Unimicron

The extraction of effective dielectric material property

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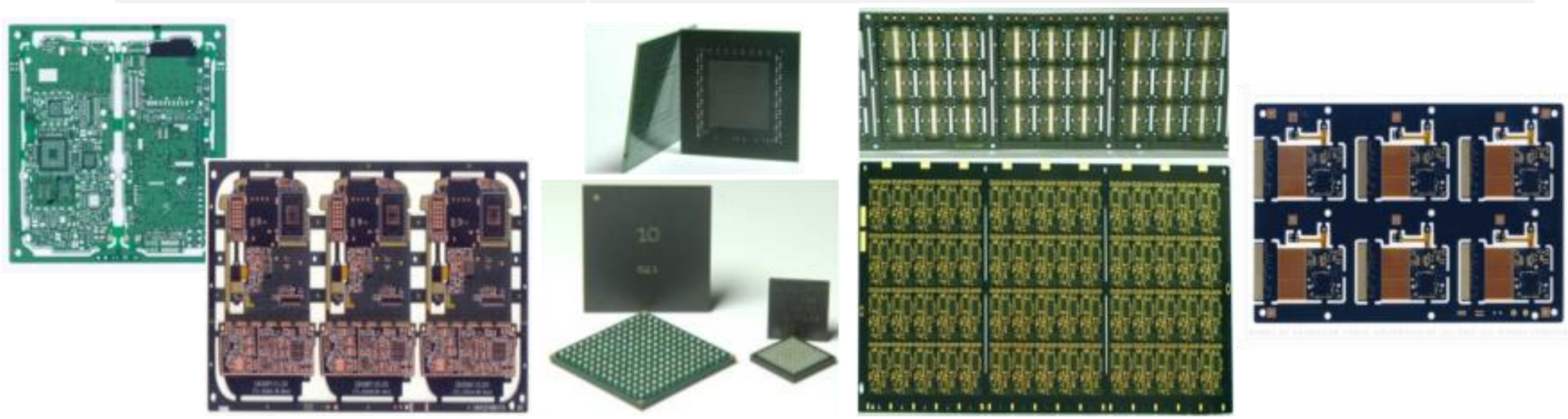
SBU/Div. : CEO Office/EDA
Date : Oct. 22, 2019

Agenda

1. Introduce of Unimicron
2. New high accuracy signal transmission line design flow
3. The statistical analysis of transmission line parameter variation for material property and physical layout structure.
4. Material Parameter Extraction.
5. Conclusion

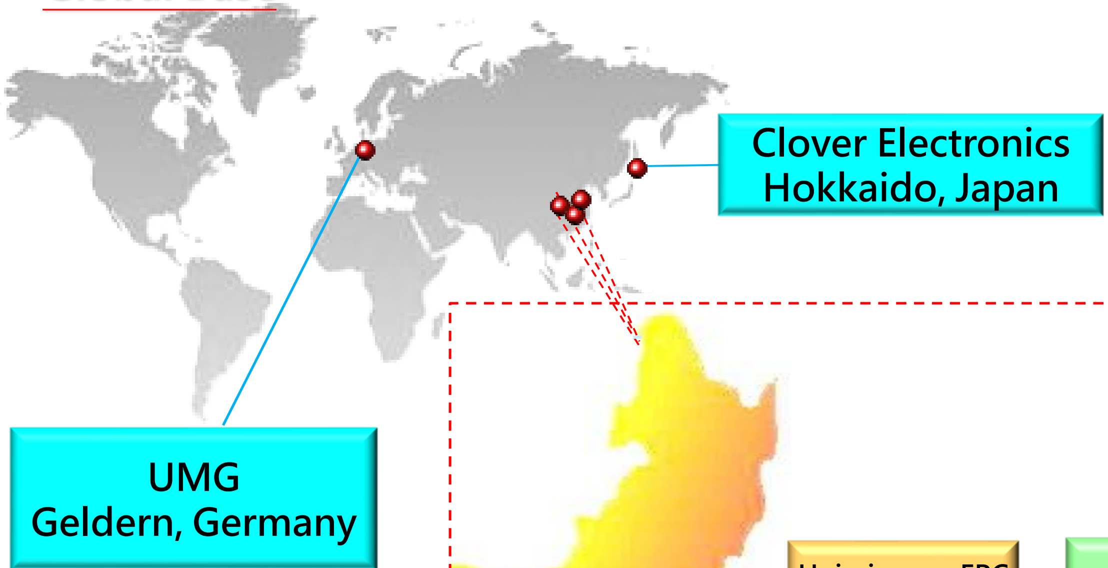
Unimicron Technology Corp.

➢ Date Incorporated	Jan. 25, 1990
➢ Chairman	T. J. Tseng
➢ Major Stockholder	UMC
➢ Employees	13,199 (Unimicron Group Taiwan) (2Q'18) 14,309 (Unimicron Group Overseas) *Total 27,508
➢ Registered Capital	NT$15.05 Billion
➢ Products	Printed Circuit Boards, Carrier, IC Burn-in & Testing



Manufacturing Site

Global Base



2019 Total Capacity

Product	K ft²/M
PCB	2,220
HDI	2,350
Carrier	2,190
FPC	370
RF	680

*:exclude touch panel

Global Ranking

HDI					Carrier				
Rank	2017		2018		Rank	2017		2018	
	Supplier	Rev.	Supplier	Rev.		Supplier	Rev.	Supplier	Rev.
1	Unimicron	707	Compeq	898	1	Unimiron	880	Unimicron	970
2	Compeq	683	TTM	837	2	Ibiden	744	Ibiden	788
3	TTM	635	AT&S	794	3	Semco	721	SEMCO	653
4	AT&S	620	Unimicron	781	4	Nanya	603	Simmtech (Inc.Eastern)	568
5	Meiko	319	Tripod	361	5	Kinsus	582	Shinko	562
6	KCC	280	Meiko	341	6	Shinko	580	Nan Ya PCB	544
7	Unitech	273	Unitech	319	7	Simmtech	440	Kinsus	535
8	Tripod	263	Zhen Ding	298	8	Daeduck	290	Daeduck Group	317
9	Zhen Ding	248	Korea Circuit	288	9	ASE Material	288	ASE Material	281
10	SEMCO	222	DAP	268	10	Kyocera	257	Kyocera	261

**Unimicron includes Subtron sales*

Source : Prismark, Q3 2018

Design/Simulation team specialties

CEO (President Webber)

EDA

Layout & Design

1.High speed PCB layout
2.Diff impedance design
3.LE/DC technology design
4.Digital signal integrity
5.SIP/SOP 3D package
6.Layer-reduction for low-cost

Electrical Simulation

1. 3D modeling with FEM
2. Multi-conductor coupled RLGC
3. Packaging parameters
4. S para & Smith Chart
5.Power/Gnd integrity
6.Signal integrity
7. Spice/IBIS simulation

Mechanical_Therm Simulation

1. Static/transient thermal simulation
2. Solder ball stress
3. FVM/CFD technology
4. Packaging reliability
5.Cross and Mix-dimensional coupling

Mechatronics Integration

1.Electrothermal current
2. Electro-optics R&D
3. SN Fatigue, response
4. 3D circuits Antenna
5. MBD (Multi-body dyn)
6. Non-Liner NVH (Noise Vibration, Harshness)

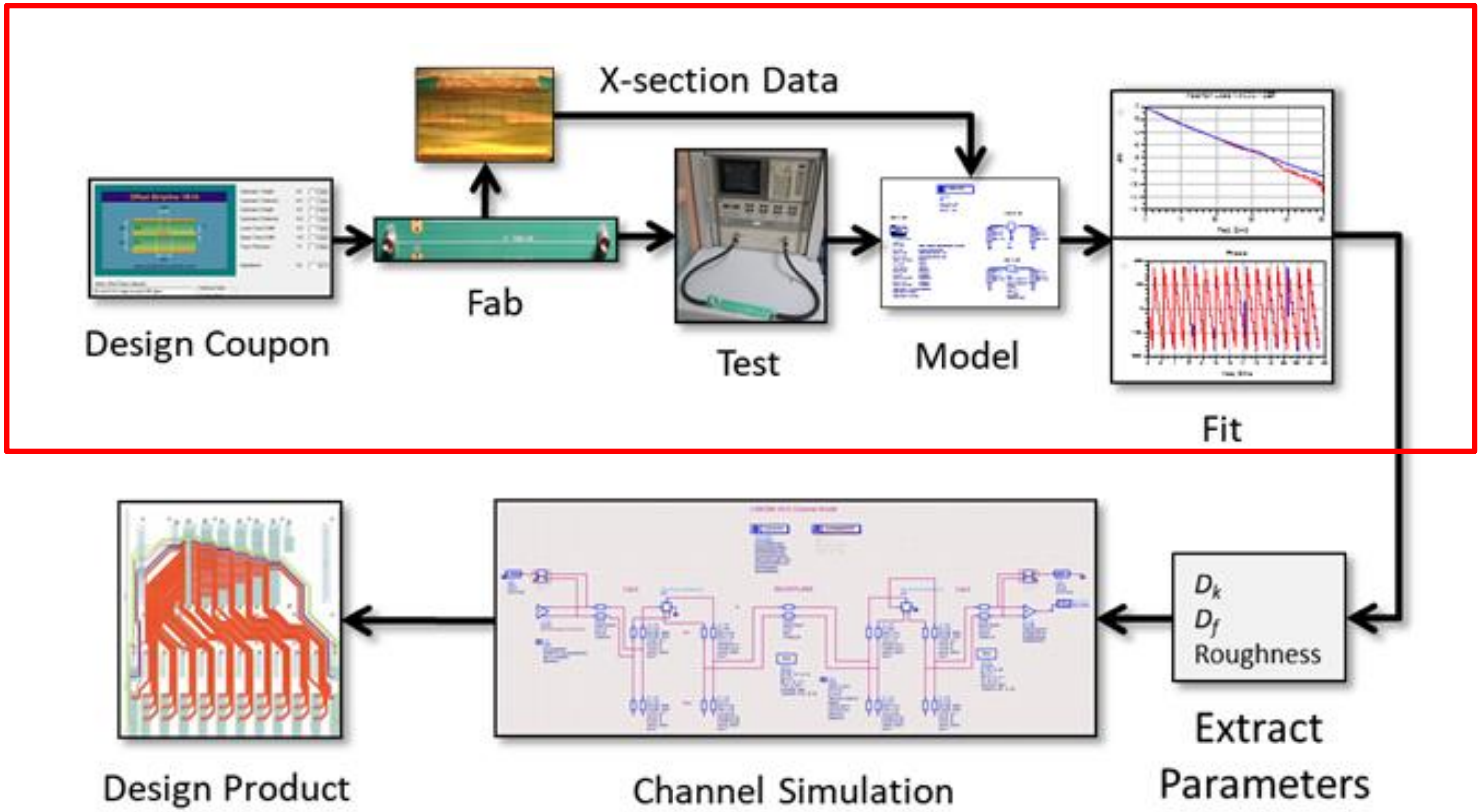
EDA Team, certificates, ISO9001, Conference

Intensive on-the-job training and seminars – Certificates from Cadence APD, Cadence High Speed, MentorGraphics, Unix Systems, Autocad

Design Quality Assurance certified by ISO9001

The design of printed circuit boards, HDI BGA and chip carriers. The burn-in and product testing of integrated circuit in packaged form.

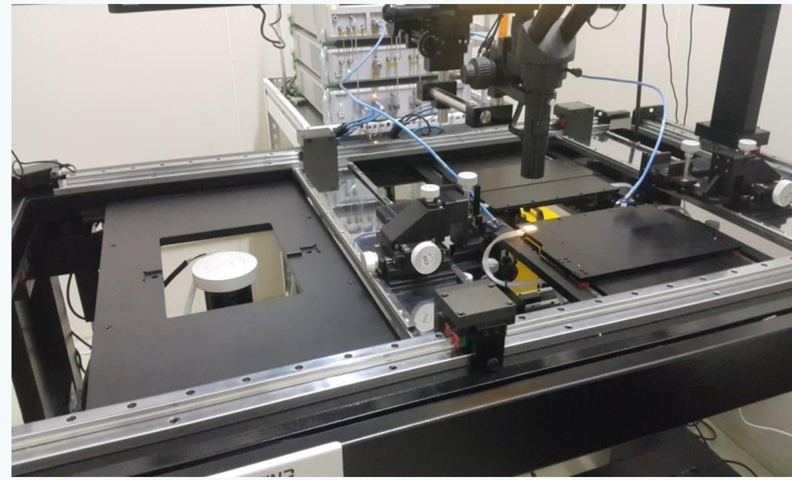
New high accuracy signal transmission line design flow



The UMTC are provide high accurate PCB product for 5G,AIOT and AI application.
That's why the customer great emphasis on validation of material properties of dielectric constant and loss tangent frequency dependence.
For next generation high speed signal design, UMTC need to provide frequency dependence Dk/Df & Roughness value to the customer.

The High frequency Double-side measurement system

Anritsu ME7838E 4-port VNA



- **The Specification of Probe Pin in Unimicron**

PN		Probe	Frequency (GHz)	Type	Pitch (μm)
ACP40-A-GSG-150		Air Coplanar Probe	40	GSG	150
67-A-GSG-150		Infinity Probe	67	GSG	150
I110-A-GSG-100			110	GSG	100

Why are obtaining accurate dielectric models so difficult?

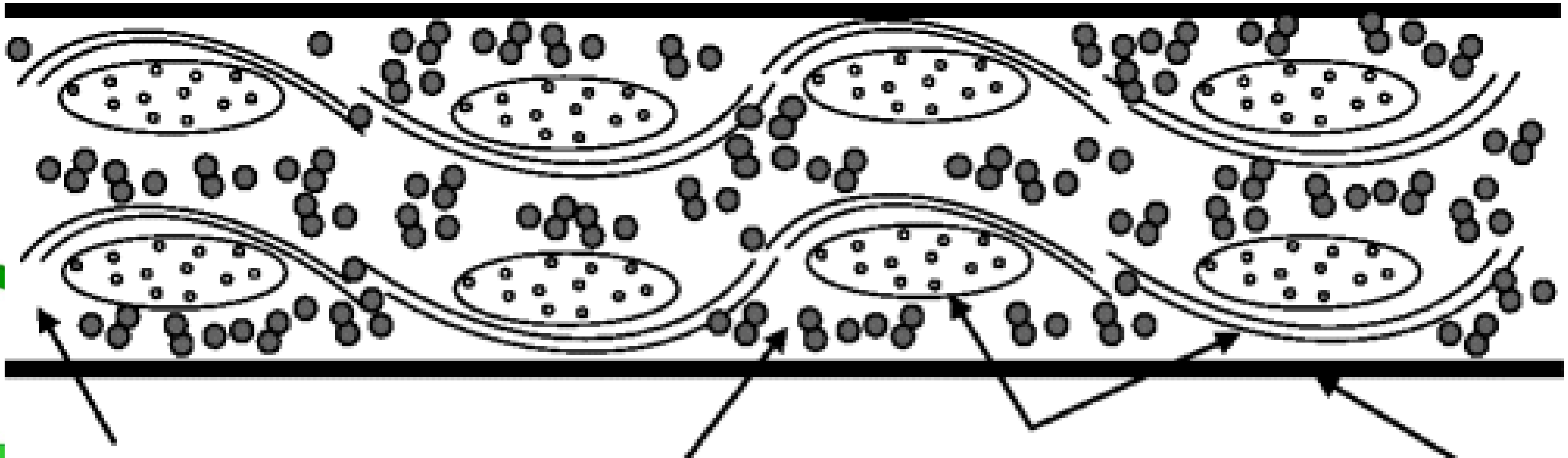
- Manufacturers of dielectrics and PCBs provide measurements for dielectric constant and loss tangent typically at one frequency point or at 2-3 points in the best cases. No continuous causal models versus frequency are usually provided. For low-cost dielectrics the measurement frequency may be even not specified at all, which is unfortunate since such dielectrics can be still used for high-speed 10Gb/s interconnects.

- Methods based on TDR and static field solvers do not produce dispersive dielectric models and may be used only at frequencies below 1-3 GHz.

- PCB dielectrics exhibit strong dependency on frequency with dielectric constant and loss tangent changing substantially over the frequency band of multi-gigabit signal spectrum. Only frequency-continuous models can accurately describe such behavior.

Ref: http://www.simberian.com/AppNotes/DesignCon2010_Paper2807.pdf

Glass weave model and physical property



Resin Matrix
- Heat Resistance
- High Tg
- Toughness
- Flammability
- Peel Strength
- Dielectric Properties
- Low Water Absorption

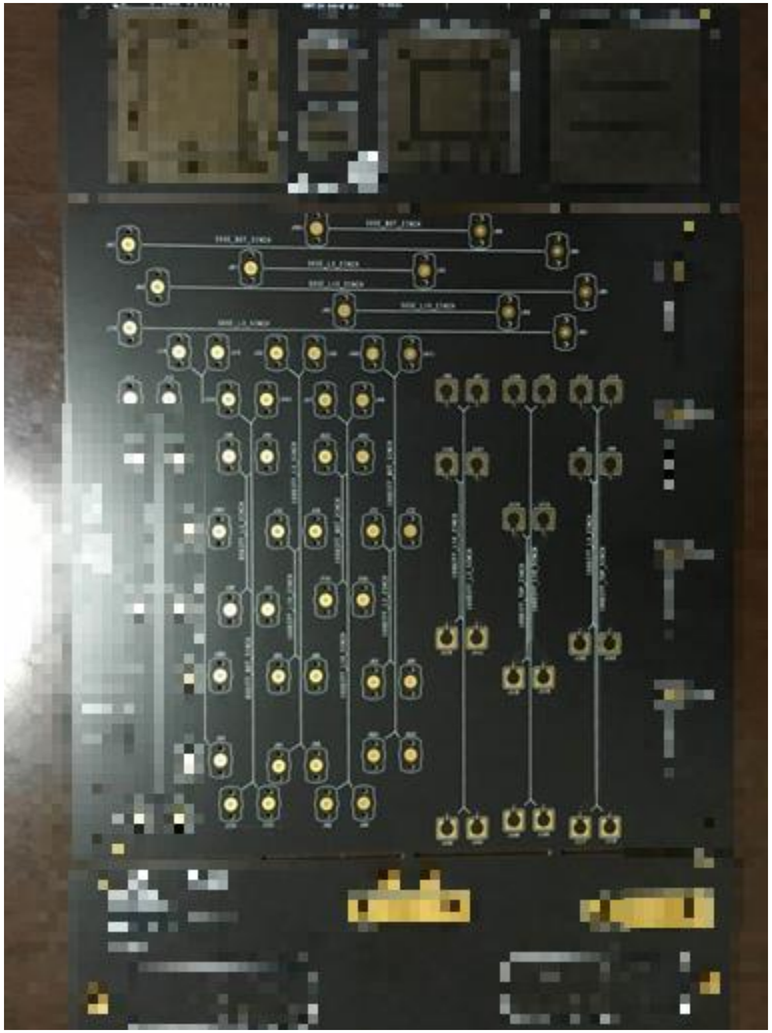
Filler
- Heat Resistance
- Low Water Absorption
- High Stiffness
- Heat Dissipation
- Warp Resistance
- Dimensional Stability
- Low CTE
- Flammability

Fiberglass Cloth
- Dimensional stability
- High Stiffness
- Low CTE
- Warp Resistance
- Flammability

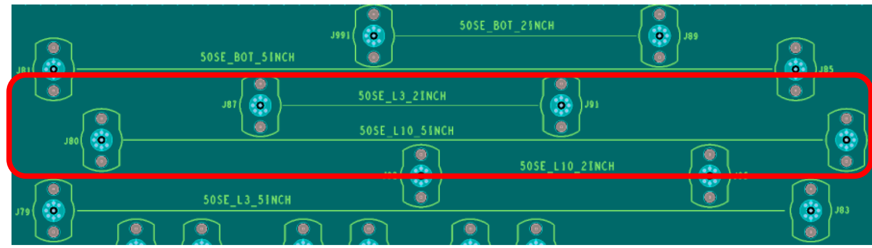
Copper Foil
- Electrical Contact
- Signal Line
- Electrical Grounding
- Heat Dissipation

The statistical analysis of transmission line parameter variation for material property and physical layout structure.

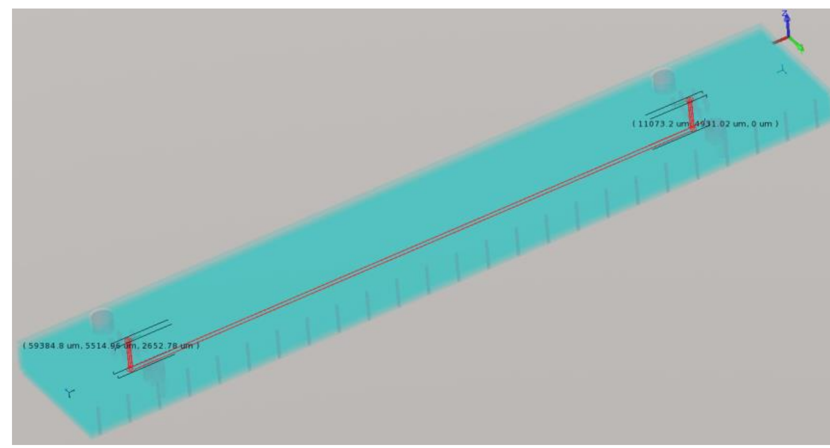
Single-End transmission line



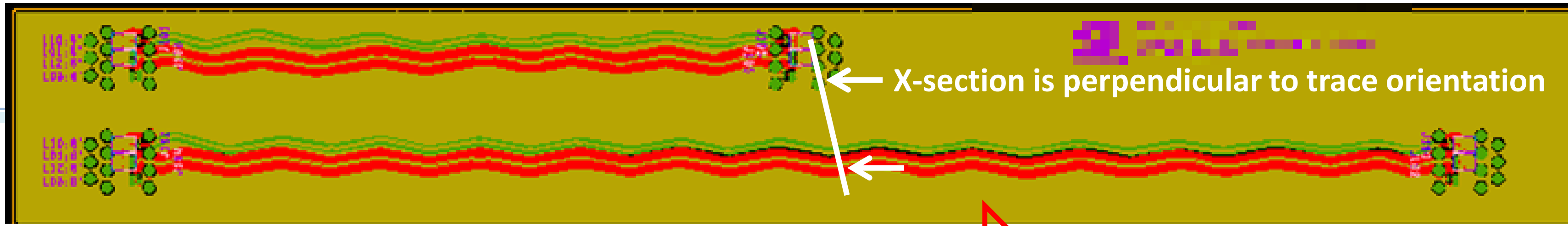
Test Board

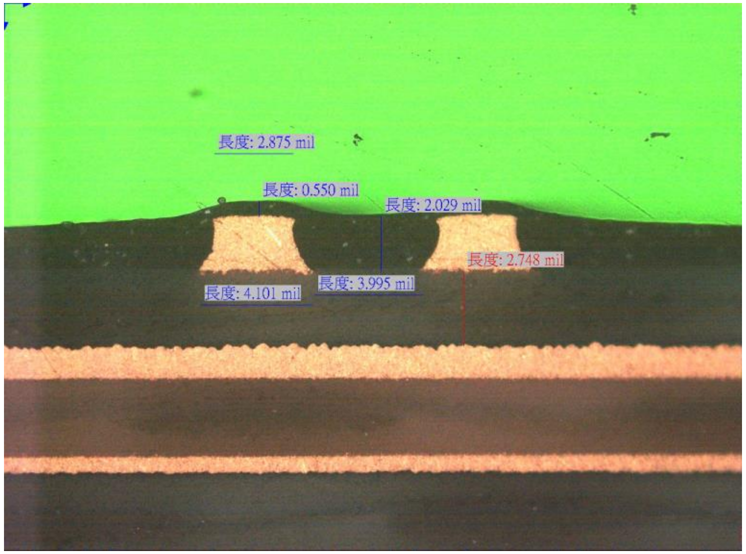


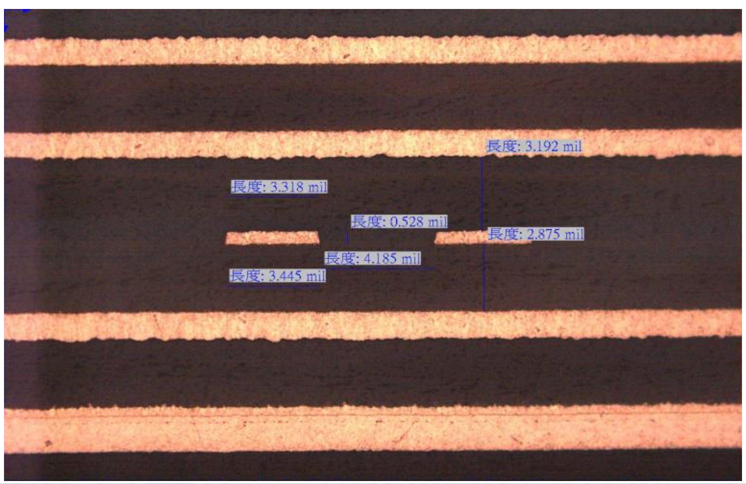
Single-End transmission line

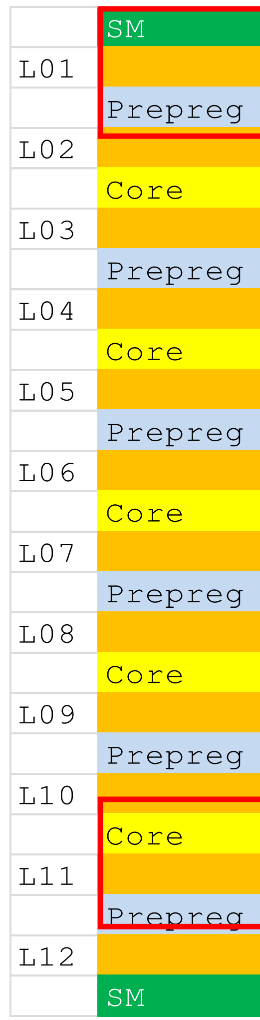


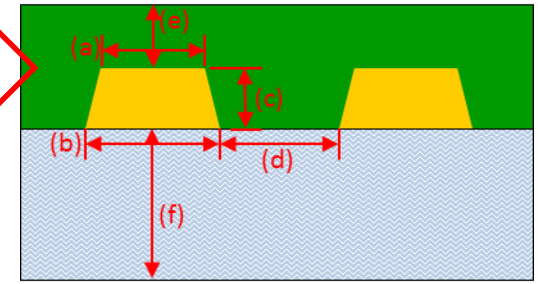
Electrical FEM model



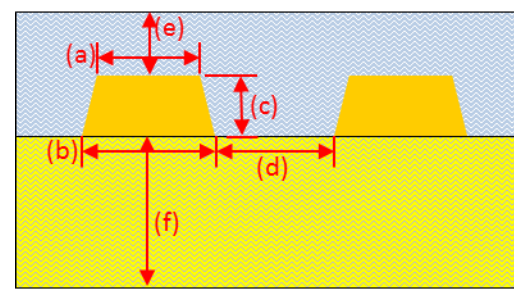




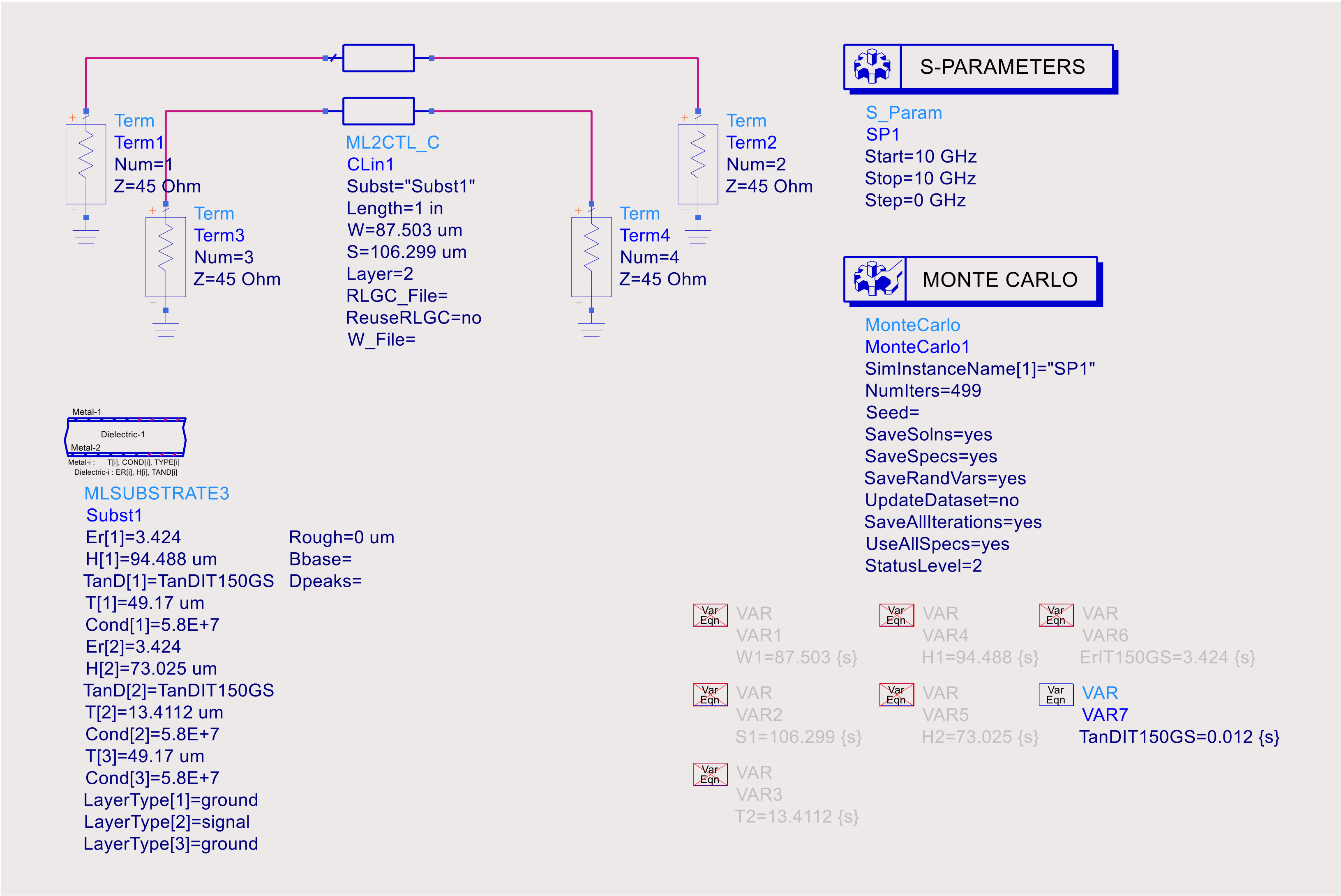




(a) Top trace width
(b) Bottom trace width
(c) Cu thickness
(d) Trace space
(e) Upper dielectric thickness
(f) Lower dielectric thickness



Monte Carlo Simulation for Insertion Loss on IT-150GS

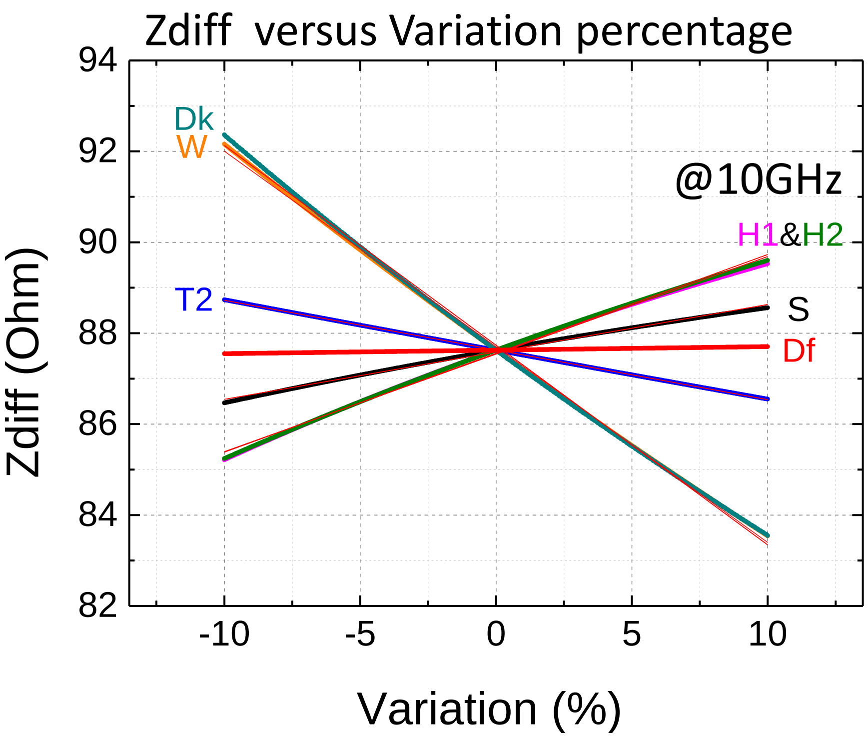


The Sensitivity analysis

Impedance V.S. Insertion Loss for W, T, H, Dk & Df

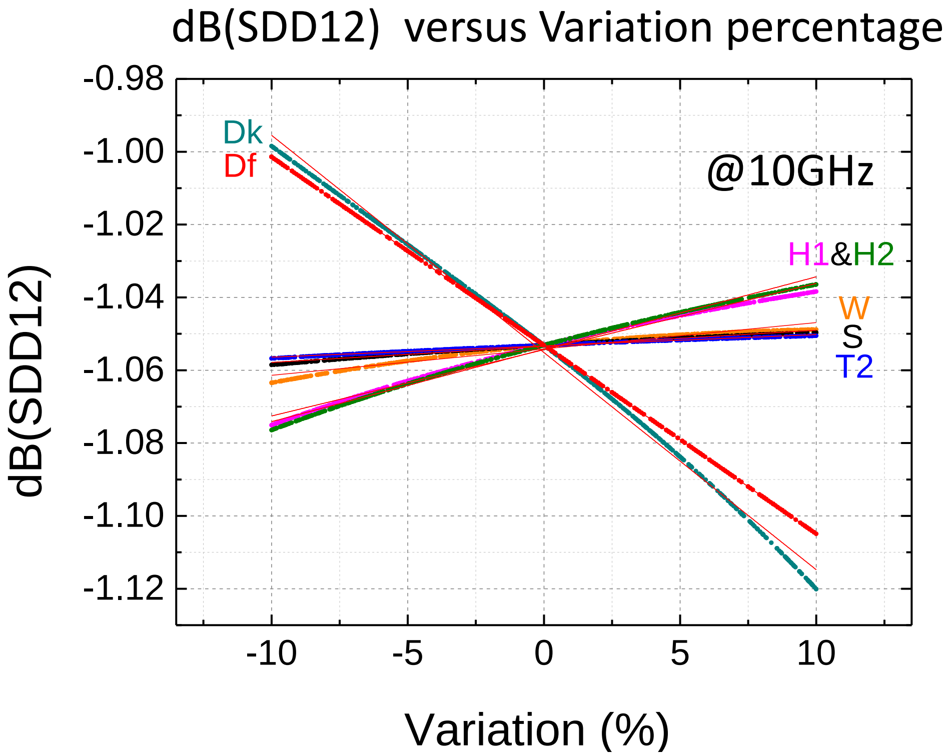
+ Slope: H1(0.21)**≈H2**(0.22)**>S**(0.10)**>Df**(0.01)

- Slope: W(-0.43)**=Dk**(-0.44)**>T2**(-0.11)



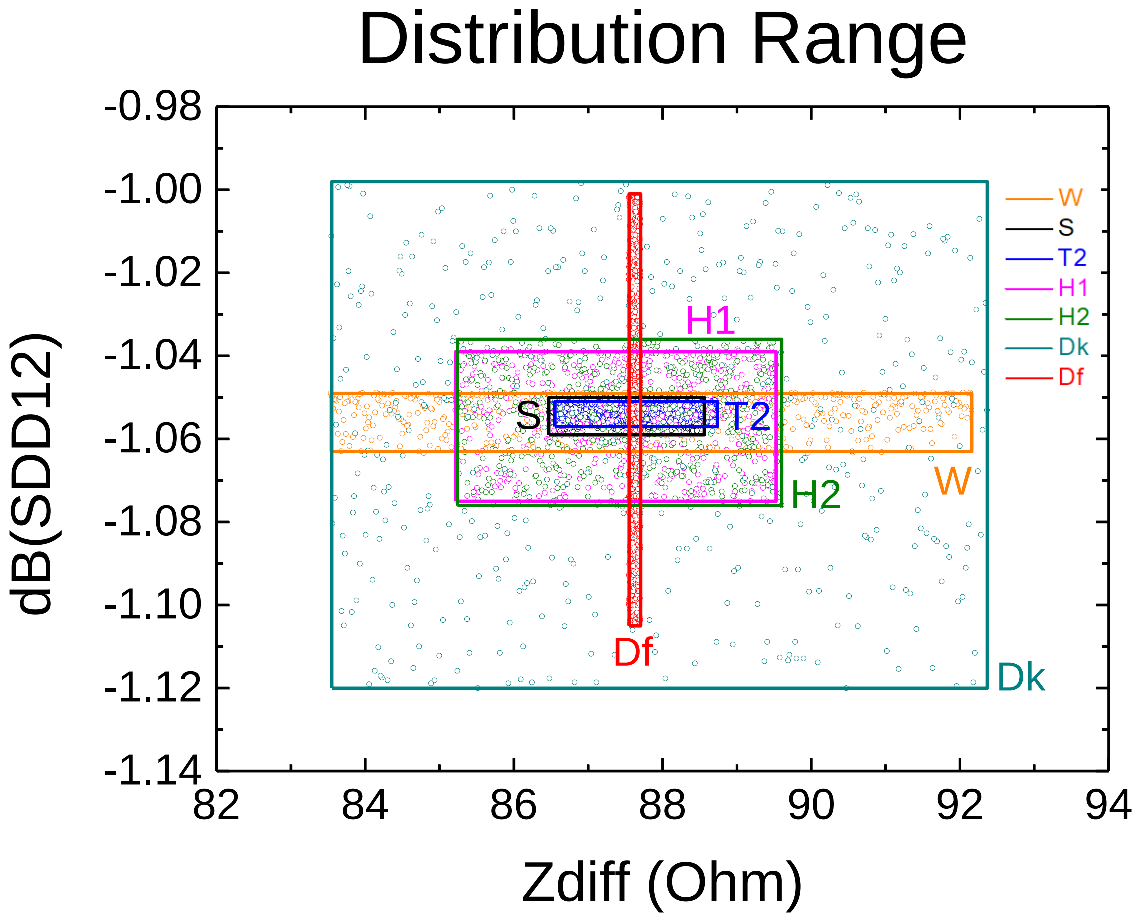
+ Slope: H1(0.002)**=H2**(0.002)**>W**(0.00072)
>S(0.00044)**>T2**(0.00031)

- Slope: Dk(-0.006)**>Df**(-0.005)

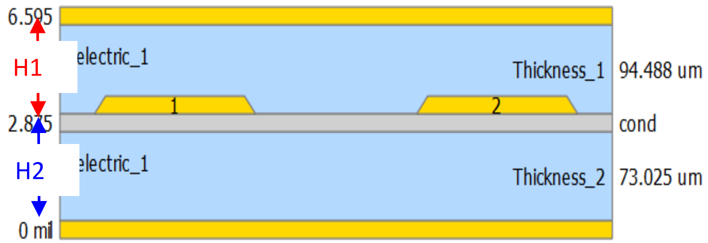


The worst case of IL & Imp corner Variations
(Monte Carlo Method)

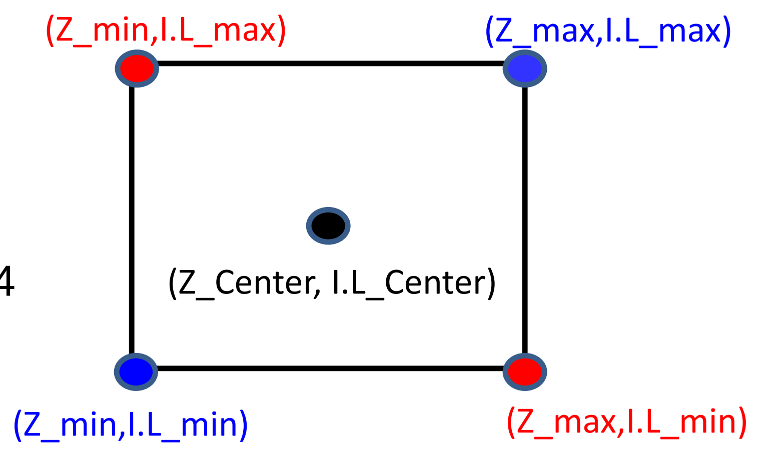
Area: Dk(68.34%)**> H2**(11.08%)**> H1**(9.86%)**> W**(7.66%)**>S**(1.20%)**>Df**(1.03%)**>T2**(0.83%)



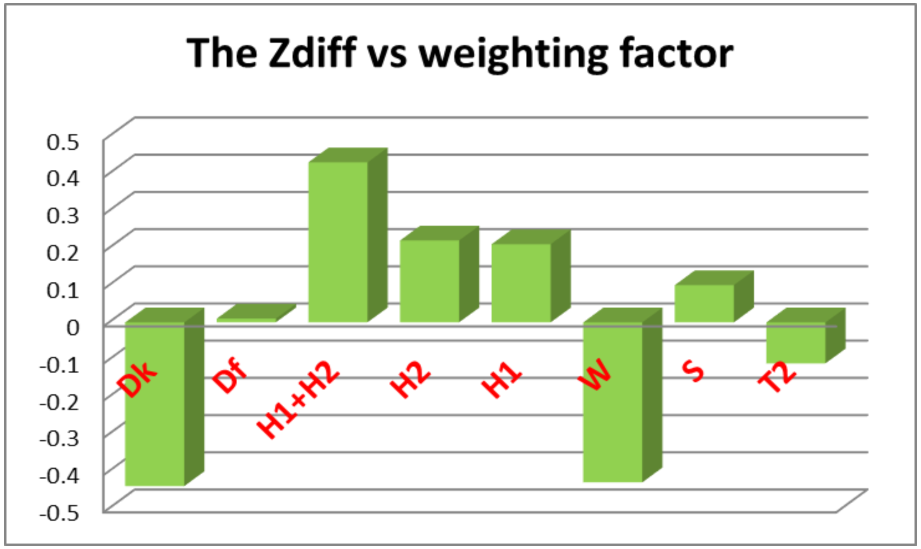
Layer Stack Up

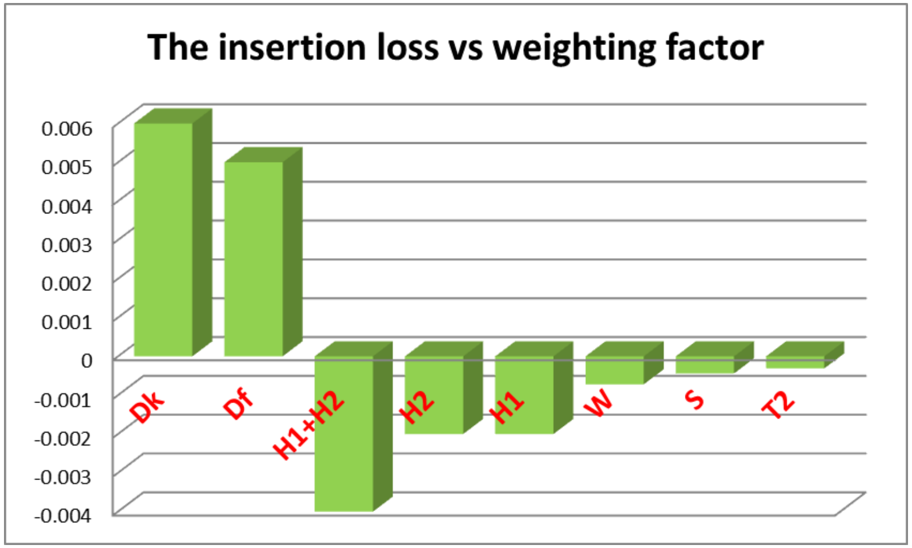


Rectangular Shape define



Z_diff and insertion loss Scenario analysis

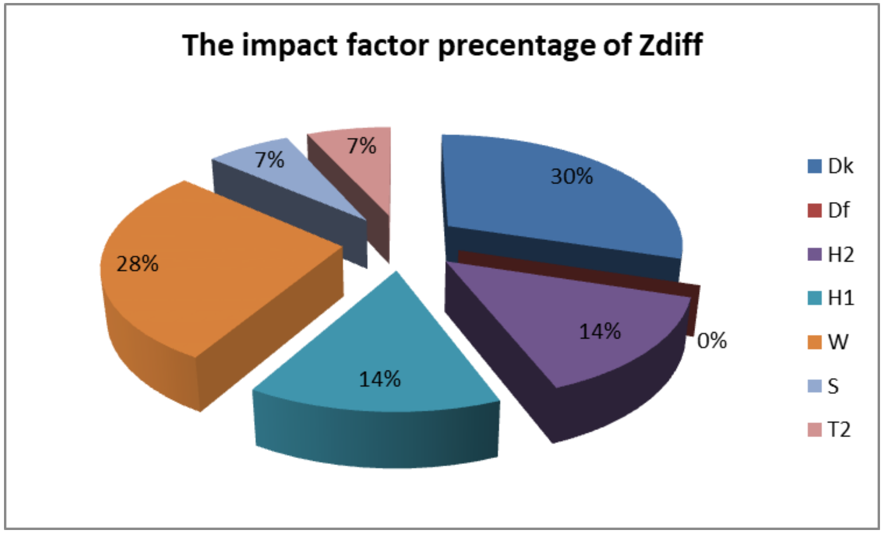


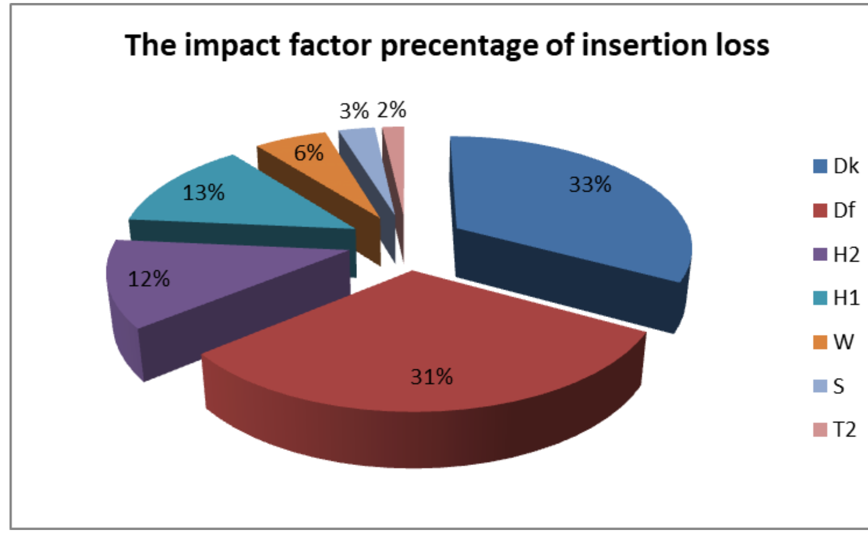


Sensitivity and Scenario analysis table

	Dk(10% ↑)	Df(10% ↑)	H1+H2 (10% ↑)	H2(10% ↑)	H1(10% ↑)	W(10% ↑)	S(10% ↑)	T2(10% ↑)
Z_diff	↓ (5.5%)	X (0.0%)	↑ (5.2%)	↑ (2.6%)	↑ (2.6%)	↓ (5.1%)	↑ (1.3%)	↓ (1.3%)
I.L.	↑ (5.3%)	↑ (5.0%)	↓ (4.1%)	↓ (2.0%)	↓ (2.1%)	↓ (0.9%)	↓ (0.5%)	↓ (0.3%)

The ranking of parameter for Z_diff and I.L.





The ranking of parameter percentage for Z_diff and I.L.

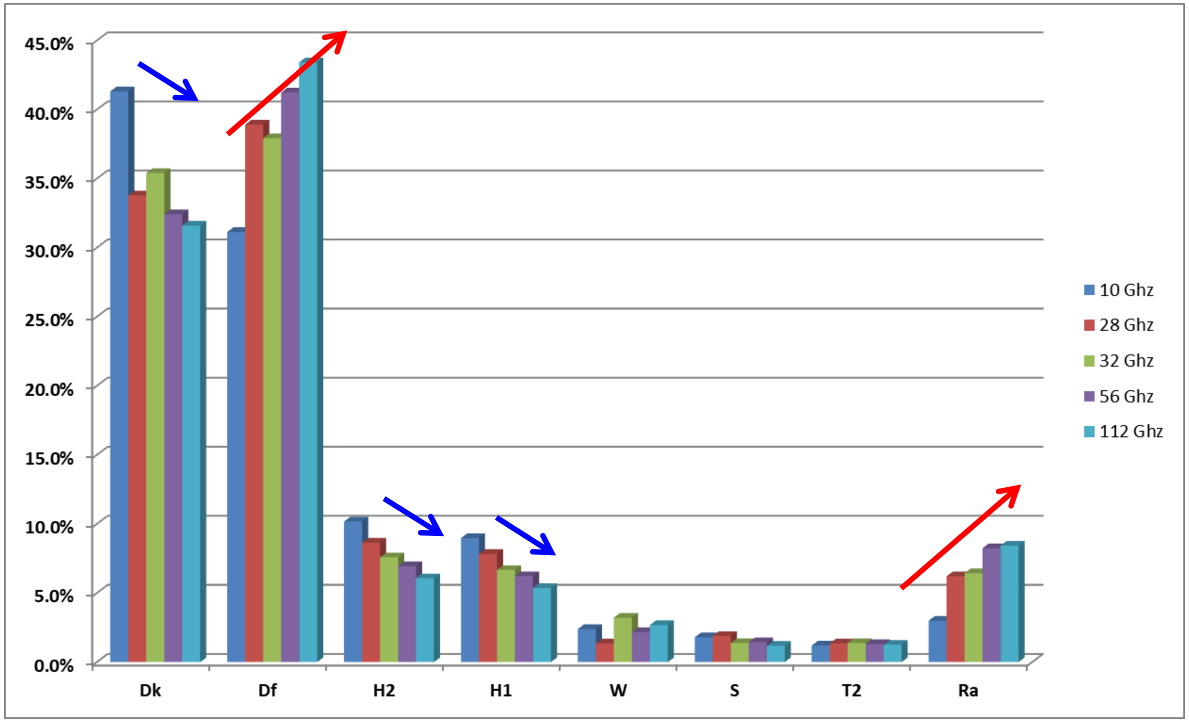
	Dk(10% ↑)	Df(10% ↑)	H2(10% ↑)	H1(10% ↑)	W(10% ↑)	S(10% ↑)	T2(10% ↑)
Z_diff	29.8%	0.0%	14.3%	14.3%	28.0%	6.8%	6.8%
I.L.	32.9%	31.2%	12.4%	12.9%	5.9%	2.9%	1.8%

The ranking of parameter for Z_diff and I.L.

	Dk(10% ↑)	Df(10% ↑)	H2(10% ↑)	H1(10% ↑)	W(10% ↑)	S(10% ↑)	T2(10% ↑)
Z_diff	1	6	2	2	3	4	5
I.L.	1	2	3	3	4	5	6

Weighting Factor vs. insertion loss Plot (frequency trend)

Weighting Factor vs. insertion loss frequency plot



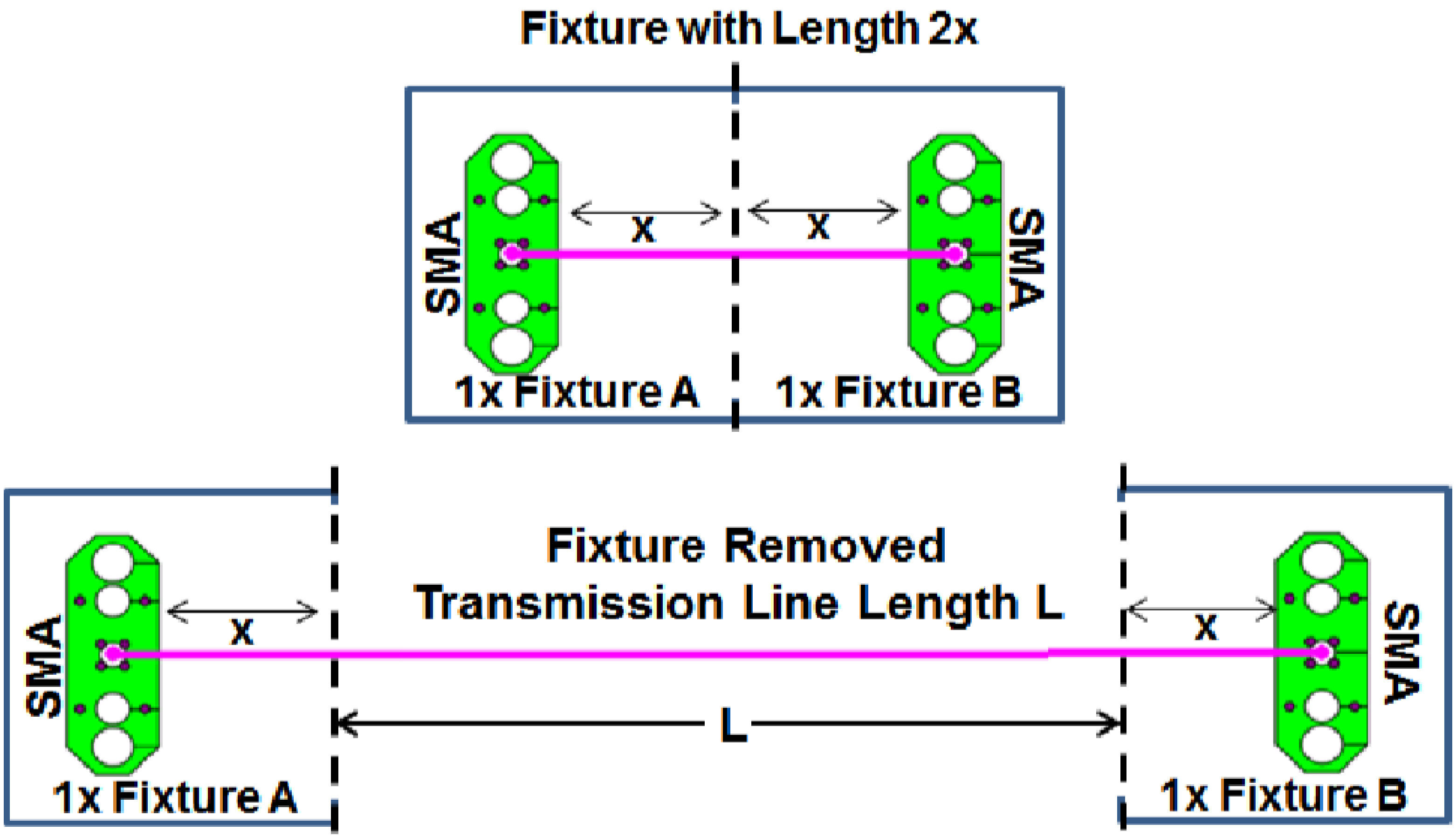
Weighting Factor vs. insertion loss frequency table

Freq\IL_wet	Dk	Df	H2	H1	W	S	T2	Ra
10 Ghz	41.3%	31.1%	10.2%	9.0%	2.4%	1.8%	1.2%	3.0%
28 Ghz	33.8%	38.9%	8.6%	7.8%	1.4%	1.9%	1.4%	6.2%
32 Ghz	35.4%	37.9%	7.6%	6.7%	3.2%	1.4%	1.4%	6.4%
56 Ghz	32.4%	41.2%	6.9%	6.2%	2.2%	1.4%	1.3%	8.2%
112 Ghz	31.6%	43.4%	6.1%	5.4%	2.7%	1.2%	1.3%	8.4%

Material Parameter Extraction.

Concept of de-embedding method

2-Line Test Coupon Structures for measuring the S-Parameters of the Length L of transmission line with the connector fixture removed.



The algorithm flow of Dk/Df extraction

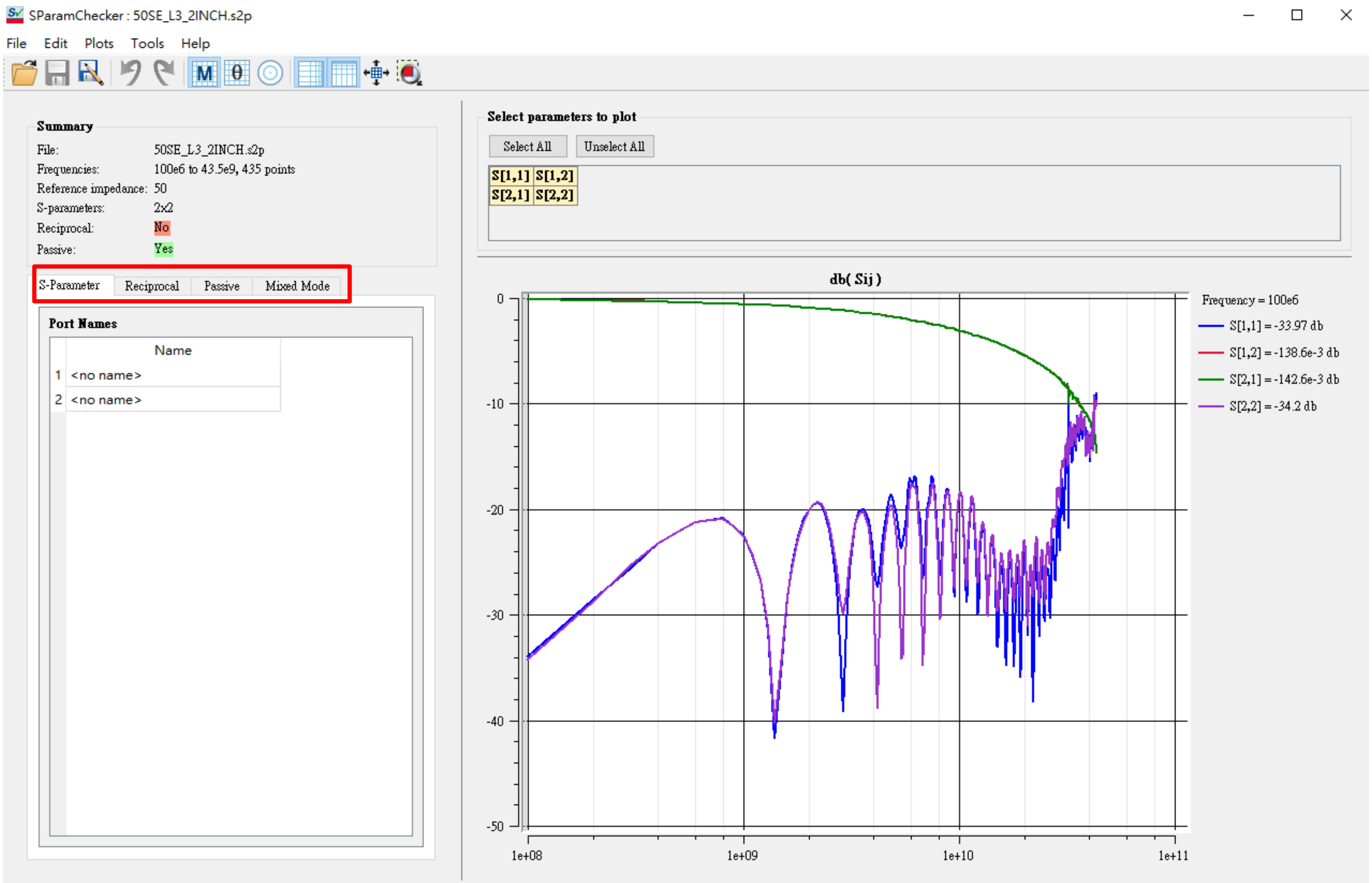
Measuring the S-parameters of two different lengths of traces on the test board by using the VNA.

Extract Dk value form group delay.

Extract phase deviation form two different lengths S-parameter.

To optimize electrical model to get dielectric constant (Dk) ,loss tangent (Df) and surface roughness.

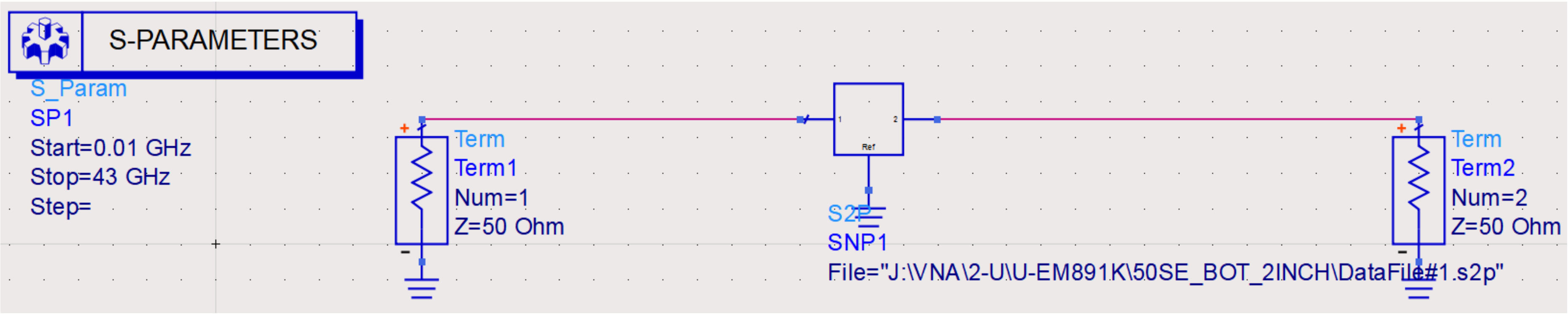
The criteria of S-para, passivity, causality , convergency tolerance



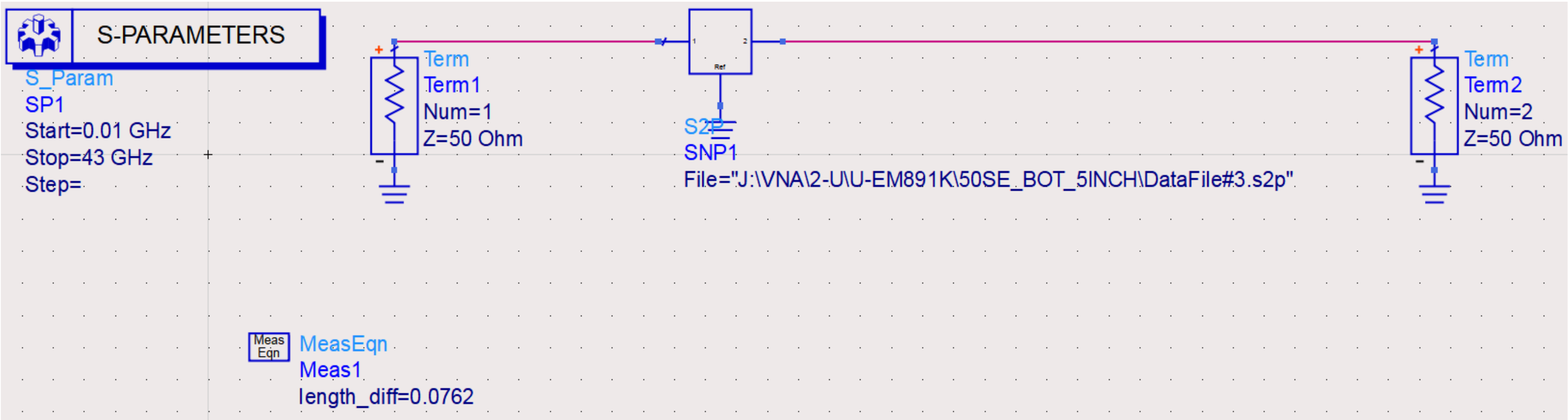
Unimicron

Import short and long trace S-parameter data

Import short trace S-parameter data

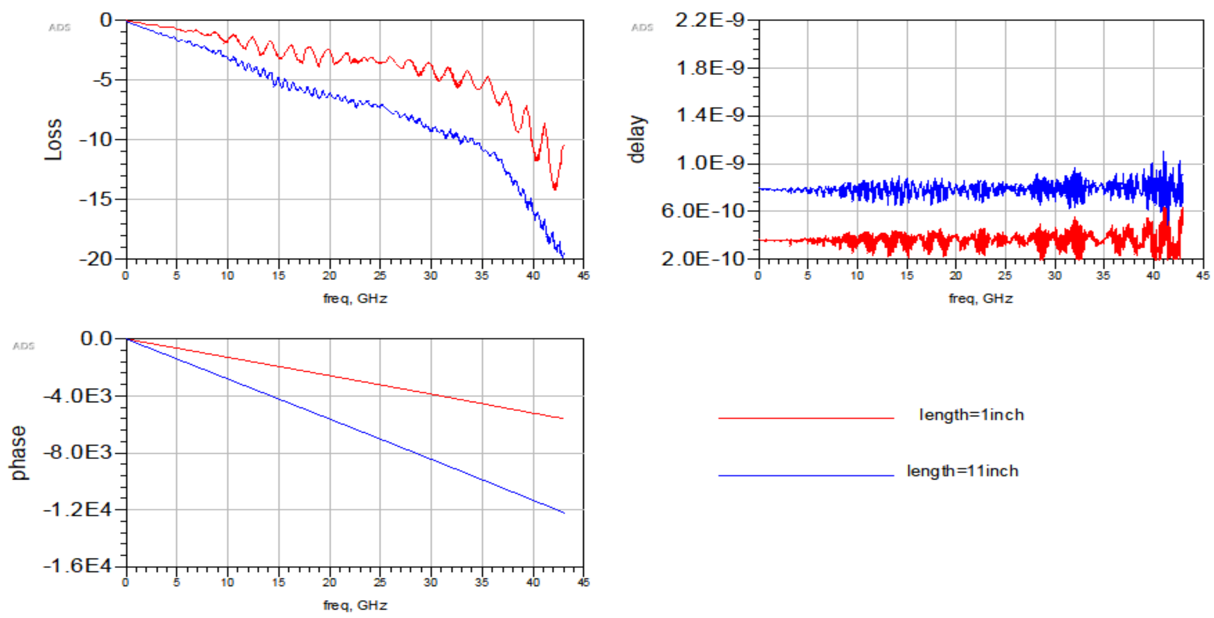


Import long trace S-parameter data



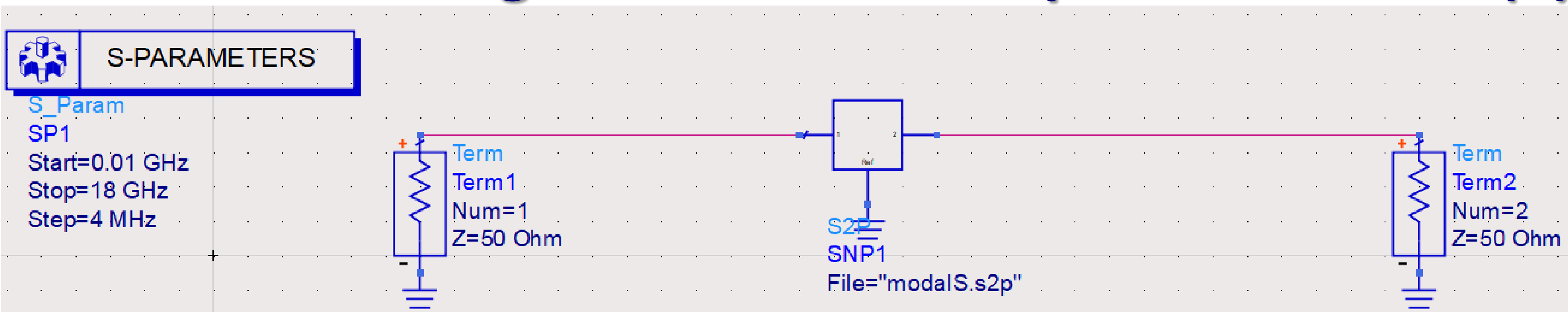
Check short and long trace S-parameter data

freq	S1			
	S1(1,1)	S1(1,2)	S1(2,1)	S1(2,2)
10.00 MHz	0.000 / 0.000	0.997 / -1.702	0.997 / -1.699	0.000 / 0.000
16.72 MHz	0.000 / 0.000	0.997 / -2.746	0.997 / -2.746	0.000 / 0.000
23.43 MHz	0.000 / 0.000	0.996 / -3.789	0.997 / -3.790	0.000 / 0.000
30.15 MHz	0.000 / 0.000	0.996 / -4.831	0.996 / -4.834	0.000 / 0.000
36.87 MHz	0.000 / 0.000	0.996 / -5.873	0.996 / -5.878	0.000 / 0.000
43.59 MHz	0.000 / 0.000	0.995 / -6.915	0.996 / -6.922	0.000 / 0.000
50.30 MHz	0.000 / 0.000	0.995 / -7.957	0.996 / -7.966	0.000 / 0.000
57.02 MHz	0.000 / 0.000	0.995 / -8.999	0.995 / -9.010	0.000 / 0.000
63.74 MHz	0.000 / 0.000	0.994 / -10.041	0.995 / -10.054	0.000 / 0.000
70.45 MHz	0.000 / 0.000	0.994 / -11.083	0.995 / -11.098	0.000 / 0.000
77.17 MHz	0.000 / 0.000	0.994 / -12.125	0.994 / -12.141	0.000 / 0.000
83.89 MHz	0.000 / 0.000	0.994 / -13.167	0.994 / -13.185	0.000 / 0.000
90.61 MHz	0.000 / 0.000	0.993 / -14.209	0.994 / -14.229	0.000 / 0.000
97.32 MHz	0.000 / 0.000	0.993 / -15.251	0.994 / -15.273	0.000 / 0.000
104.0 MHz	0.000 / 0.000	0.993 / -16.292	0.993 / -16.311	0.000 / 0.000
110.8 MHz	0.000 / 0.000	0.993 / -17.332	0.993 / -17.345	0.000 / 0.000
117.5 MHz	0.000 / 0.000	0.992 / -18.372	0.993 / -18.380	0.000 / 0.000
124.2 MHz	0.000 / 0.000	0.992 / -19.412	0.992 / -19.414	0.000 / 0.000
130.9 MHz	0.000 / 0.000	0.992 / -20.452	0.992 / -20.448	0.000 / 0.000
137.6 MHz	0.000 / 0.000	0.992 / -21.493	0.992 / -21.482	0.000 / 0.000
144.3 MHz	0.000 / 0.000	0.991 / -22.533	0.991 / -22.517	0.000 / 0.000
151.1 MHz	0.000 / 0.000	0.991 / -23.573	0.991 / -23.552	0.000 / 0.000
157.8 MHz	0.000 / 0.000	0.991 / -24.608	0.991 / -24.590	0.000 / 0.000
164.5 MHz	0.000 / 0.000	0.991 / -25.642	0.991 / -25.628	0.000 / 0.000
171.2 MHz	0.000 / 0.000	0.990 / -26.677	0.990 / -26.666	0.000 / 0.000

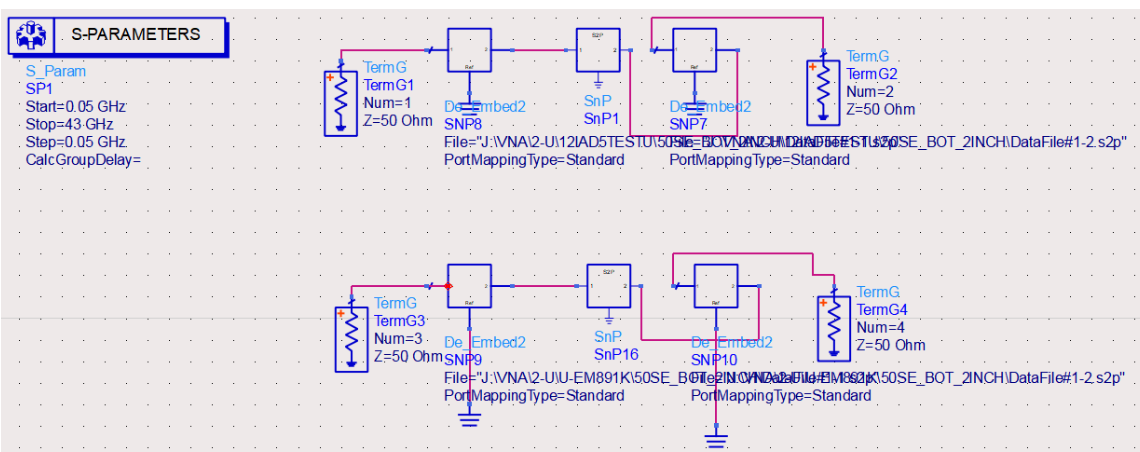


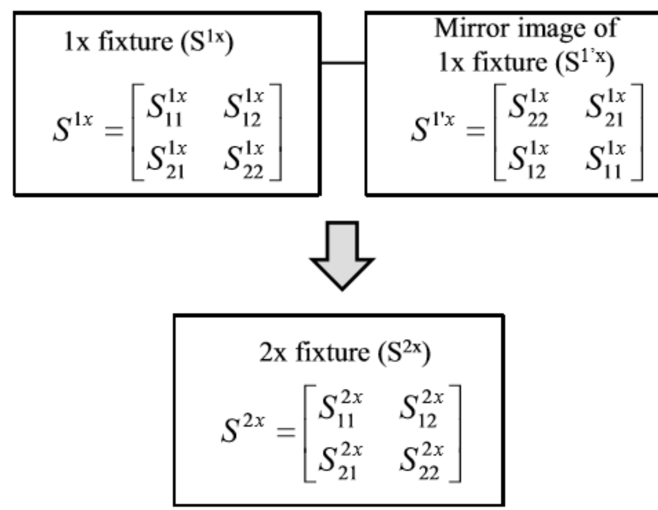
De-embeded Method

De-embeded long and short trace S-parameter data (1)

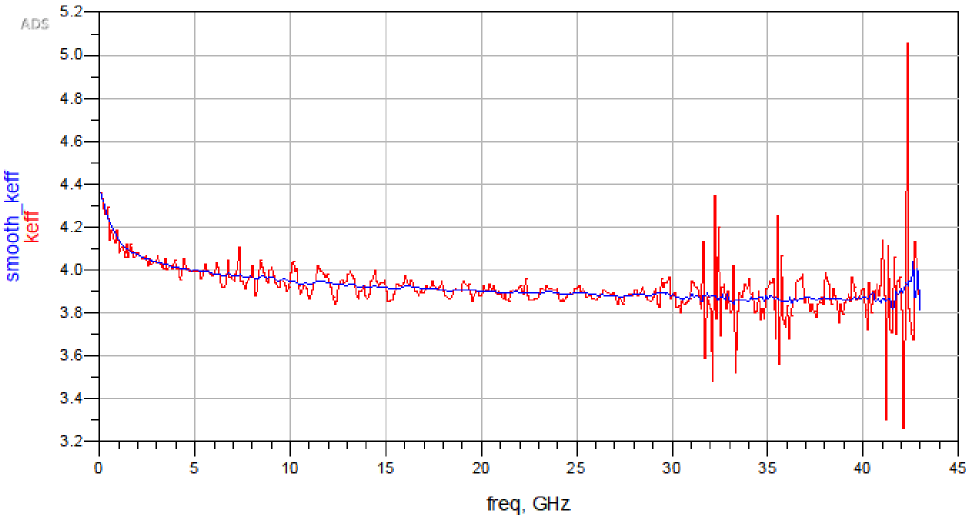


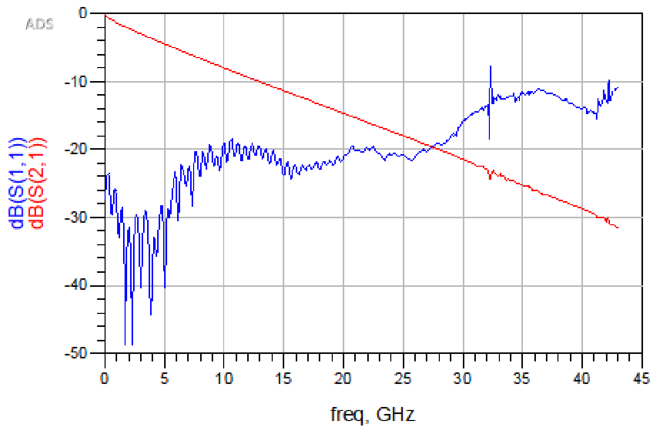
De-embeded long short trace S-parameter data (2)

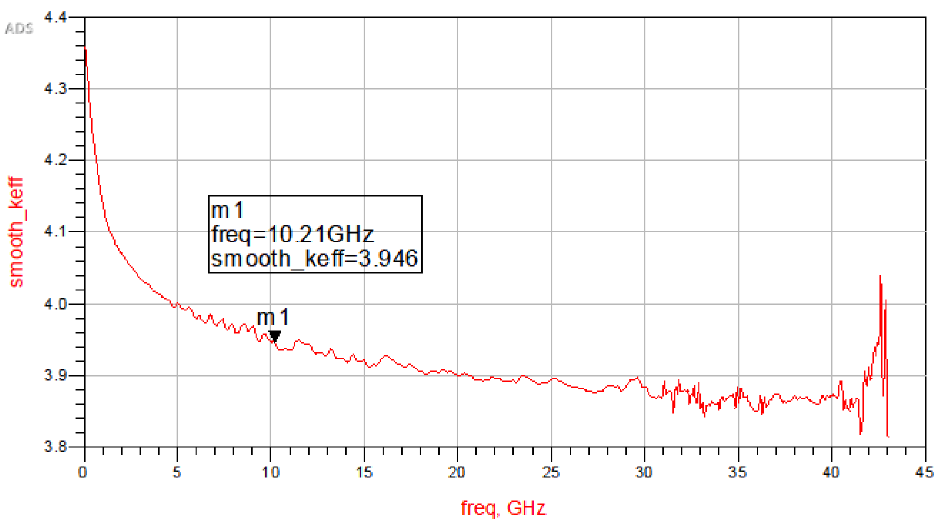




Dk extraction result

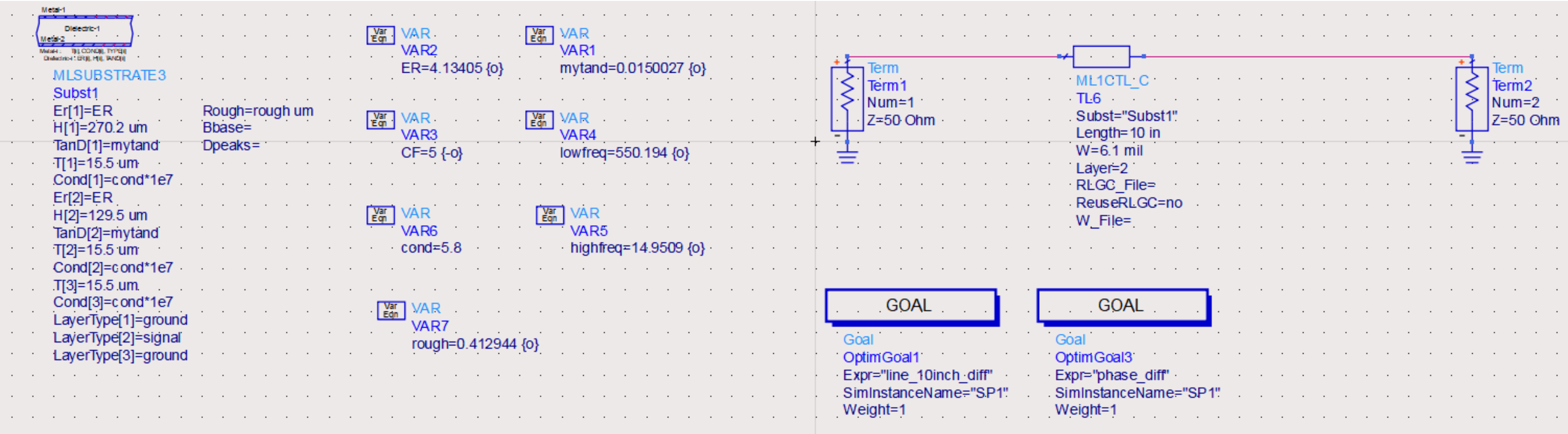




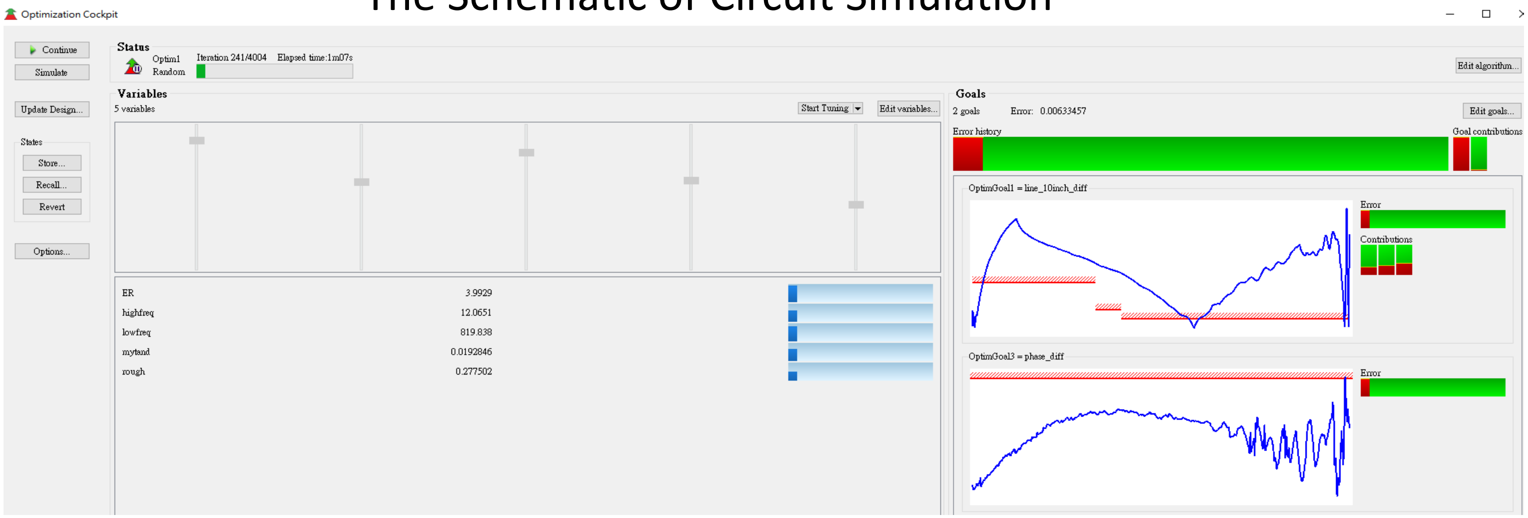


Unimicron

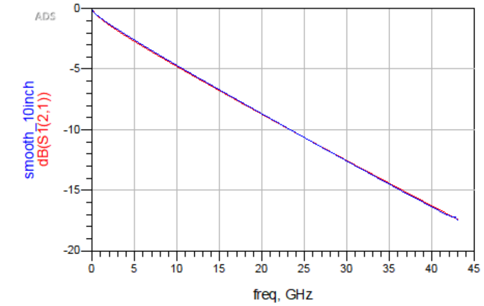
The Schematic of Circuit Simulation

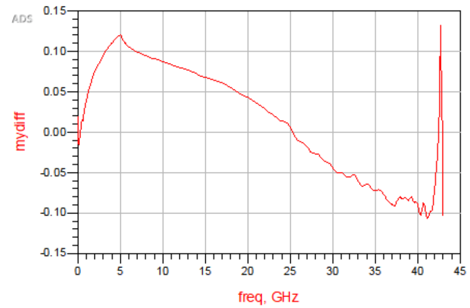


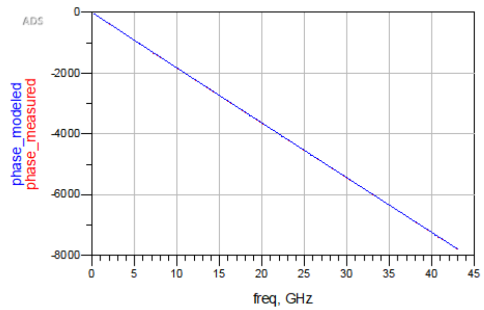
The Schematic of Circuit Simulation



Df and Phase extraction result

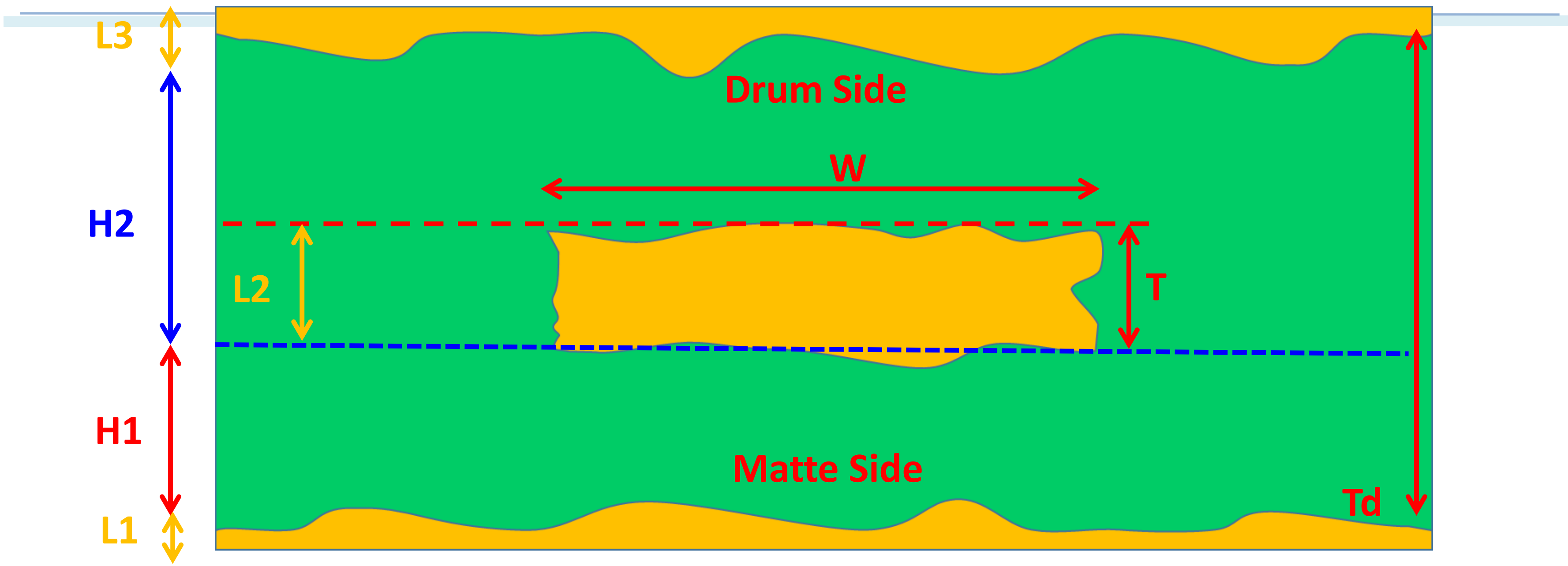






freq	real_er_final	tand_final
10.0000 MHz	4.29749	0.01699
20.0000 MHz	4.26362	0.01760
30.0000 MHz	4.24376	0.01784
40.0000 MHz	4.22966	0.01797
50.0000 MHz	4.21873	0.01807
60.0000 MHz	4.20979	0.01814
70.0000 MHz	4.20223	0.01819
80.0000 MHz	4.19568	0.01824
90.0000 MHz	4.18991	0.01828
100.000 MHz	4.18474	0.01831
110.000 MHz	4.18007	0.01834
120.000 MHz	4.17580	0.01837
130.000 MHz	4.17187	0.01839
140.000 MHz	4.16824	0.01841
150.000 MHz	4.16486	0.01843
160.000 MHz	4.16169	0.01845
170.000 MHz	4.15872	0.01847
180.000 MHz	4.15592	0.01848
190.000 MHz	4.15326	0.01850
200.000 MHz	4.15075	0.01851
210.000 MHz	4.14836	0.01852
220.000 MHz	4.14608	0.01853
230.000 MHz	4.14390	0.01855
240.000 MHz	4.14181	0.01856
250.000 MHz	4.13981	0.01857
260.000 MHz	4.13788	0.01858
270.000 MHz	4.13603	0.01859
280.000 MHz	4.13425	0.01860
290.000 MHz	4.13253	0.01861
300.000 MHz	4.13087	0.01861
310.000 MHz	4.12926	0.01862
320.000 MHz	4.12770	0.01863
330.000 MHz	4.12619	0.01864
340.000 MHz	4.12473	0.01865
350.000 MHz	4.12331	0.01865
360.000 MHz	4.12193	0.01866
370.000 MHz	4.12058	0.01867
380.000 MHz	4.11927	0.01867
390.000 MHz	4.11800	0.01868

Strip line roughness model (Single-End)



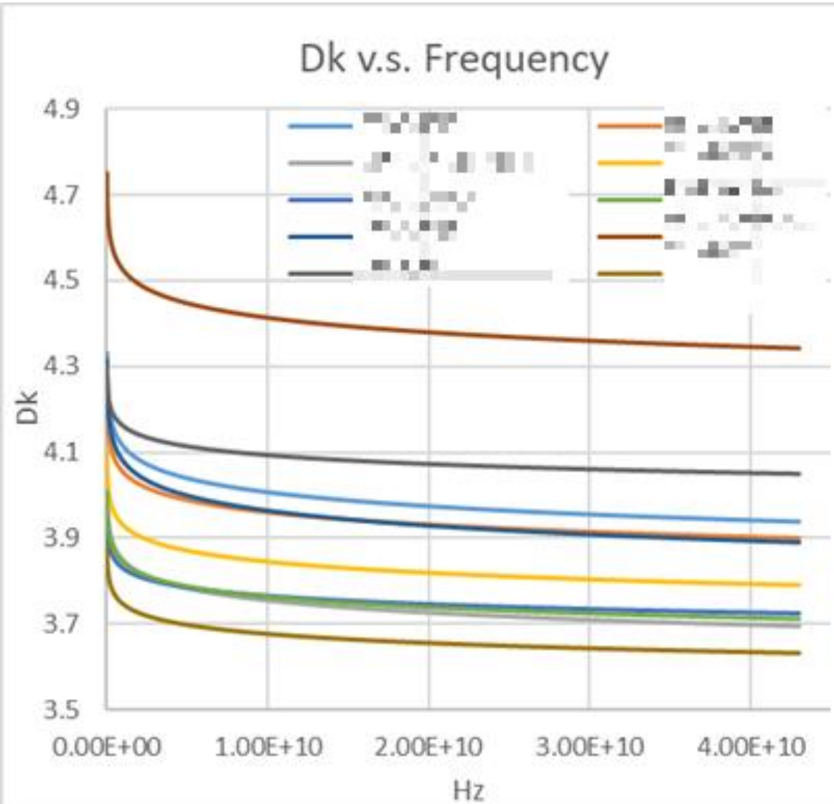
Dk and Df extraction result

	Dk	Df	Roughness (um)	W (mil)	T (um)	Td (um)	L1 (um)	H1 (um)	L2 (um)	H2 (um)	L3 (um)	Dk	Df	Freq	Dk_err	Df_err	[illegible]
[illegible]	4.0827	0.01812	0.34153	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3.33	0.013	2	22.60%	39.38%	[illegible]
[illegible]	3.95996	0.01633	0.340716	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3.9	0.012	10	1.54%	36.08%	[illegible]
[illegible]	3.84922	0.01673	0.270181	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4.2	0.01	1	-8.35%	67.30%	[illegible]
[illegible]	3.84498	0.01528	0.33228	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4.2	0.012	10	-8.45%	27.33%	[illegible]
[illegible]	3.76551	0.0117	0.261575	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4.1	0.007	10	-8.16%	67.14%	[illegible]
[illegible]	3.76324	0.01474	0.281086	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3.8	0.012	10	-0.97%	22.83%	[illegible]
[illegible]	3.96401	0.02009	0.274224	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4	0.015	10	-0.90%	33.93%	[illegible]
[illegible]	4.42694	0.01962	0.261186	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3.9	0.01	10	13.51%	96.20%	[illegible]
[illegible]				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4.2	0.007	1	-100.00%	-100.00%	[illegible]
[illegible]	4.09395	0.01145	0.278182	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3.9	0.008	10	4.97%	43.13%	[illegible]
[illegible]	3.67557	0.01293	0.280686	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4	0.008	10	-8.11%	61.63%	[illegible]

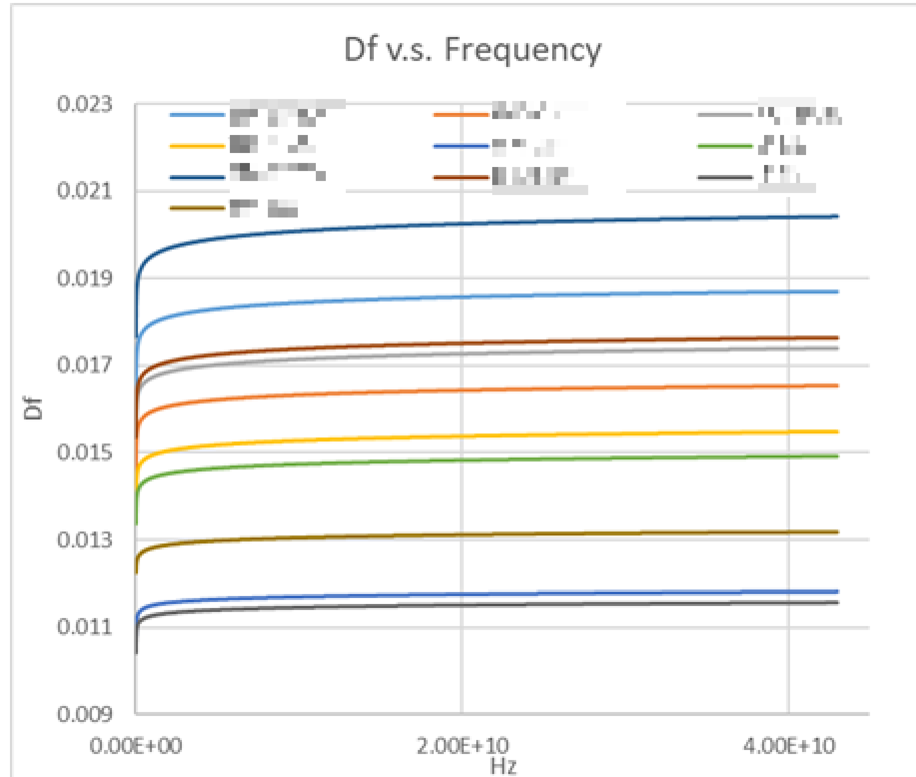
Extraction result

Initial value

Frequency dependence of Dk & Dk Properties



Dk v.s. Frequency Plot



Df v.s. Frequency Plot

Conclusion

1. According to the structure of layer stack up and the dielectric material coefficient provided by the material supplier as the initial value, we have been able to give effective Dk, Df and surface roughness parameters from the return loss and insertion loss measurement by vector network analyzer.
2. The equivalent Dk/Df transmission line extraction algorithm is a solution developed by bilateral collaboration of UMTC and Keysight to meet the needs of low-loss materials and high-speed transmission lines for customers' 5G NR products.
3. The electrical model of the dielectric layer mixed glass fiber will be further studied in order to solve the problem of signal integrity skew of the 5G high-speed transmission line of the PCB board.

Thank you for your attention!!!