High Frequency CCL Materials for Automotive Radar Applications

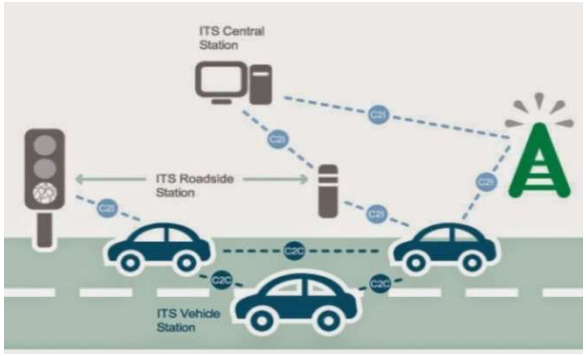
OUTLINE

1	**Introduction & Background**
2	Low Dielectric Laminates Design
3	Nan Ya Laminates for Automotive Radar and Electric Vehicle Applications
4	Summary

The Trend of Automotive Electronic

NAN YA

Internet of Vehicle (5G)



ADAS

New Energy

SAE – Level of Automated Driving

Level 0	Level 1	Level 2	Level 3	Level 4	Level 5
No Automation	Driver Assistance	Partial Automation	Conditional Automation	High Automation	Full Automation
▪ Airbag ▪ ABS	▪ Adaptive Cruise Control ▪ Automatic emergency braking ▪ Blind spot warning ▪ Lane departure warning ▪ Park assist	▪ Automated parking ▪ Lane keep assist	▪ Autonomous parking ▪ Highway assist ▪ Stop and go ▪ (Highway)	▪ Highway automated driving ▪ Stop and go (Urban)	▪ Autonomous driving

Level 0 Consumer vehicle introduction: 1900-present

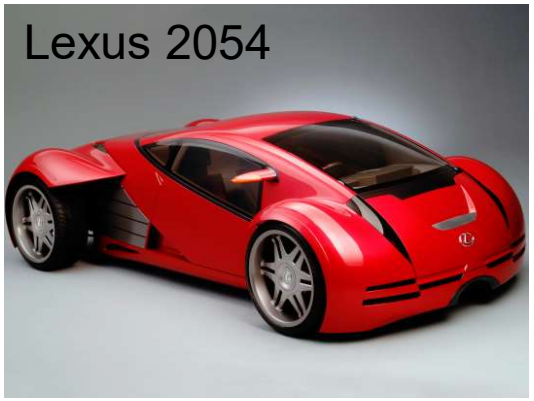
Level 1 Consumer vehicle introduction: 2007

Level 2 Available in some luxury cars-consumer vehicle introduction: 2014

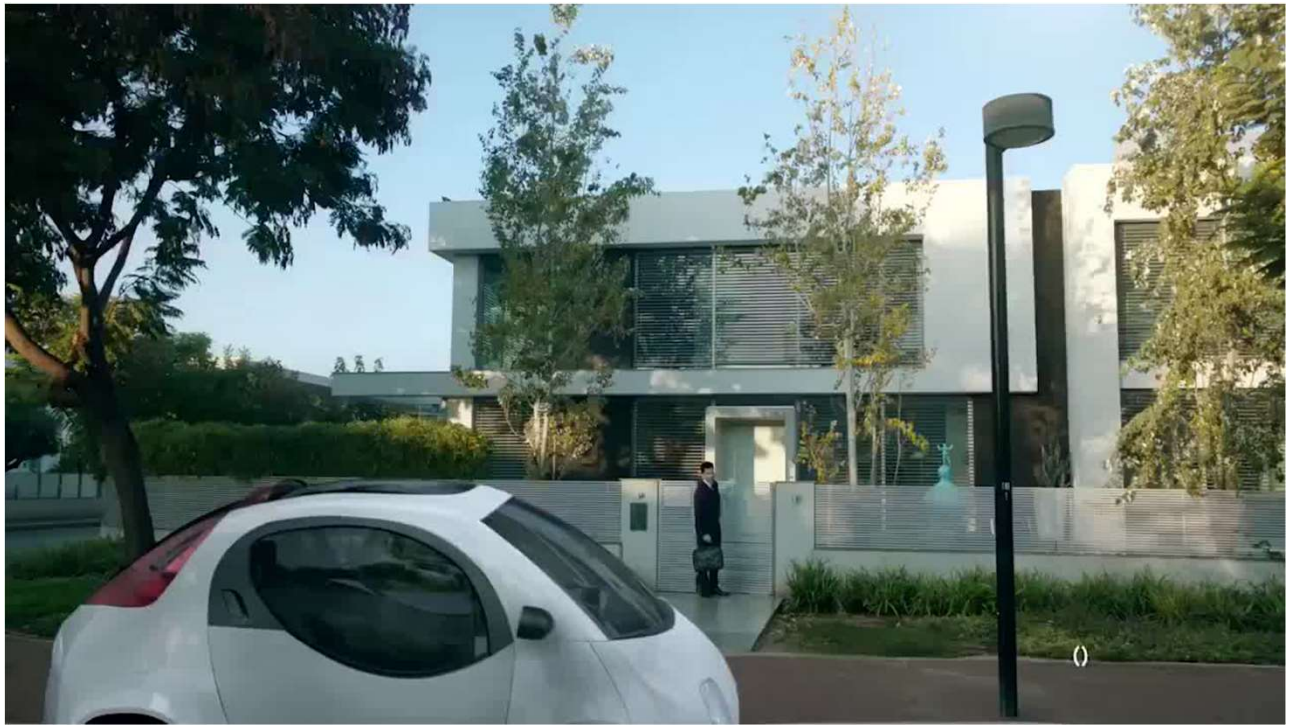
Level 3 Where only a few, like Audi, dare venture today-consumer vehicle introduction: 2018

Level 4 Offices and cinemas on wheels – consumer vehicle introduction: 2021

Level 5 The Lexus 2054 from Minority Report – consumer vehicle introduction: mid-2020s

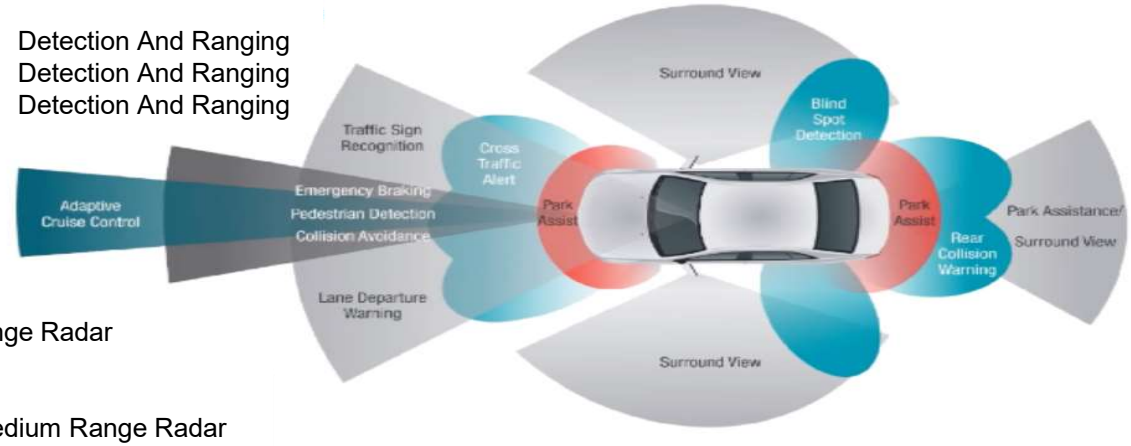


Level 5



FMCW Automotive Radar in a Vehicle

LIDAR : Light Detection And Ranging
LADAR : Laser Detection And Ranging
RADAR : Radar Detection And Ranging



Long-Range Radar
LIDAR
Camera
Short-/Medium Range Radar
Ultrasound

		Camera	LIDAR	RADAR
Range	Accuracy	-	+	+
	Resolution	-	-	+
Angle	Accuracy	+	+	-
	Resolution	+	+	--
Velocity	Accuracy	-	o	+
Night capability		-	+	+
All-weather capability		-	-	+
Object classification		+	o	-

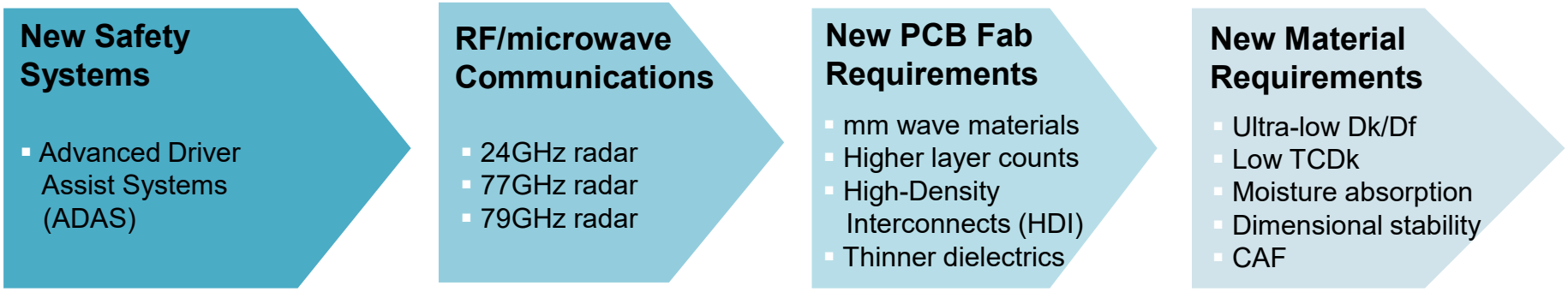
Available Automotive Radar Bands

There are 4 major frequency bands allocated for radar applications

- 24.125 GHz with a bandwidth of around 200MHz (short/mid-range radar)
- 24 GHz with a bandwidth of 5GHz (short/mid-range radar)
- 76 - 77 GHz (narrow-band long range radar)
- 77 - 81 GHz (wideband radar short/mid-range range)

Area	24GHz	60GHz	77GHz	79GHz
Europe	**V**		**V**	**V**
USA	**V**		**V**	**V**
Japan		**V**	**TBD**	**TBD**
China	**V**		**V**	**TBD**

Emerging Industry Requirements Automotive Radar Communication

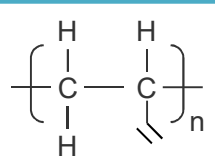


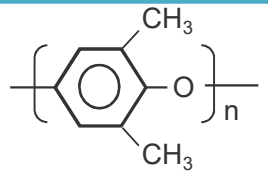
The critical properties of millimeter wave materials for automotive radars

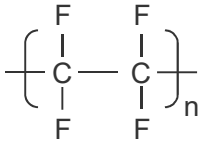
1. Dielectric constant (Dk)
   - Tightly controlled Dk tolerance enables more consistent performance
2. Dissipation factor (Df)
   - Low Df can contribute to the low loss characteristics
3. Copper surface roughness
   - By choosing low roughness copper foil to reduce skin effect and signal loss
4. Thermal Coefficient of Dielectric Constant (TCDk)
   - Low TCDk can maintain stable electrical properties in severe environment
5. Moisture absorption
   - Low moisture absorption will reduce Dk, Df and insertion loss variance
6. Dimensional stability
   - To increase production yield and benefit for volume production

How to develop excellent Electrical Performance Materials

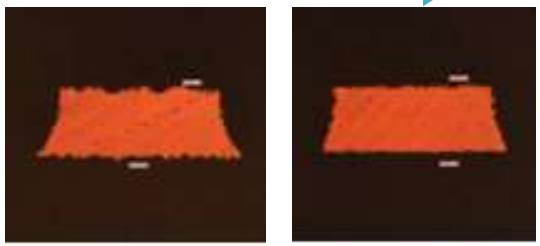
Hydrocarbon reduce polarity **PPE** increase symmetry **PTFE** decrease Dk/Df



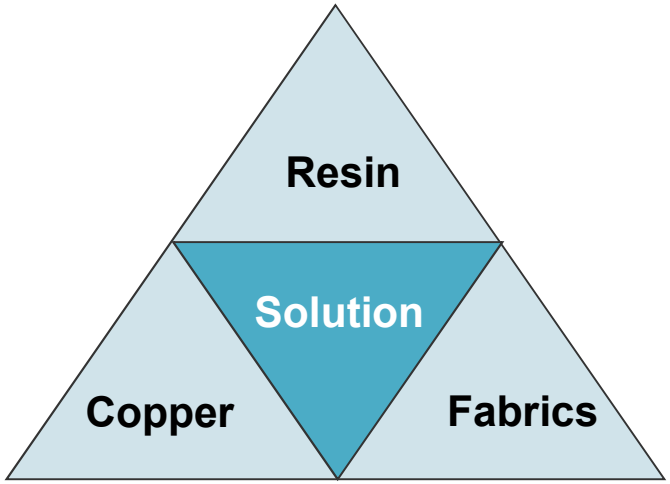




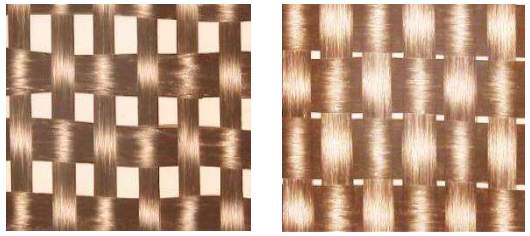
RTF vs VLP copper lower roughness



decreased skin effect



Spread fabrics are more uniform

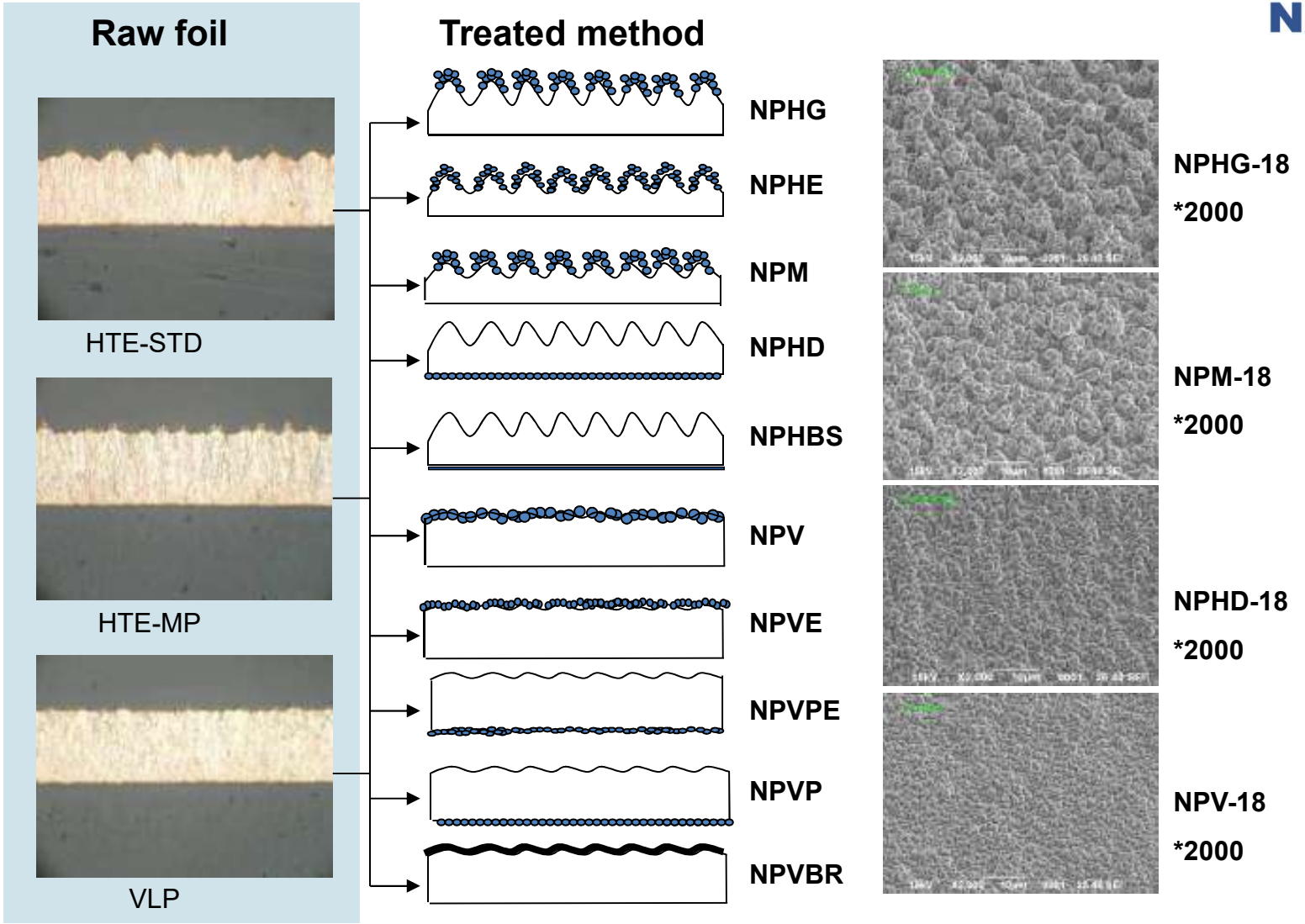


reduced inhomogeneity

E – glass	
Dk @ 10GHz	6.5 – 7.2
Df @ 10GHz	0.006 – 0.008

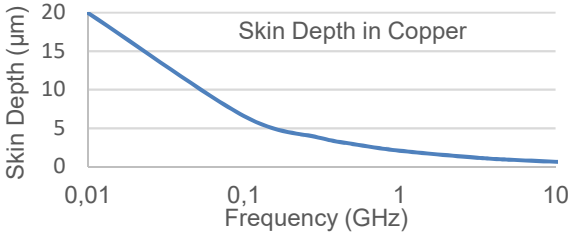
Low Dk - glass	
Dk @ 10GHz	4.6 – 5.0
Df @ 10GHz	0.003 – 0.004

Cu Foil – Arsenic (As) Free



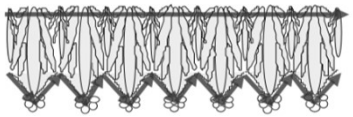
Copper Foil for High-Frequency Application

1. When the frequency is higher, the skin effect is more obvious and the current density will concentrate on the surface of copper foil
2. To choose RTF copper foil will have the benefit on low PIM and low insertion loss

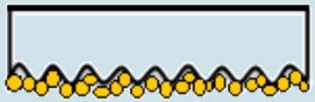
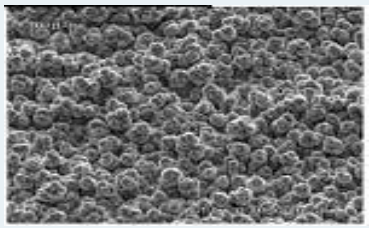
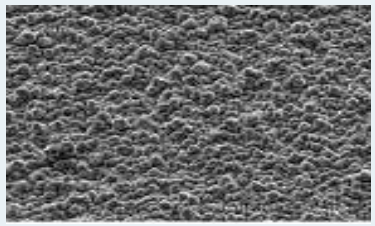


GHz	Skin Depth (µm)
0.01	20
0.1	6.61
1	2.09
5	0.93
50	0.30

High Frequency



increasing Path Length

Type	Standard	RTF
	HTE	Reverse HTE
Roughness	Rz: 7.0 µm	Rz: 2,5 µm
Structure		
Copper Surface Morphology		

Millimeter Wave Material Development

Products	Electrical properties (@ 10GHz) IPC-TM-650 2.5.5.13	Resin	Filler Glass fabrics	Application
NP-930	Dk = 3.0 Df = 0.0012	PTFE	Ceramic-filled glass fabrics	Automotive Radar Systems (77 – 79 GHz)
NP-LD5	Dk = 3.6 Df = 0.0035	Hydrocarbon	Ceramic-filled glass fabrics	Automotive Radar Systems (24 GHz)

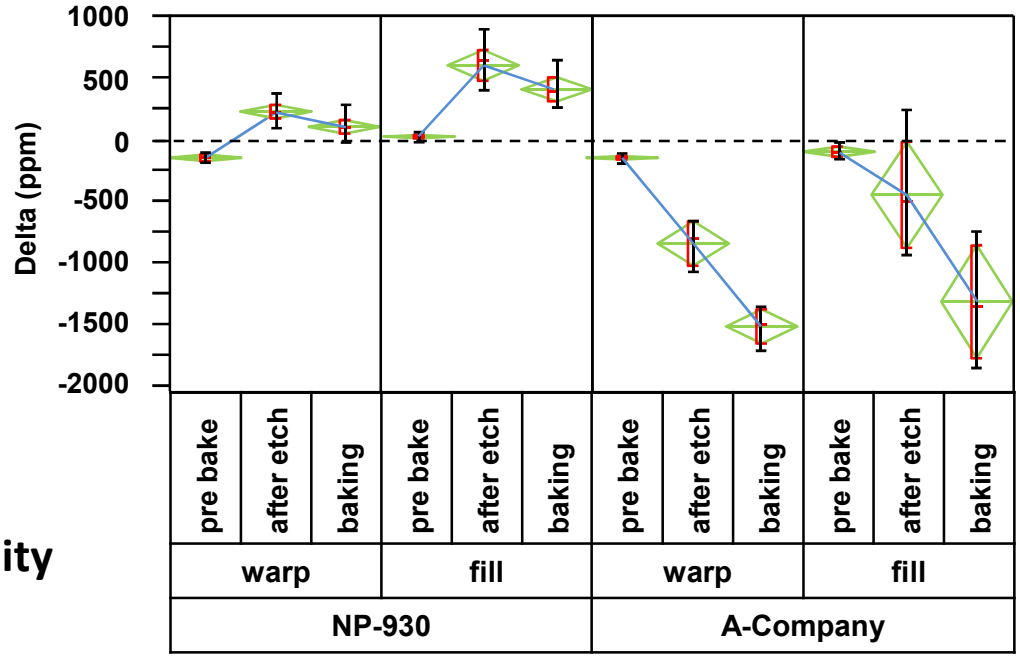
NP-930 Features and Benefits

- Dk = 3.0 @ 10GHz
- Df = 0.0012 @ 10GHz
- Tightly controlled Dk tolerance +/- 0.04
- Low water absorption
- Thermal coefficient of Dk (TCDk) is 22 ppm/K
- High peel strength
- Lower roughness of copper foil
- Excellent dimensional stability
- Competitive price

NP-930 General Properties

Test items	Unit	NP-930	A–Company
Composites		PTFE Ceramic-filled Glass fabrics	PTFE Ceramic-filled
Thickness	mm	0.13	0.13
Copper	½ oz	18 µm	18 µm
Dk	@ 10GHz	3.0	3.1
Df	@ 10GHz	0.0012	0.0011
TCDk	ppm/K	22	20
Peel strength	lb/in (N/mm)	9.0 (1,57)	8.1 (1,42)
Decomposition temp. Td	°C	538	532
Thermal resistance T288	min	> 60	> 60
Water absorption ½ hour PCT	%	0.05	0.06

NP-930 Dimensional Stability

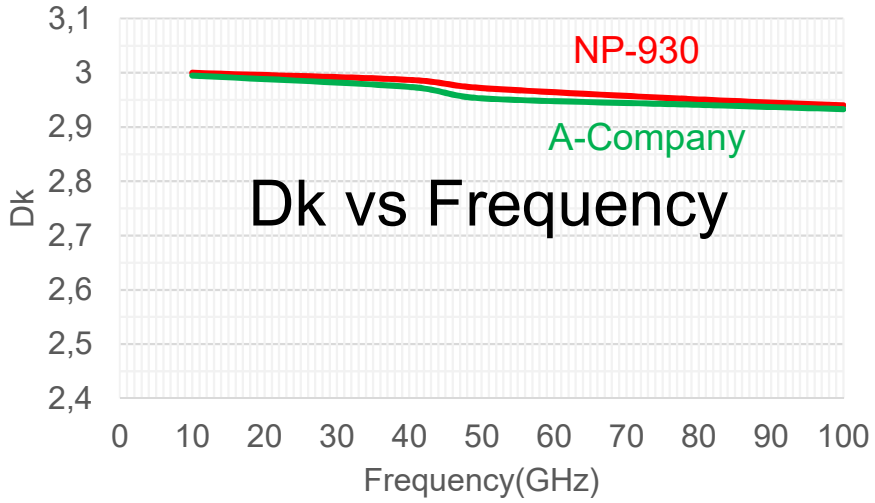


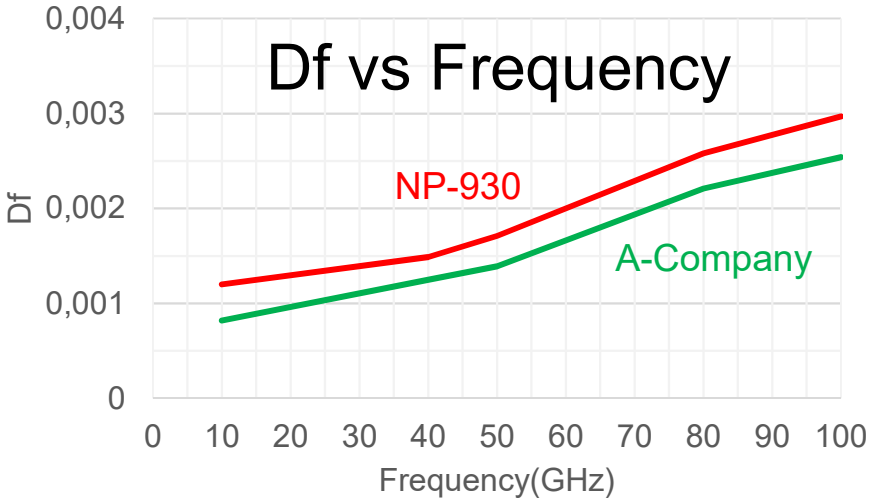
NP-930 provides greater dimensional stability

		NP-930			A–Company		
Conditions		pre bake	after etching	baked 150°C/1h	pre bake	after etching	baked 150°C/1h
warp	average (ppm)	-141	229	122	-140	-832	-1482
	σ standard deviation	23	91	89	20	169	113
fill	average (ppm)	29	607	424	-96	-437	-1290
	σ standard deviation	27	155	109	37	442	457

NP-930 Dk / Df vs Frequency

1. When the frequency increases, the Dk shows a decreasing trend and Df shows an increasing trend
2. The change of Dk, Df of NP-930 is extremely small and stable





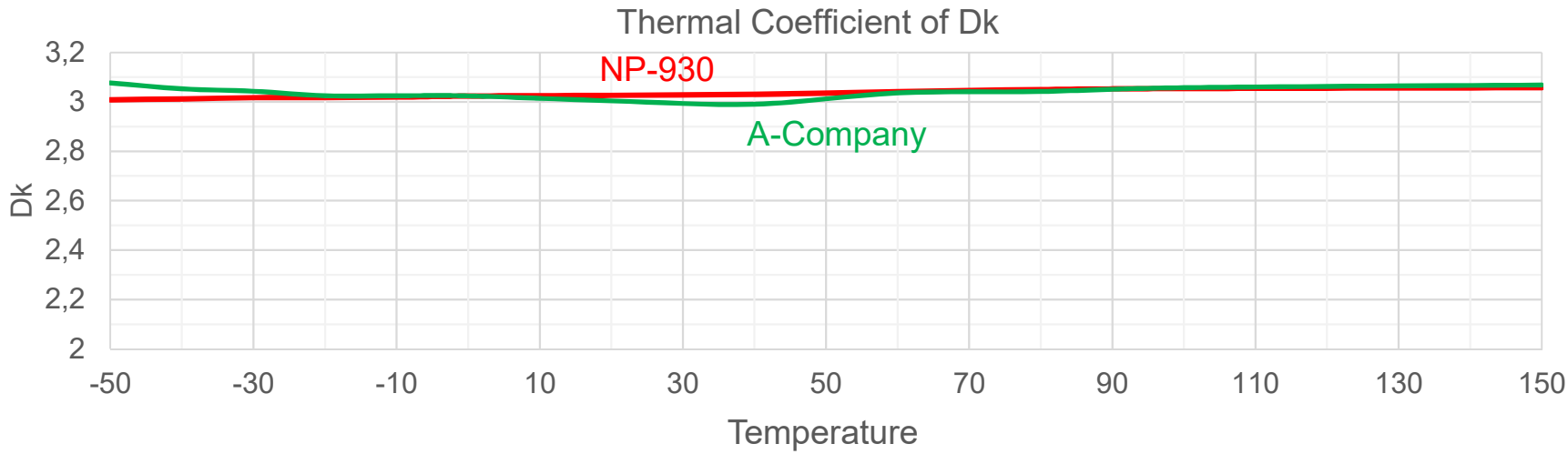
	Dk			
GHz	10	50	80	100
NP-930	3.00	2.97	2.95	2.94
A-Company	2.99	2.95	2.94	2.93

Df			
10	50	80	100
0.0012	0.0017	0.0026	0.0030
0.0008	0.0014	0.0022	0.0025

NP-930 Thermal Coefficient of Dk

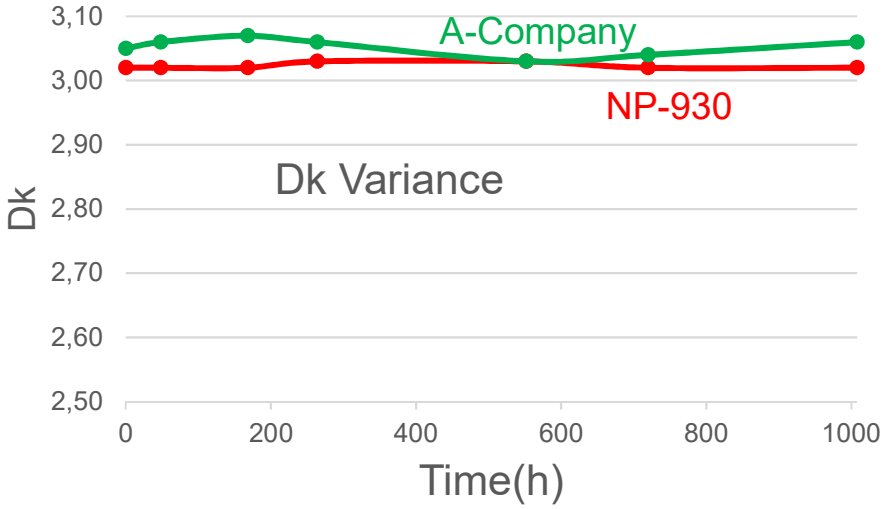
1. Thermal coefficient of Dk (TCDK) is the change rate of Dk under severe temperature and it's an important parameter of the millimeter-wave materials
2. Typically TCDK< 50 ppm/˚C is good
3. NP-930 TCDK is 22 ppm/˚C

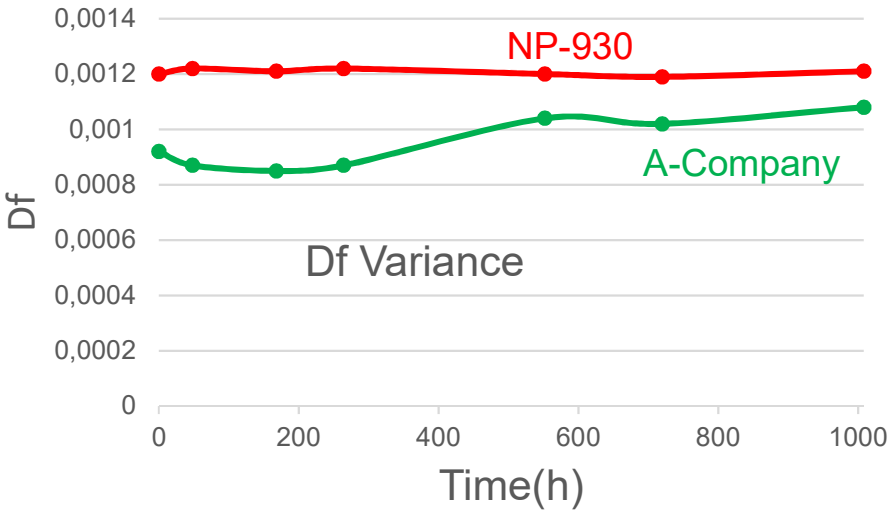
Thermal Coefficient of Dk	NP-930	A-Company
-50°C / +150°C	22 ppm/K	20 ppm/K



NP-930 Long Term Aging

NP-930 performs very stable regarding Dk and Df. They did not change at 150˚C within 1000 hours testing.
Conclusion: the material keeps consistent electrical properties under severe thermal environmental conditions.



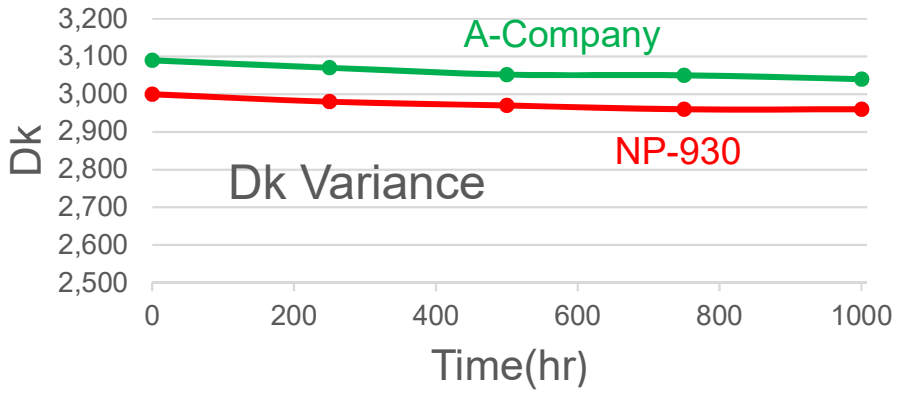


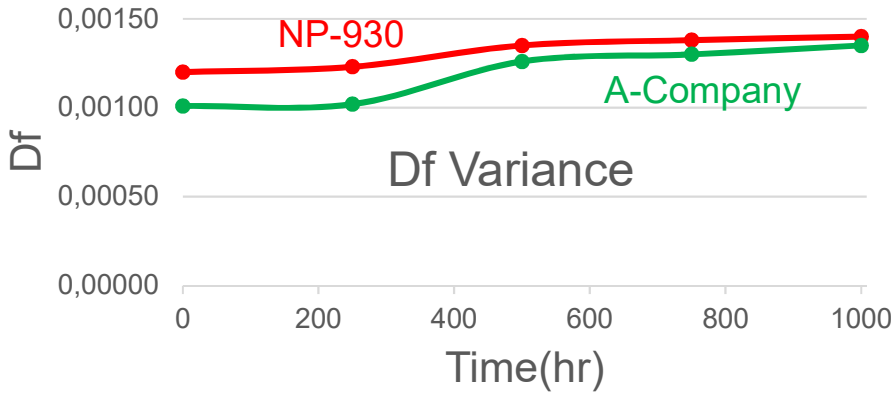
	Dk @ 10Ghz			
Time (h)	Start	264	552	1008
NP-930	3.02	3.03	3.03	3.02
A-Company	3.05	3.06	3.03	3.06

Df @ 10 GHz			
Start	264	552	1008
0.0012	0.0012	0.0012	0.0012
0.0009	0.0009	0.0010	0.0011

NP-930
High Temperature / High Humidity

NP-930 performs very stable Dk and Df. It has very little change in 85 ˚C and 85 %RH environment for 1000 hours testing.
Conclusion: the material keeps consistent electrical properties under severe climate conditions.

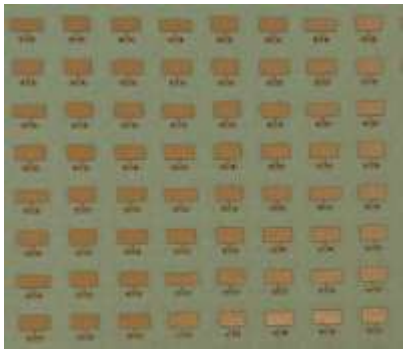


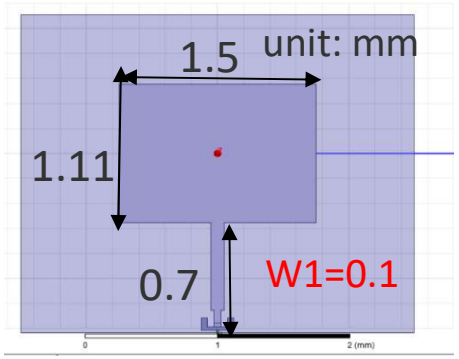


	Dk @ 10Ghz				
Time (h)	Start	250	500	750	1000
NP-930	3.00	2.98	2.97	2.96	2.96
A-Company	3.09	3.07	3.05	3.05	3.04

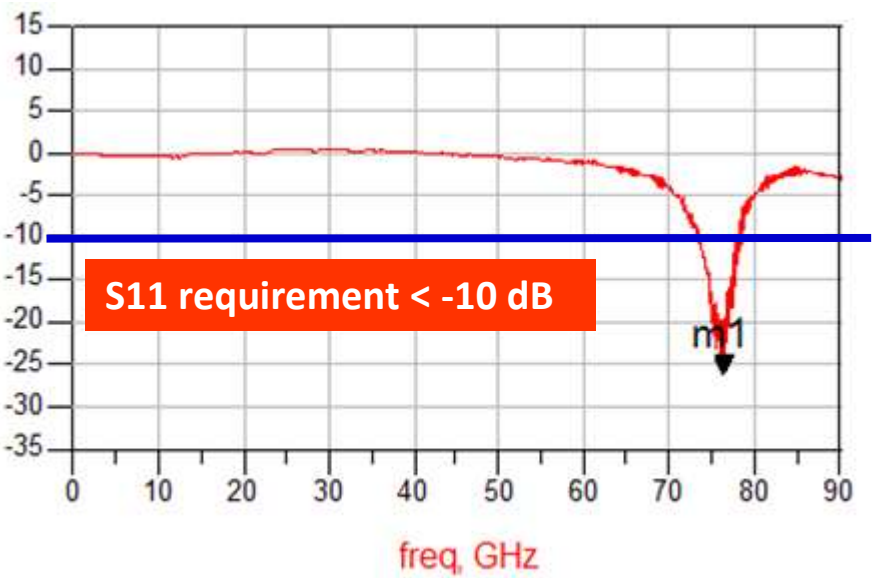
Df @ 10 GHz				
Start	250	500	750	1000
0.0012	0.0012	0.0013	0.0014	0.0014
0.0010	0.0010	0.0013	0.0013	0.0014

NP-930
Radiation Pattern Measurement





The transmitting frequency of NP-930 is measured @ 76.89 GHz with the return loss S11 -27 dB by VNA



NP-930 S11 return loss is -27dB @ 76.89GHz

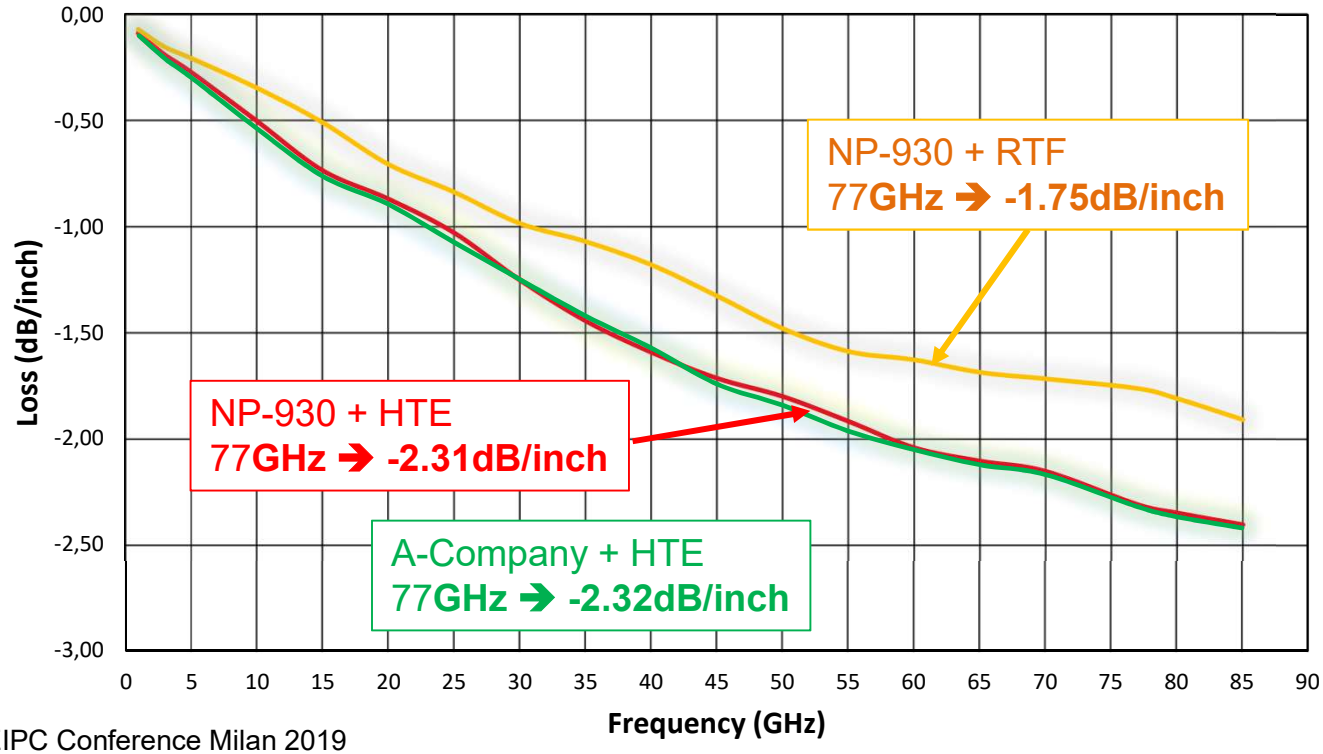
110 GHz VNA

NP-930 Insertion Loss Test

Insertion Loss Measurement

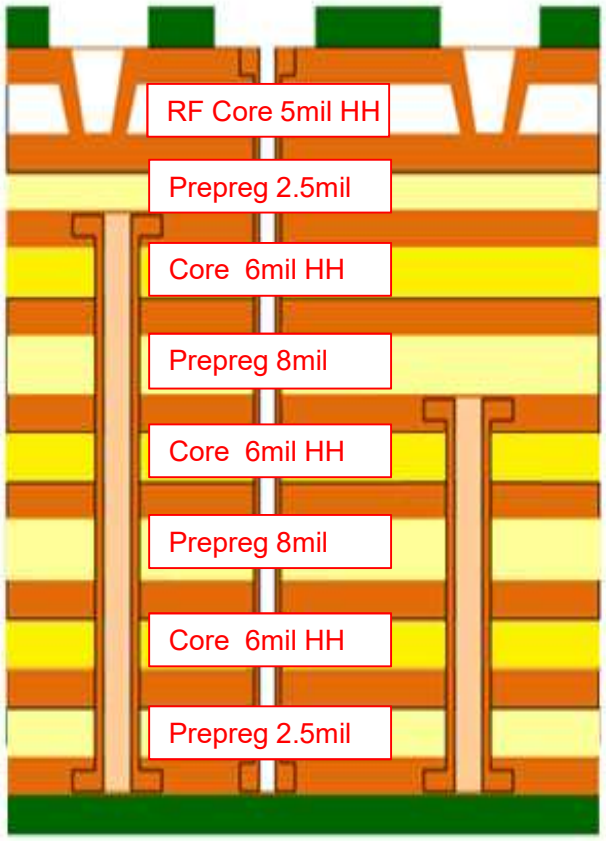
- Insertion of Structure A: IL (A) - 6 inches + Vias
- Insertion of Structure B: IL (B) - 2 inches + Vias
- dB/inch loss = (IL(A) – IL(B)) / (A-B)

NP-930 with RTF copper has better electrical performance



Automotive Radar Hybrid Structure

Automotive radars are designed by Hybrid Structures, which is a mixture of millimeter-wave materials and High-Tg FR4 materials



77 GHz car radar

NP-175FBH	
Resin	PN cured high Tg
Tg (DSC)	170 °C
T288 (TMA)	> 20 min
Td (TGA)	351 °C
Peel strength	8 lb/inch (1,4 N/mm)
CTEz prior Tg	30 – 40 ppm/K
CTEz about Tg	210 – 230 ppm/K

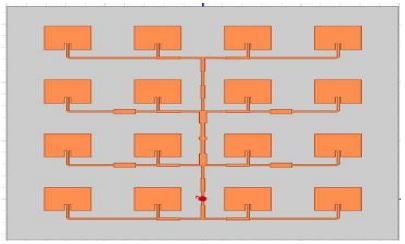
NP-LD5 Features and Benefits

- High-Tg = 220 ˚C
- Dk = 3.6 @ 10 GHz
- Df = 0.0035 @ 10 GHz
- Manufactured by standard FR4 process
- Enhanced Young´s Modulus, reduced assembly warpage
- Low CTEz / reliable plated through holes
- Excellent dimensional stability
- Competitive price

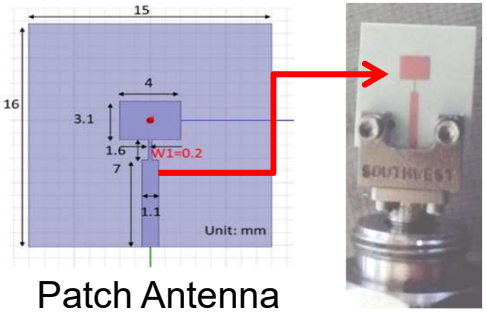
NP-LD5 General Properties

Test items	Unit	NP-LD5	A–Company
Thickness	mm	0.25	0.25
Copper	½ oz	18 µm	18 µm
Dk	@ 10 GHz	3.62	3.63
Df	@ 10 GHz	0.0035	0.0035
Peel strength	lb/inch (N/mm)	5.12 ( )	4.51
CTEz 50 – 260°C	%	130	135
Thermal resistance T288 (TMA)	min	>60	>60
Thermal Conductivity	W/mK	0.65	0.63
Water absorption ½ hour PTC	%	0.115	0.112

NP-LD5
Radiation Pattern Measurement

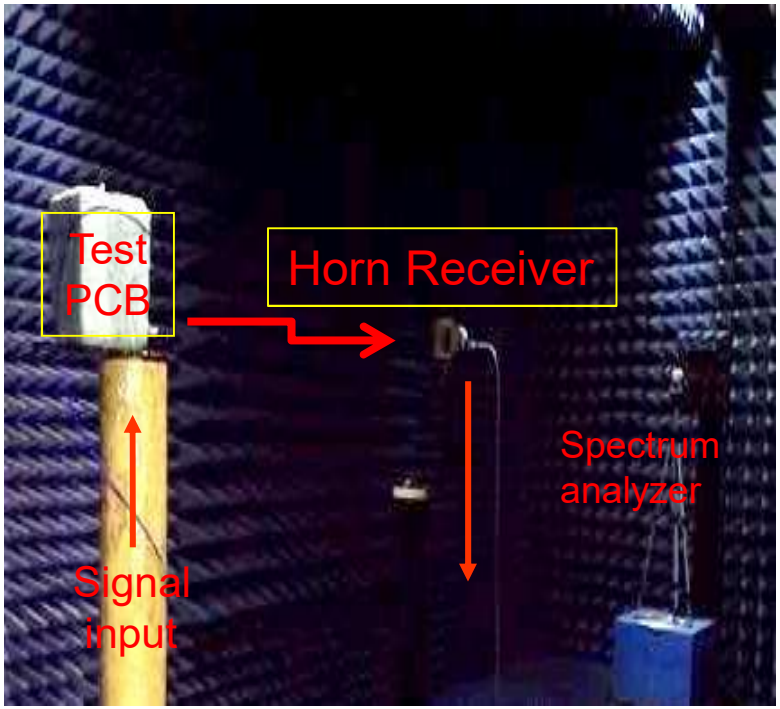


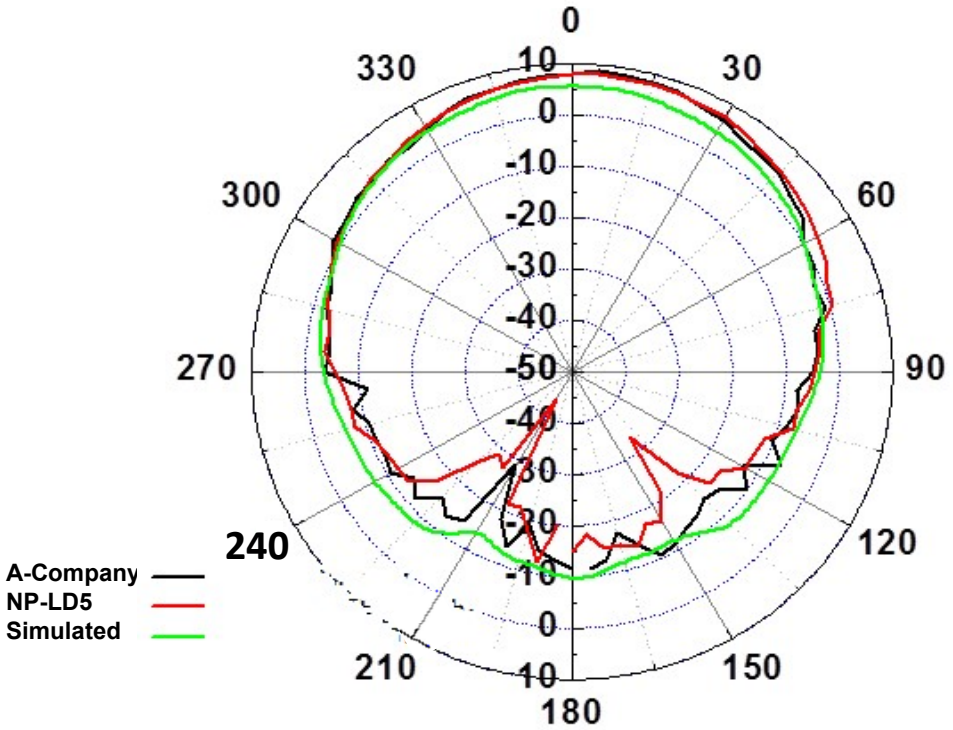
Phase Array



Patch Antenna

Max Gain:
NP-LD5 = 6.17 dBi
A-Company = 6.25 dBi





Product List for Automotive Application

Product	NPG-151	NP-155F	NP-155FBH	NP-175FBH
Properties	Halogen free Mid Tg	Phenolic Mid Tg	Phenolic Mid Tg Low CTE	Phenolic High Tg
Tg (DSC)	150 °C	150 °C	150 °C	170 °C
Td (TGA)	360 °C	350 °C	350 °C	351 °C
Filler	Yes	Yes	Yes	Yes
Peel strength @ 1oz	9 lb/inch 1,57 N/mm	8,00 lb/inch 1,40 N/mm	9 lb/inch 1,57 N/mm	6,69 lb/inch 1,17 N/mm
Flammability (UL94)	V-0	V-0	V-0	V-0
CTEz prior Tg	30 – 40 ppm/K	40 – 60 ppm/K	35 - 45 ppm/K	30 – 60 ppm/K
CTEz above Tg	200 – 230 ppm/K	230 - 270 ppm/K	200 - 240 ppm/K	210 – 230 ppm/K
Z – Axis 50 – 260 °C	2.8 %	3.3 %	2.8 %	3.0 %
T288 (TMA)	>20 min	>20 min	>20 min	>20 min
Anti CAF	Yes	Yes	Yes	Yes

Sample: 1.6mm 1oz CCL

Summary

- NP-930 is ideal for 77 GHz automotive radar and NP-LD5 is ideal for 24 GHz automotive radar
- NP-930 has excellent Dk consistency with tight Dk tolerance, such Dk consistency can keep more stability on the transmitting frequency of automotive
- NP-930 has very low dissipation factor which contributes to the low signal loss characteristics
- By using glass fabric as reinforcement, therefore the warpage and dimensional stability of NP-930 are more stabilized and diminished which can increase production yield and benefit for mass production

Many Thanks for your Attention

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