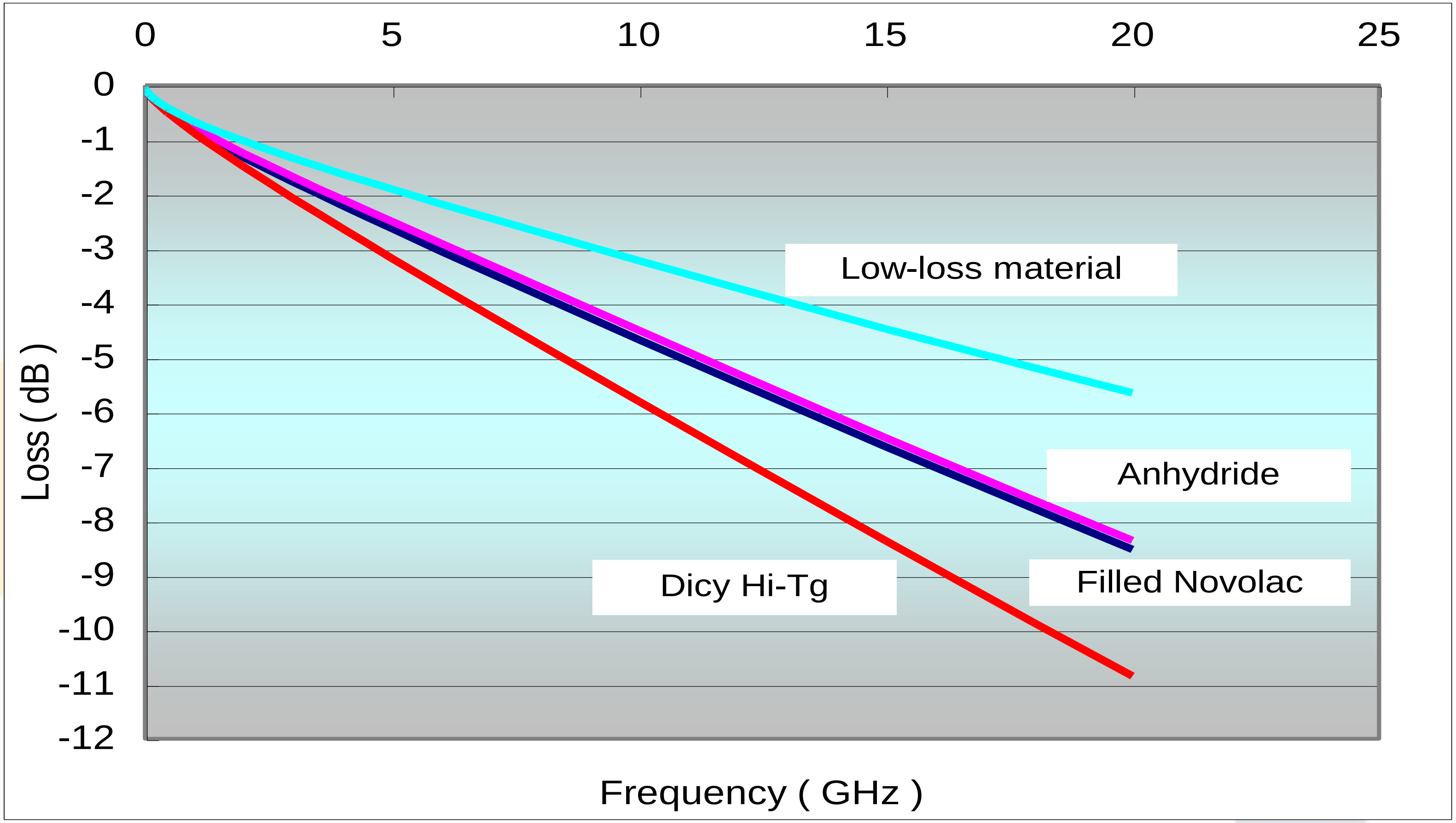
C : TUC mid-Tg material system

D : TUC Hi-Tg material

E : Hi-Tg dicy-cured

F : phenol novolac system

Mid / Low Loss Materials



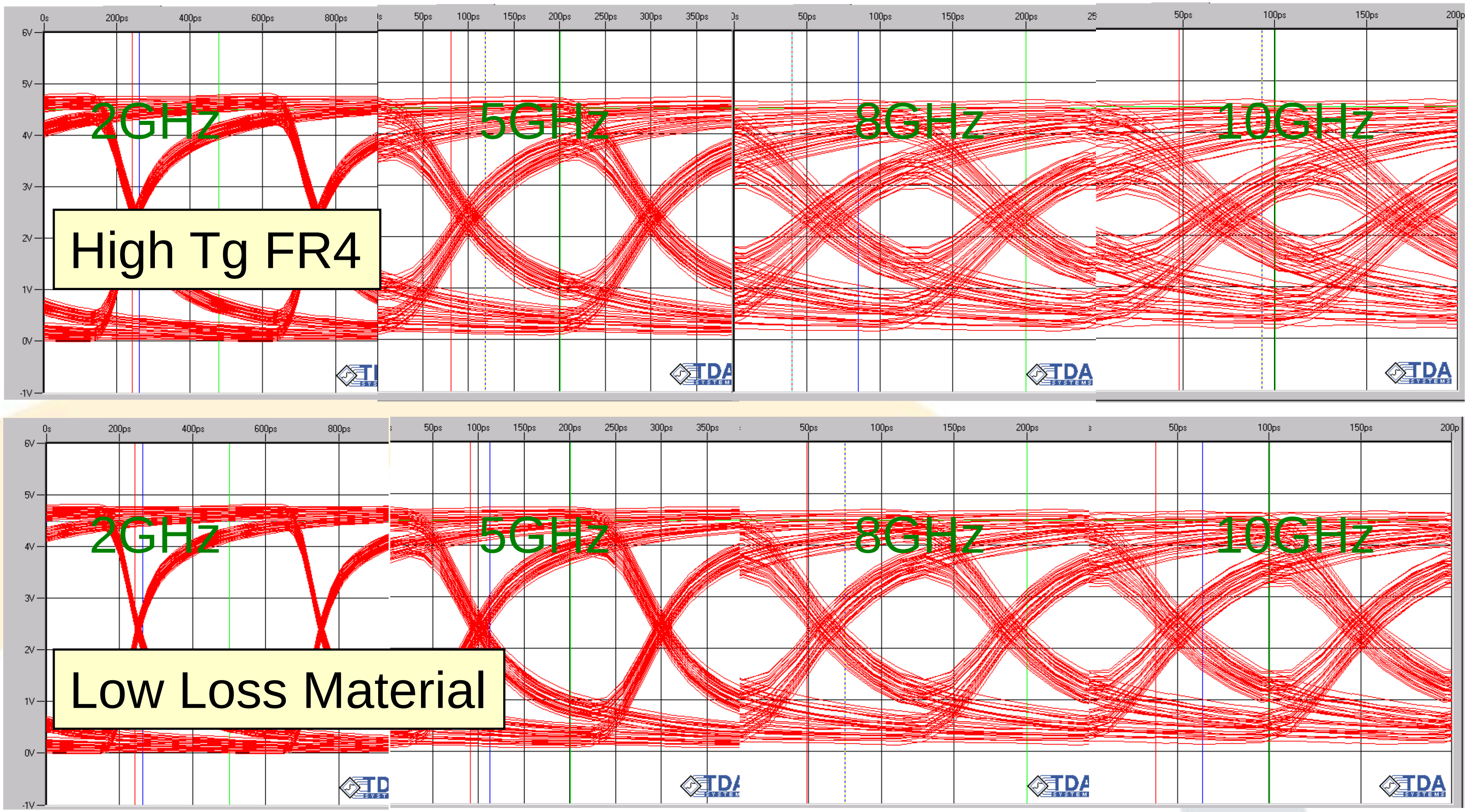
Mid / Low Loss Materials

Transmission length for different resin system

Material / -3dB	3GHz	5GHz	8GHz	BW
Dicy Hi-Tg	5.6 in	3.7 in	2.4 in	5.2GHz
mid-loss : Filled Novolac	6.7 in	4.5 in	3.1 in	5.9GHz
mid-loss : Anhydride	6.9 in	4.6 in	3.1 in	6.2GHz

BW is base on 4 inch line

Eye Diagram



16“ stripeline

Loss Elements

Attenuation

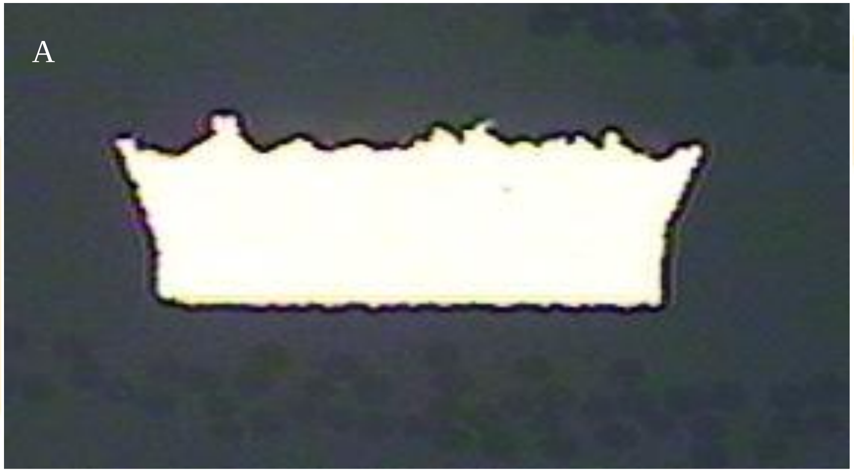
= Dielectric loss + Conductor loss

= Loss (base material) + Loss (circuit trace)

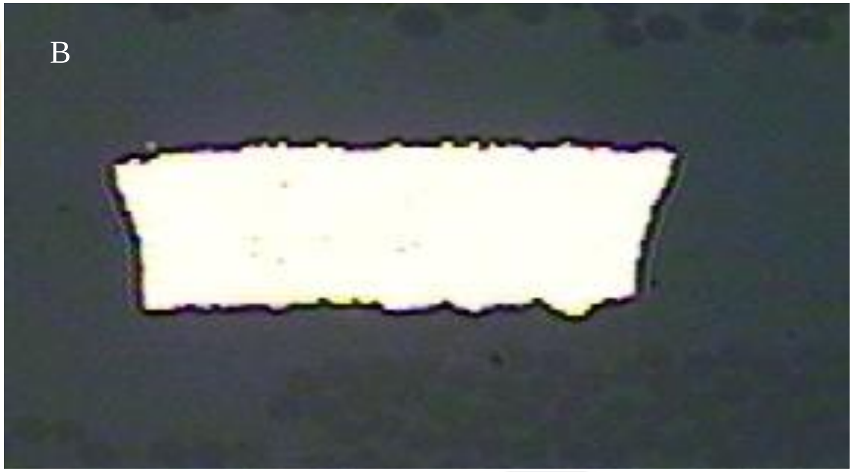
= Material Dk / Df + Circuit Geometry and Roughness

Conduct Loss – Roughness

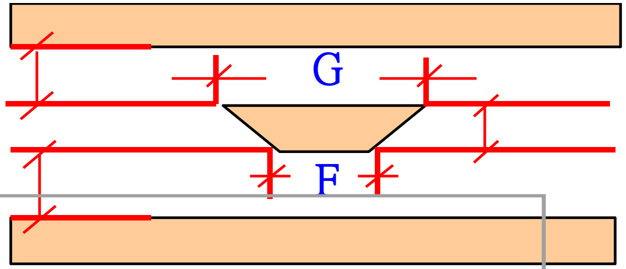
HTE – roughened foil



RSTF – smooth foil

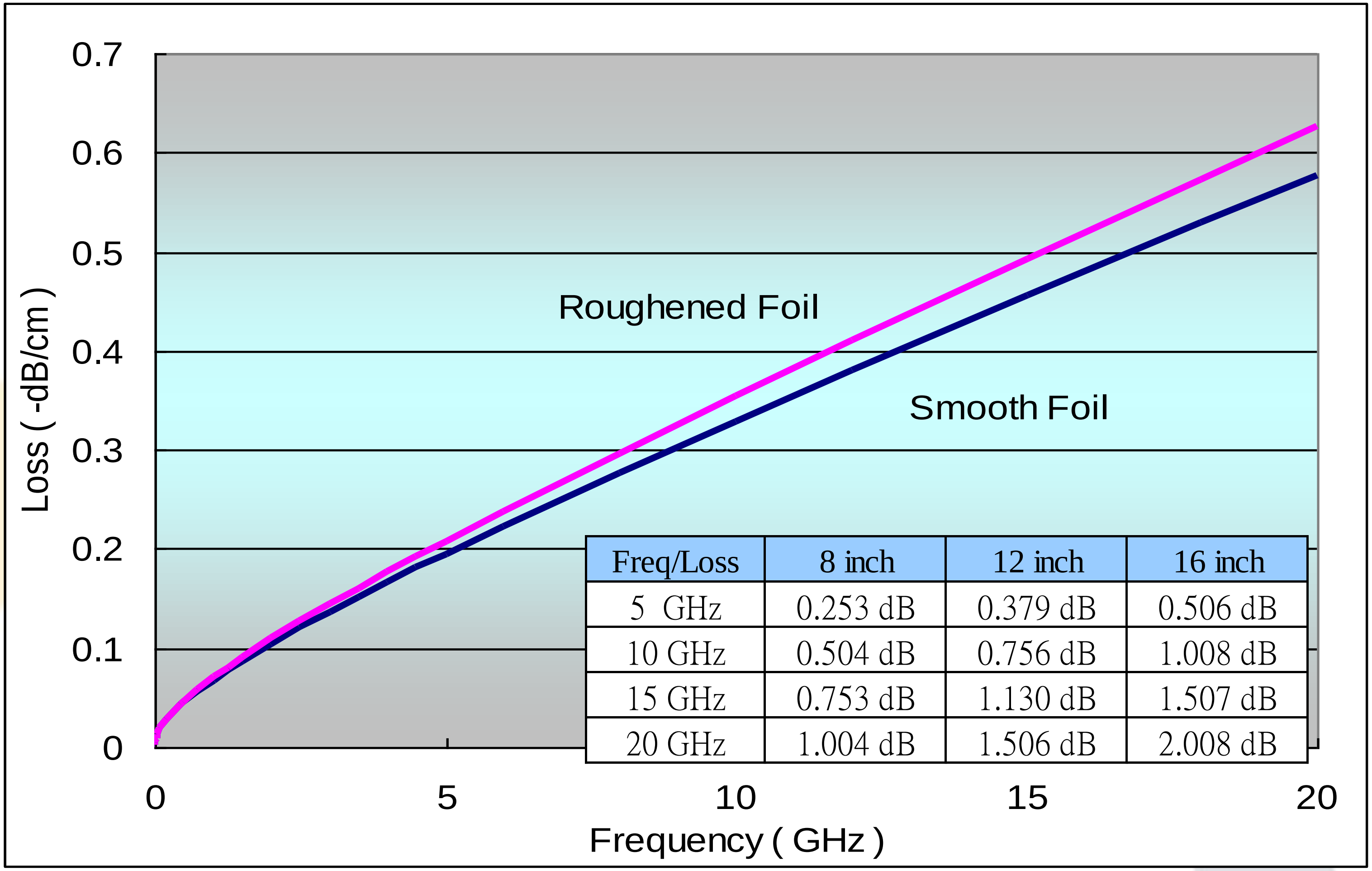


Conduct Loss – Roughness



Circuit trace surface roughness level			
Type	Position	sample N	Roughness
HTE Foil	F : shinning side	14	0.115 mil
	G : mate side	14	0.313 mil
RTF Foil	F : shinning side	14	0.192 mil
	G : mate side	14	0.207 mil

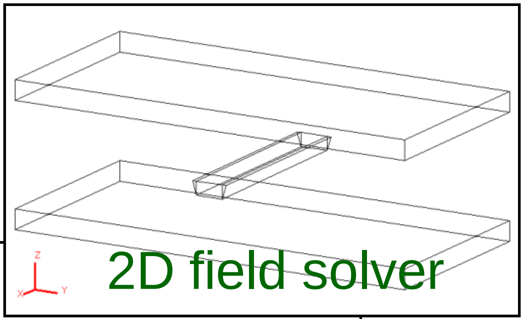
Conduct Loss – Roughness

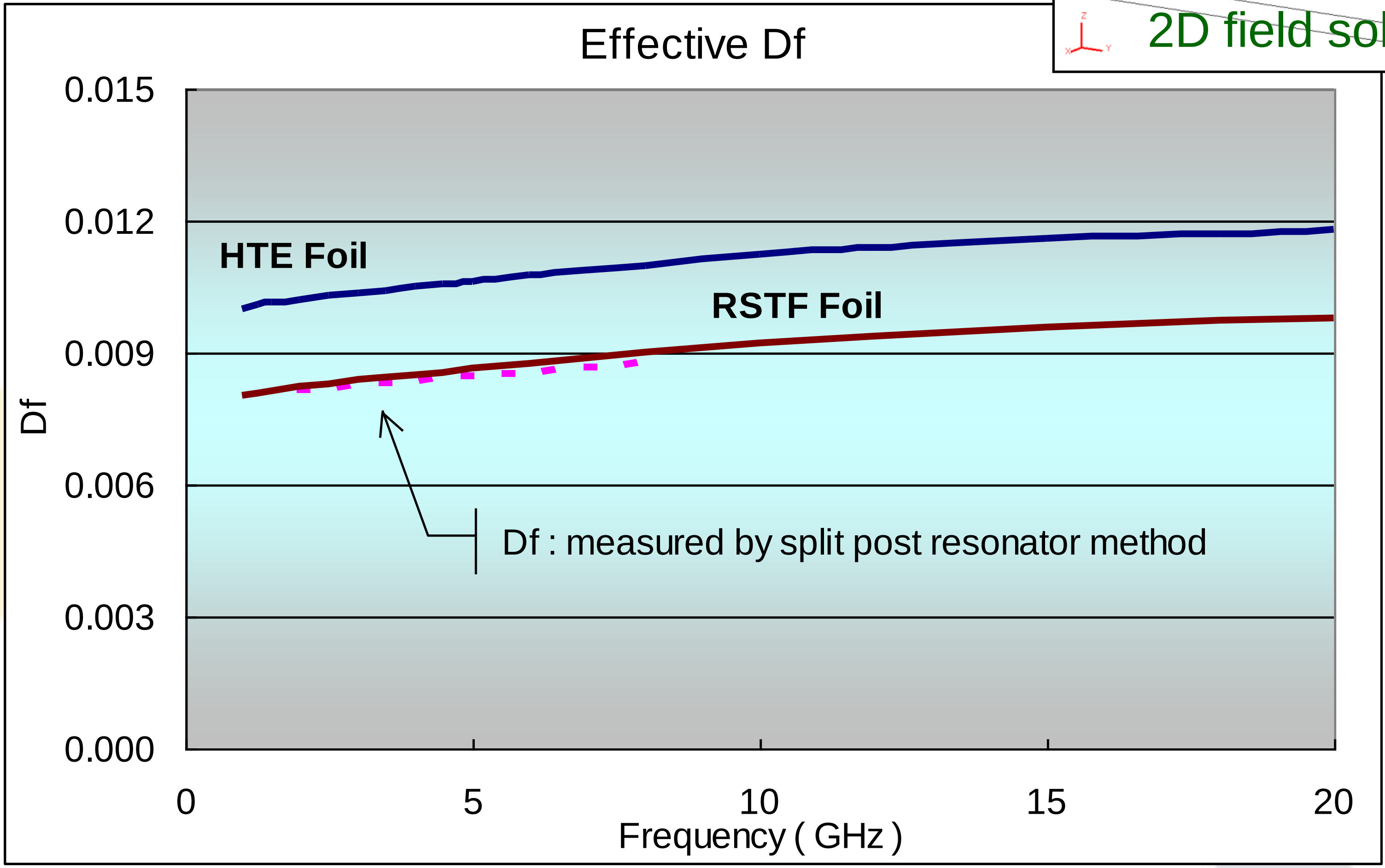


Freq/Loss	8 inch	12 inch	16 inch
5 GHz	0.253 dB	0.379 dB	0.506 dB
10 GHz	0.504 dB	0.756 dB	1.008 dB
15 GHz	0.753 dB	1.130 dB	1.507 dB
20 GHz	1.004 dB	1.506 dB	2.008 dB

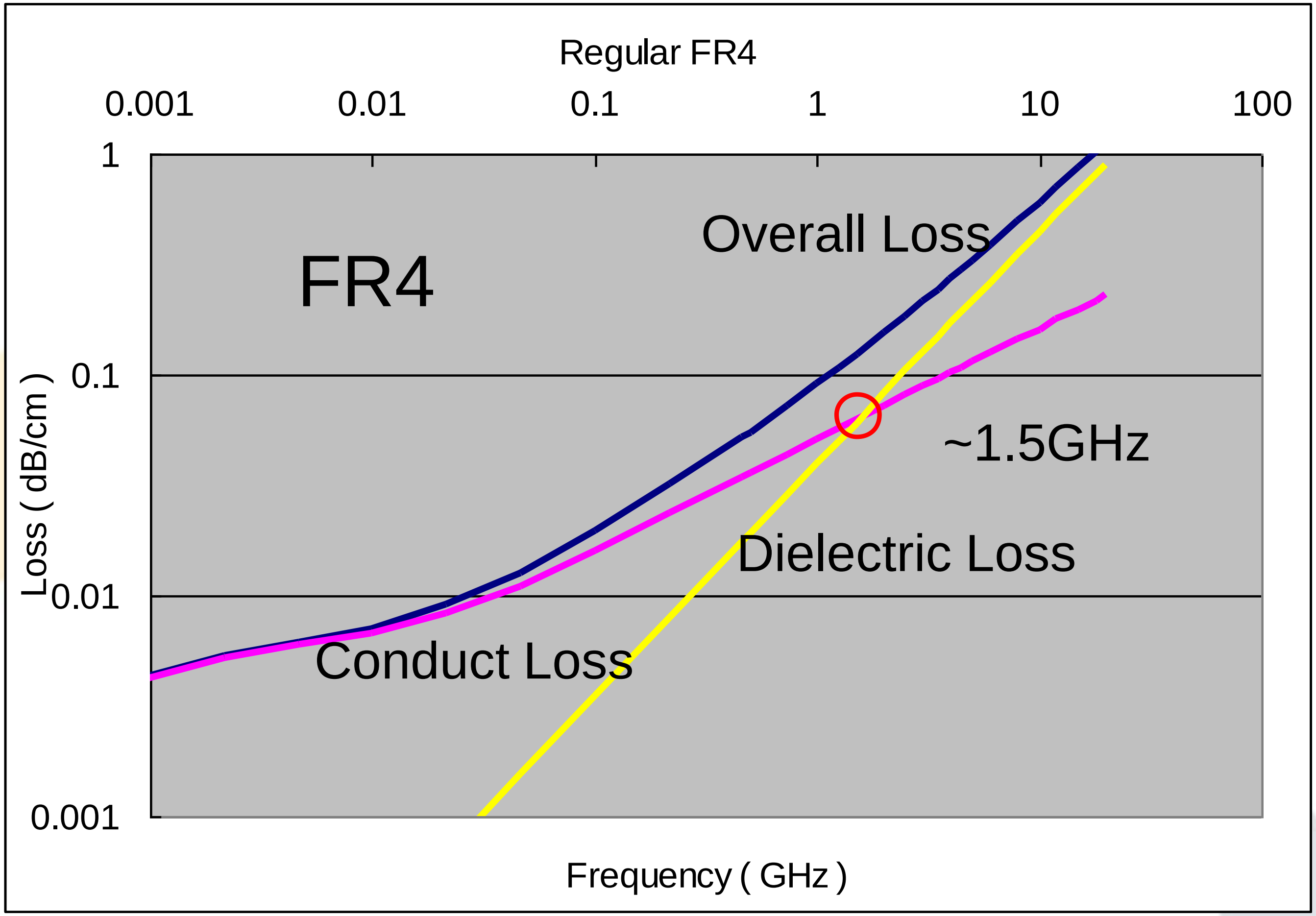
Material : Low Loss Material

IBM SPP - Effective Dk/Df

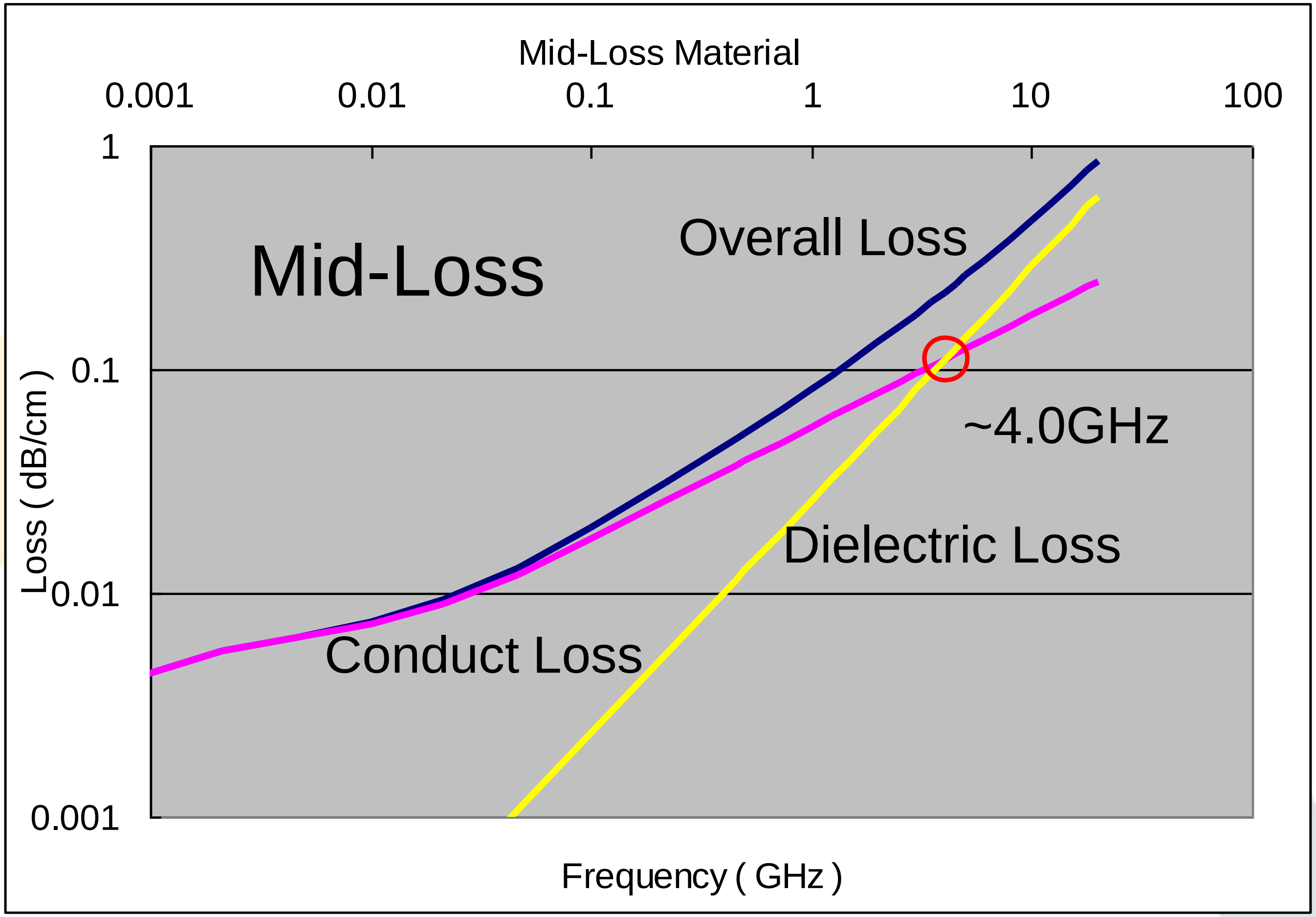




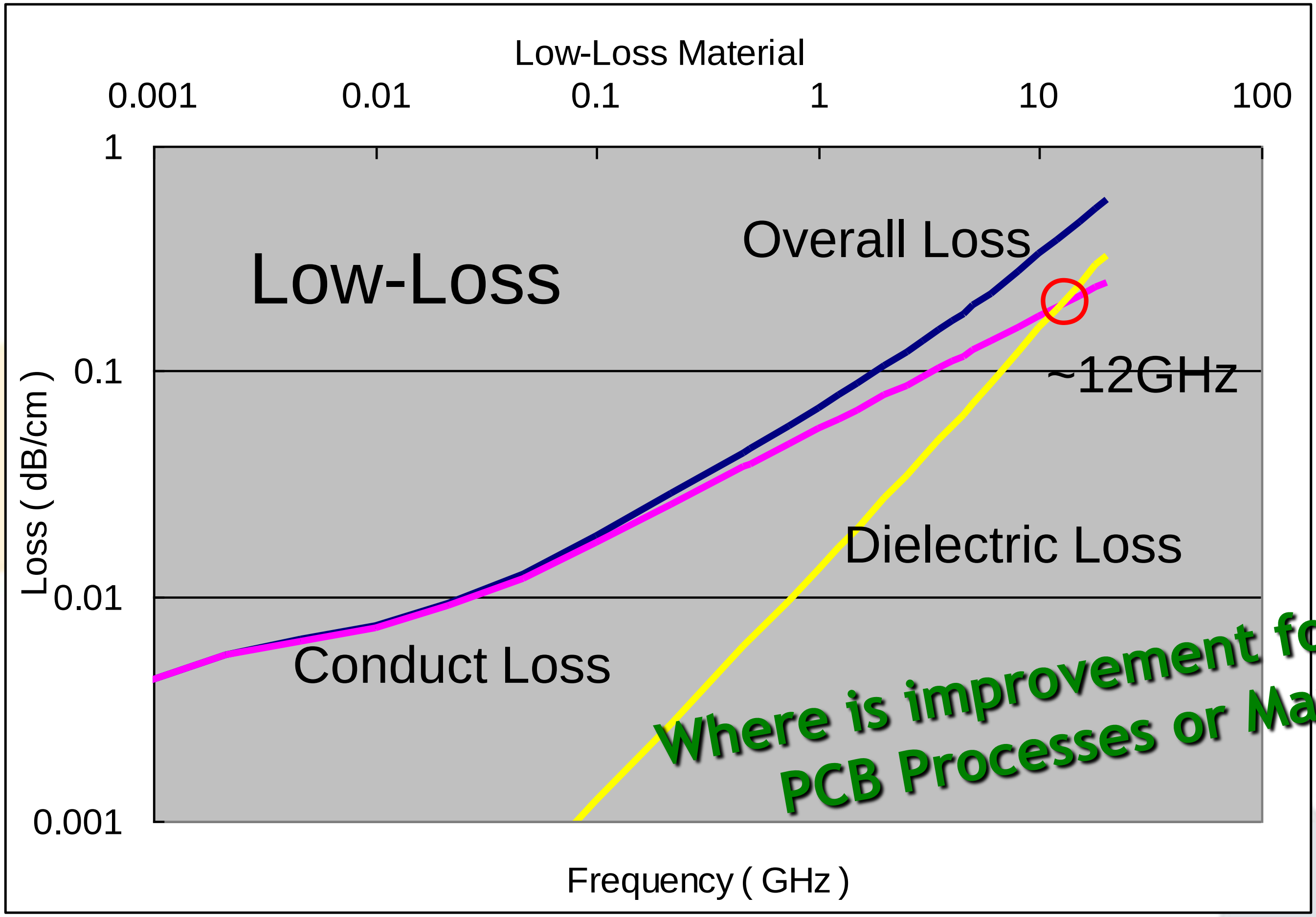
Loss Dominator



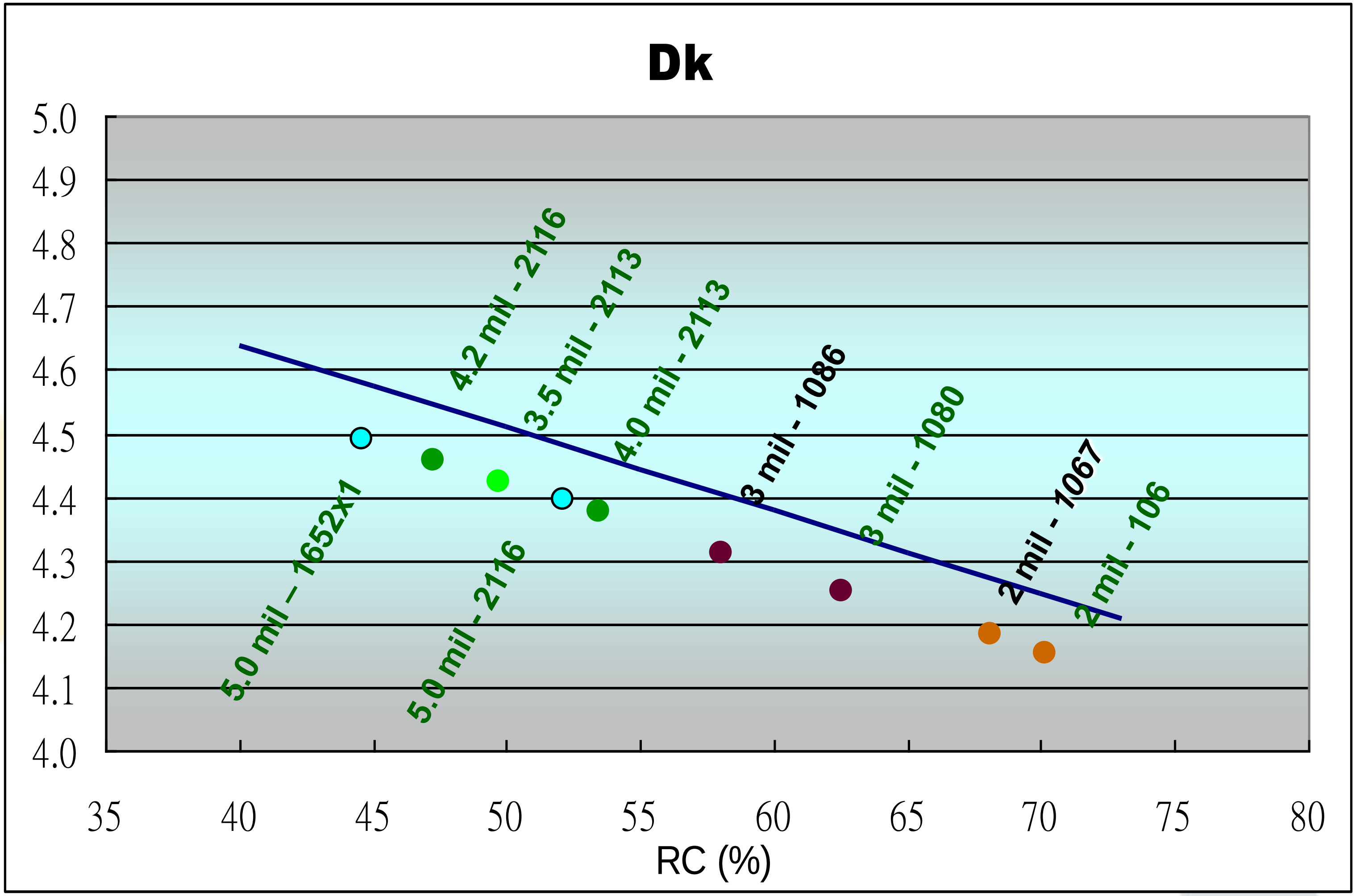
Loss Dominator



Loss Dominator

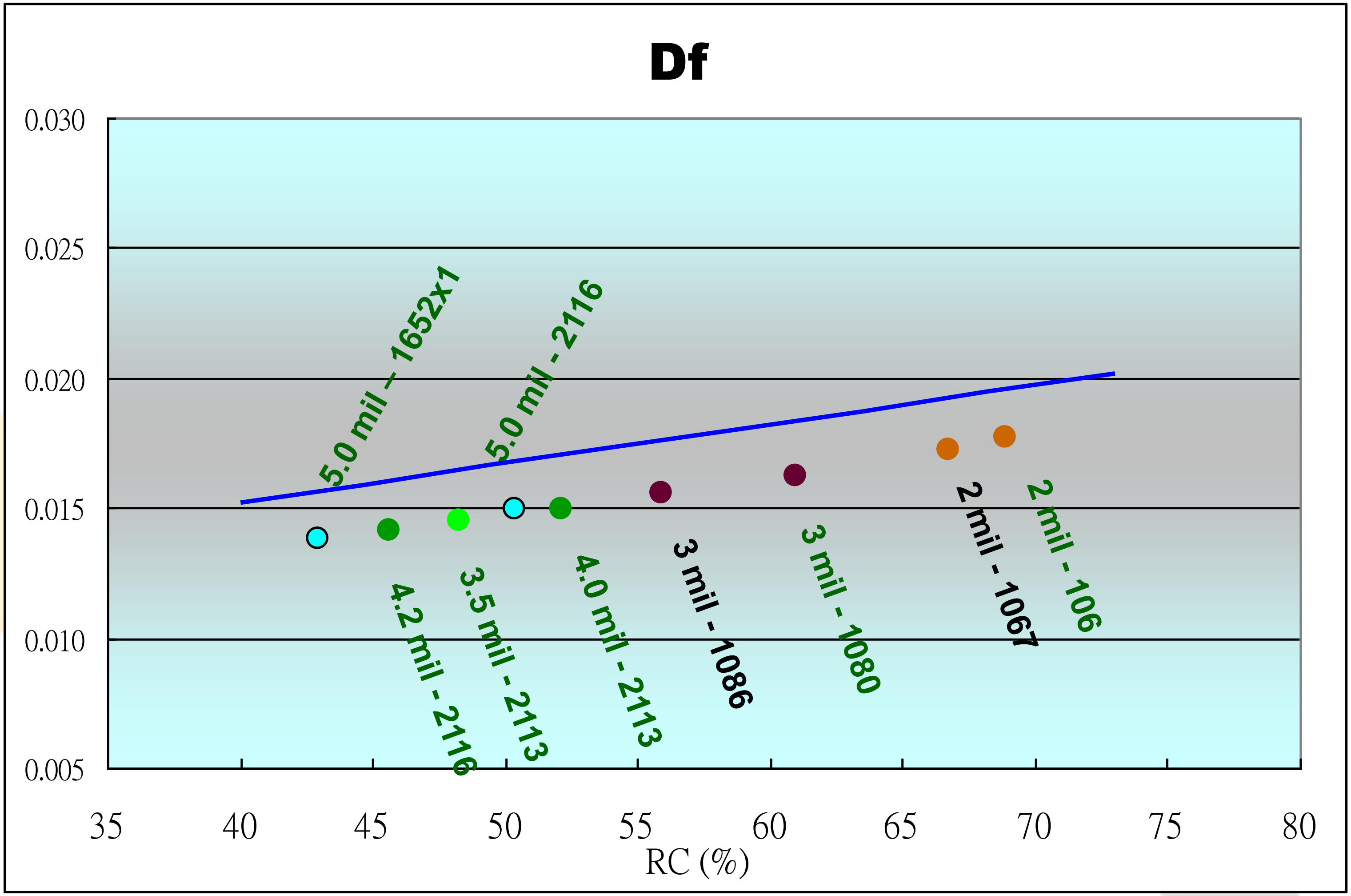


Dk – Construction



1MHz : LCR meter

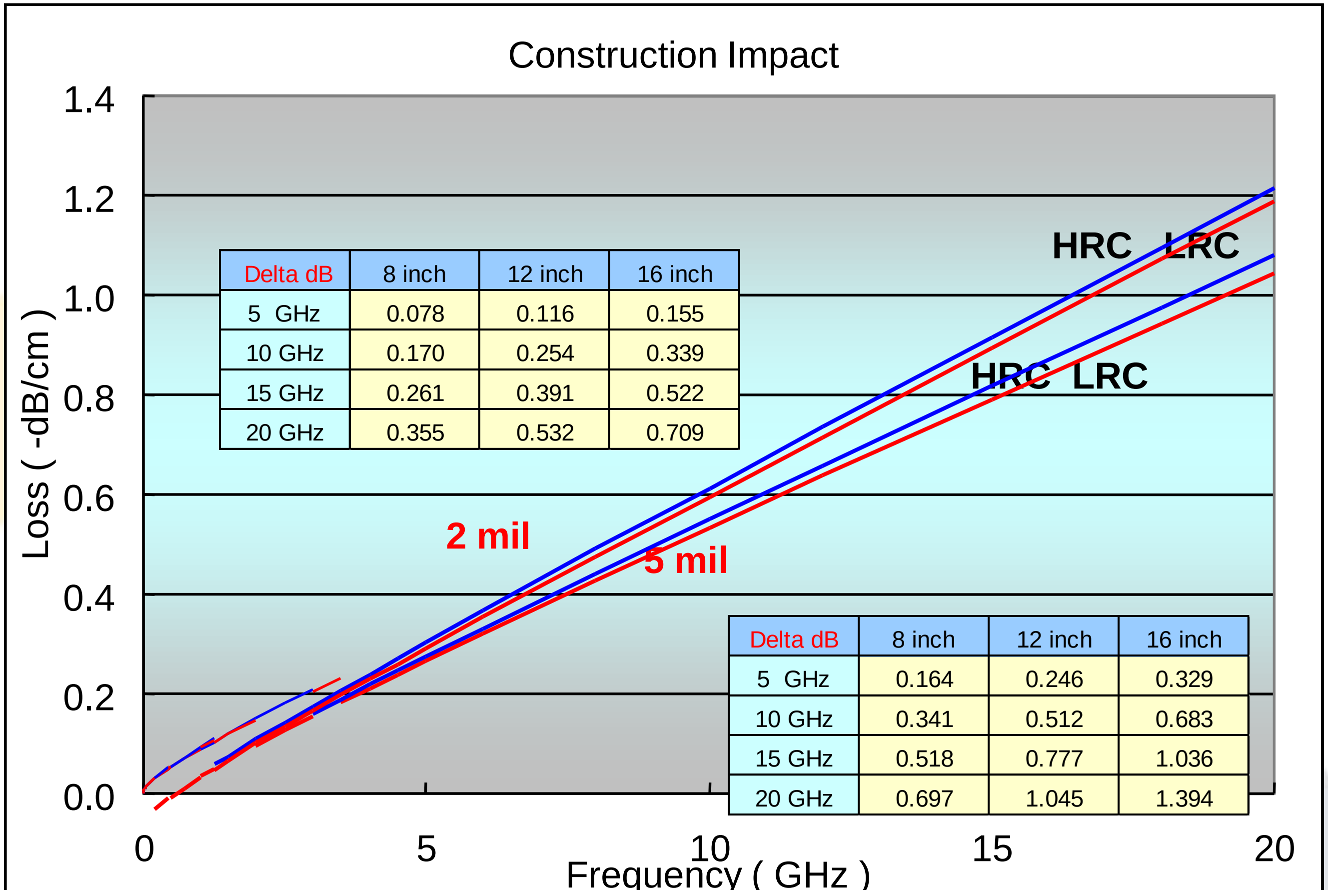
Df – Construction



1MHz : LCR meter

Loss – Construction

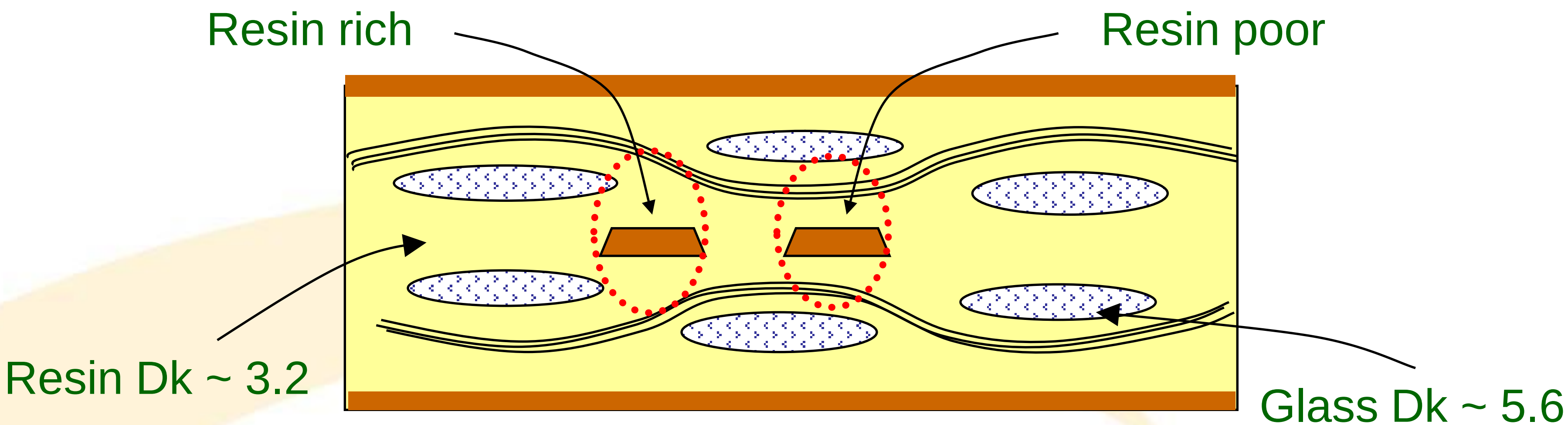
- Construction is one of key factor for loss.



Delta dB	8 inch	12 inch	16 inch
5 GHz	0.078	0.116	0.155
10 GHz	0.170	0.254	0.339
15 GHz	0.261	0.391	0.522
20 GHz	0.355	0.532	0.709

Delta dB	8 inch	12 inch	16 inch
5 GHz	0.164	0.246	0.329
10 GHz	0.341	0.512	0.683
15 GHz	0.518	0.777	1.036
20 GHz	0.697	1.045	1.394

Signal Skew – Fabric Selection

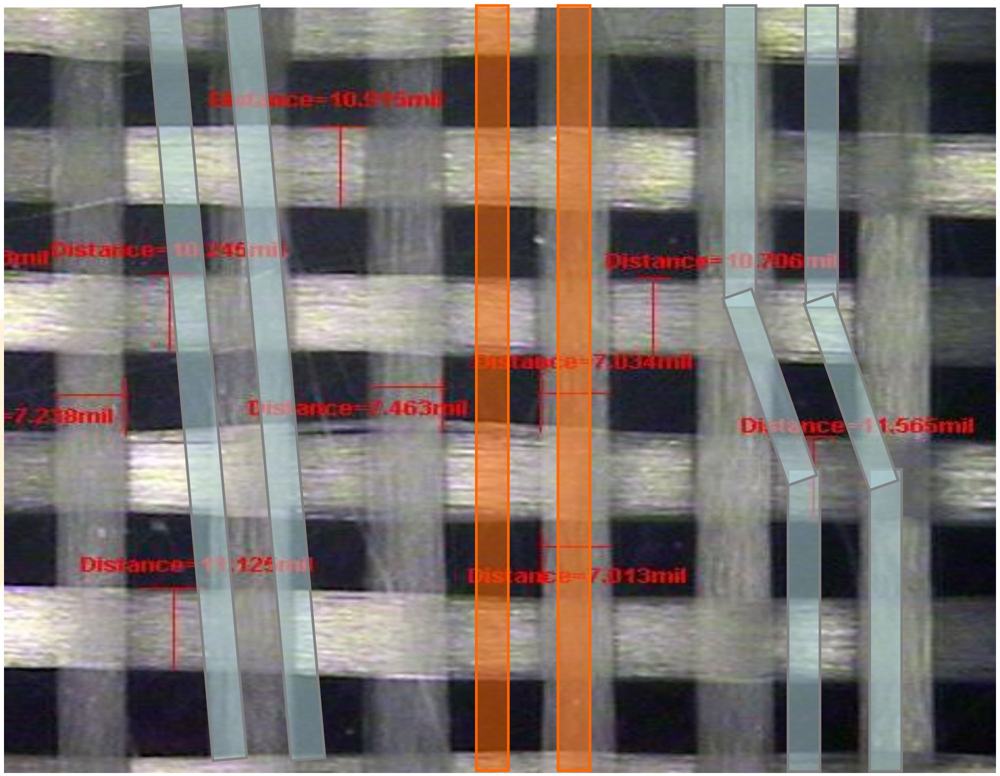


- Special Layout and Routing
- Designer Rotates Image
- Lopsided glass weaving

- Use low Dk fabric
- Increase weaving density
- Even / flatten count weaving

Signal Skew – Fabric Selection

1080 FABRIC

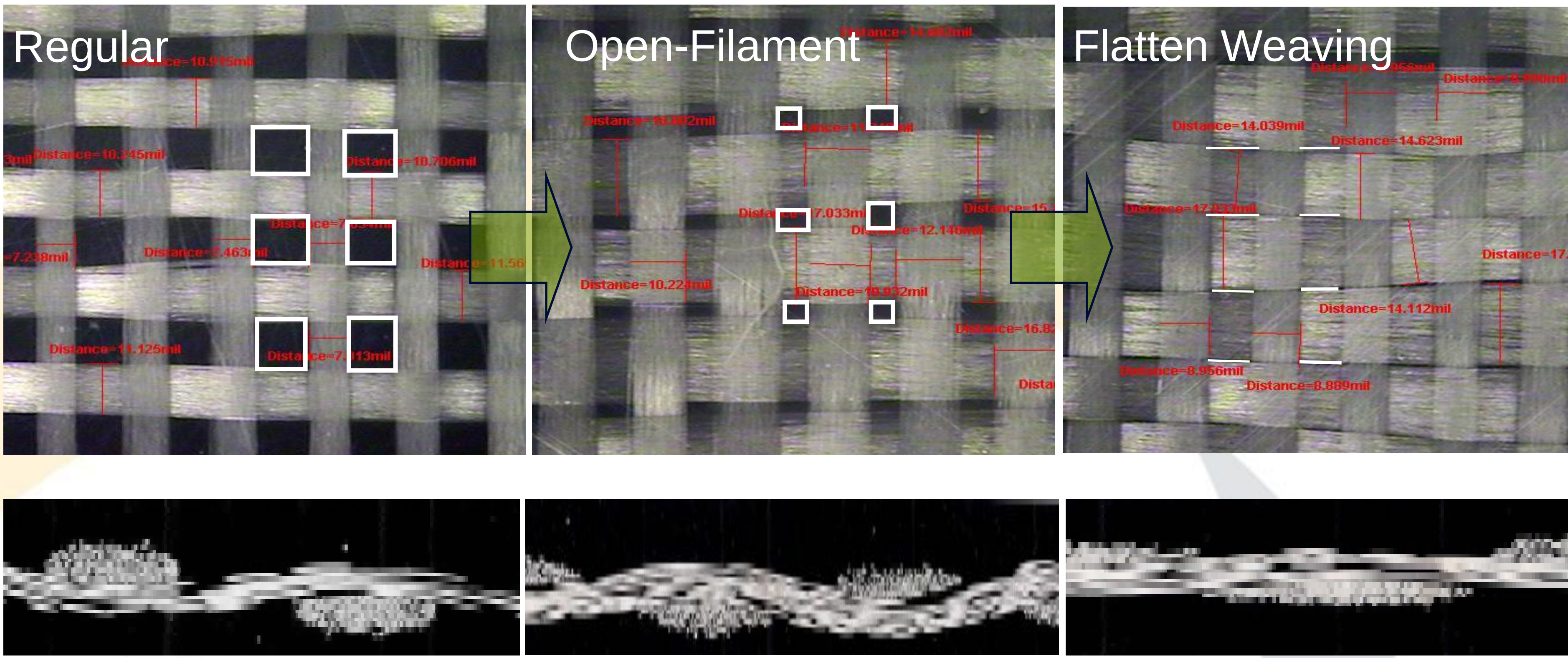


- Special Layout and Routing
- Designer Rotates Image
- Lopsided glass weaving

- Use Low Dk fabric
- Increase weaving density
- Even / flatten count weaving

Signal Skew – Fabric Selection

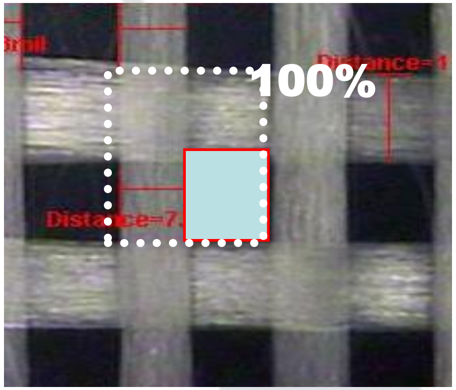
1080 Grade Fabric



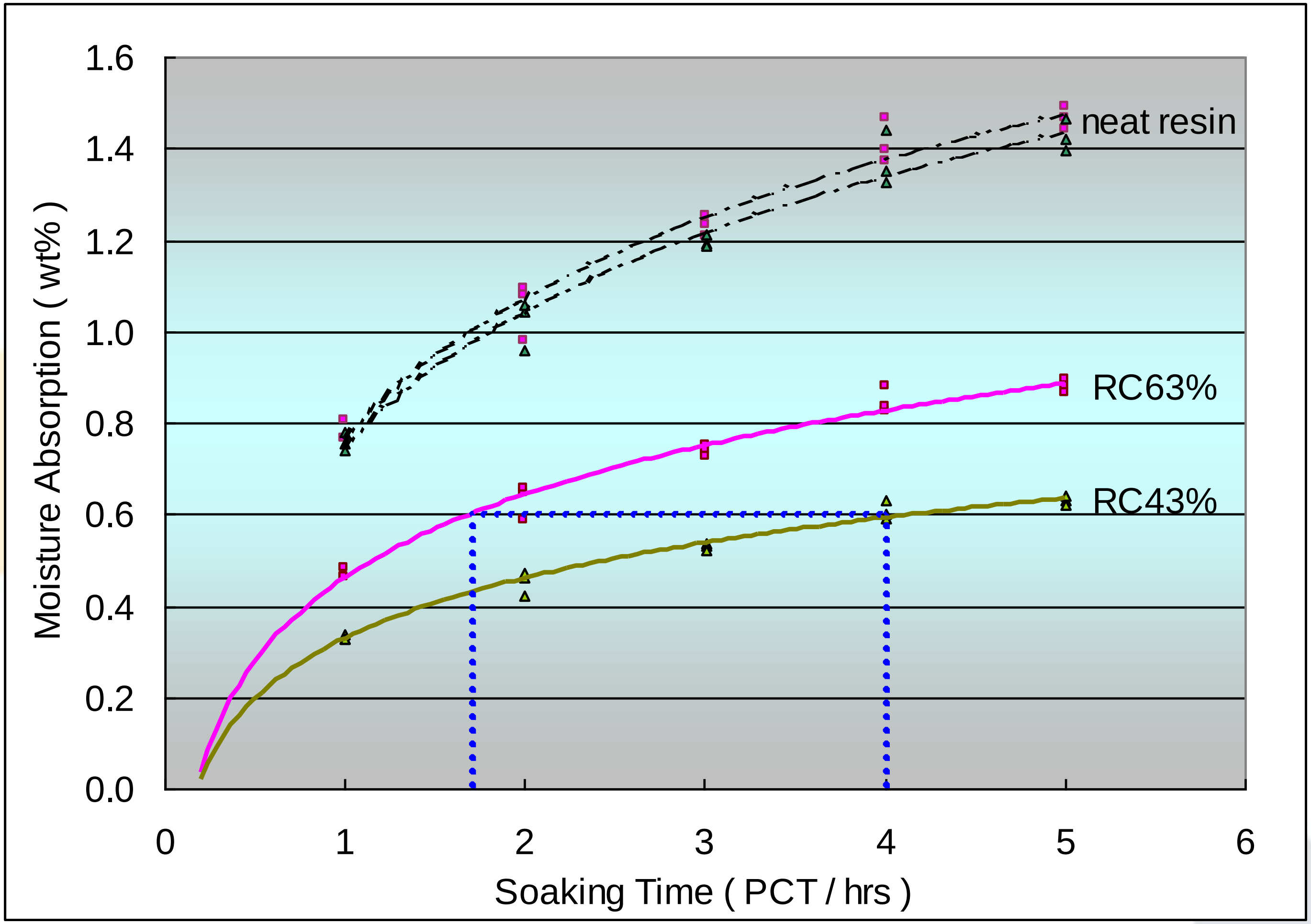
Signal Skew – Fabric Selection

Window Area Ratio	Regular Type	Open-filament Type	Flatten Weaving Type
2 mil	~30 %	~15 %	~1 %
3 mil	~25 %	~8 %	~3 %
4 mil	~10 %	~3 %	~1 %

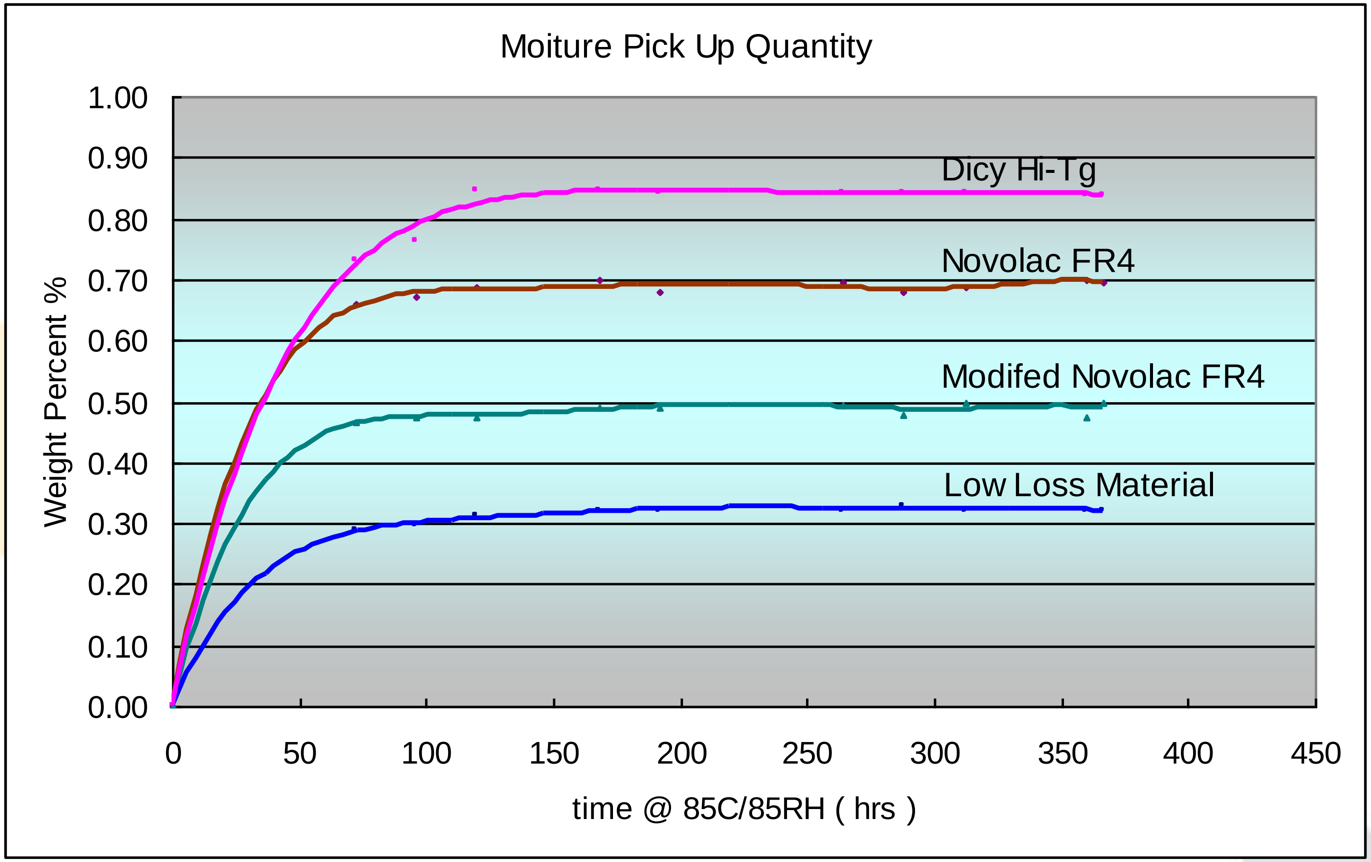
- Optimize fabric can moderate the signal skew effect.



Moisture – Condition

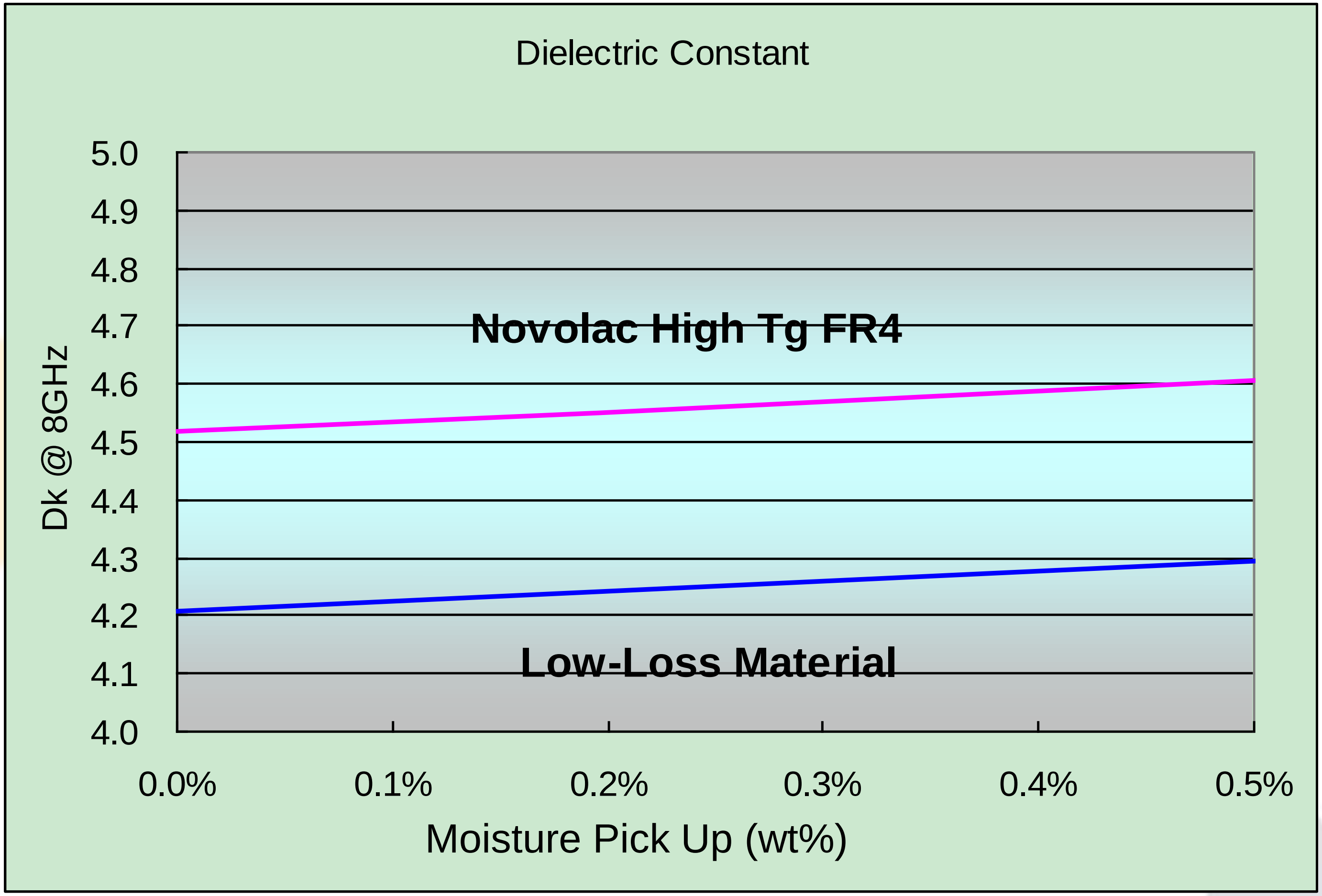


Moisture – Resin Systems

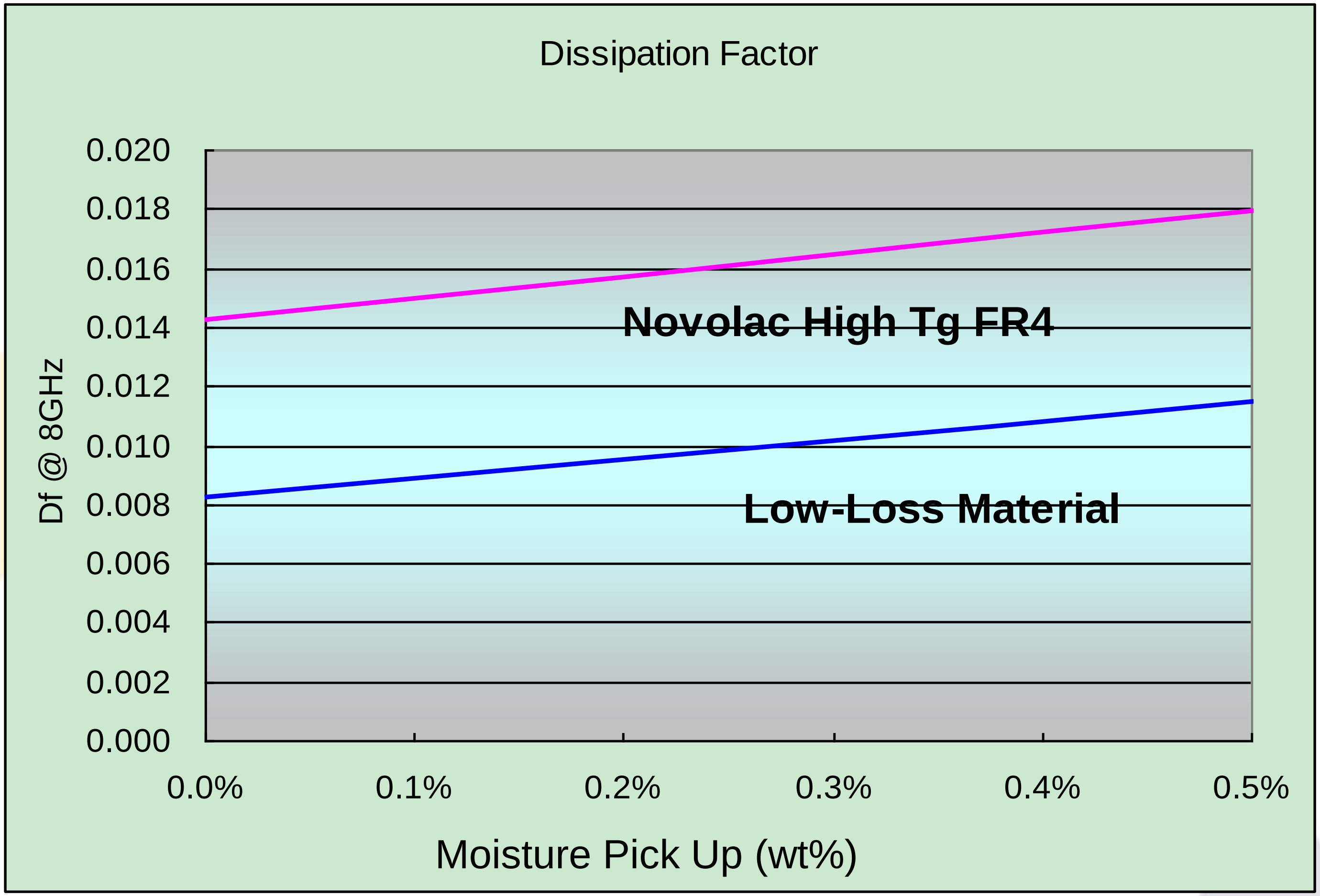


- Resin system is a factor for moisture pick up.

Dk - Moisture

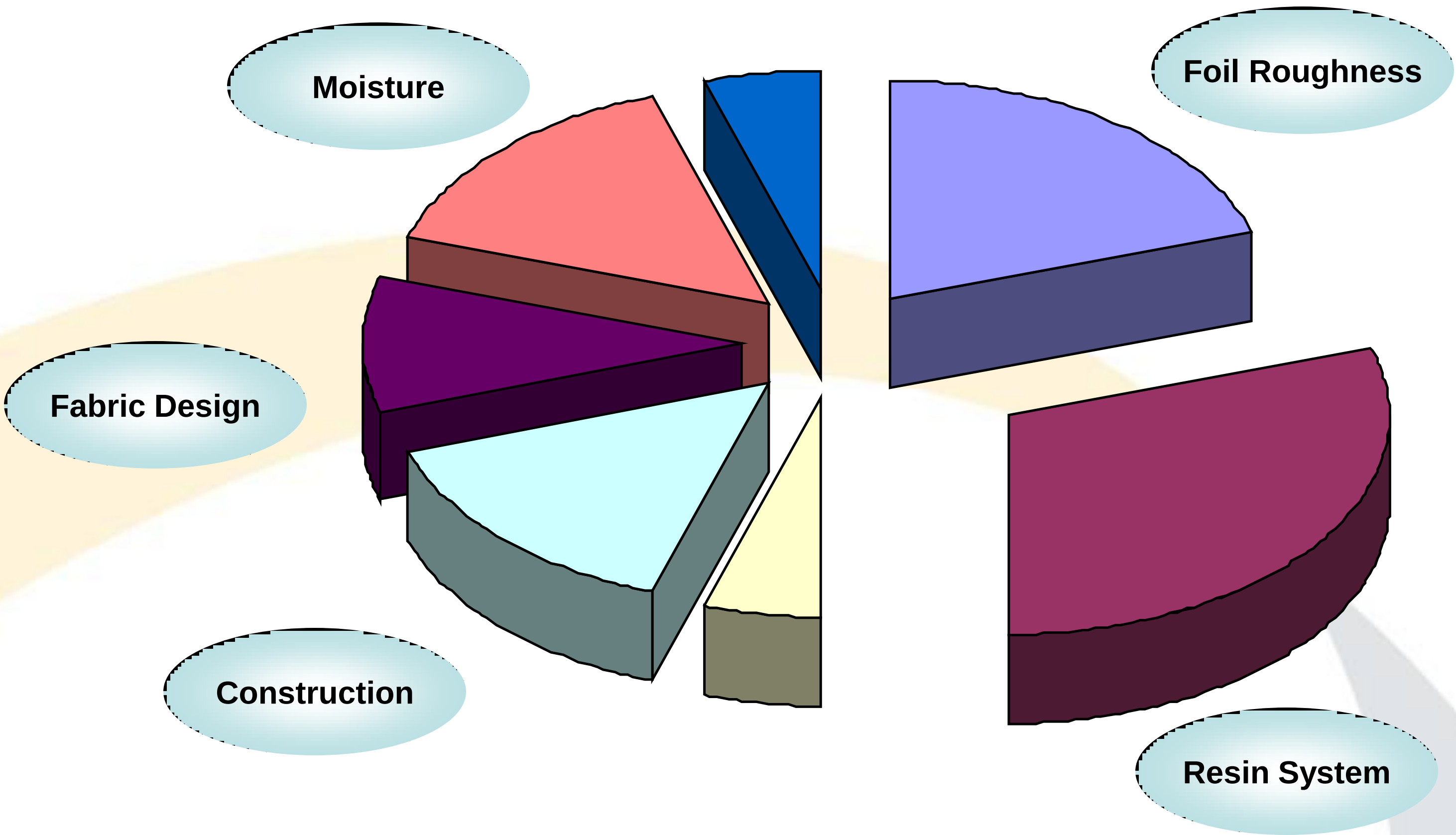

Dielectric Constant
5.0
4.9
4.8
4.7
4.6
4.5
4.4
4.3
4.2
4.1
4.0
Dk @ 8GHz
Novolac High Tg FR4
Low-Loss Material
0.0%
0.1%
0.2%
0.3%
0.4%
0.5%
Moisture Pick Up (wt%)

Df - Moisture



Dissipation Factor
0.020
0.018
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0.000
Df @ 8GHz
Novolac High Tg FR4
Low-Loss Material
0.0%
0.1%
0.2%
0.3%
0.4%
0.5%
Moisture Pick Up (wt%)

Signal Integrity – Conclusion



Conclusion

- Signal integrity is a complex topic.
- Resin system is the most critical factor for base material.
- Suitable resin system with smooth foil is 1st priority.
- Fabric design might be a solution for signal skew issue.

Q & A

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