Advanced PCB Material Development for 5G and mm Wave Applications

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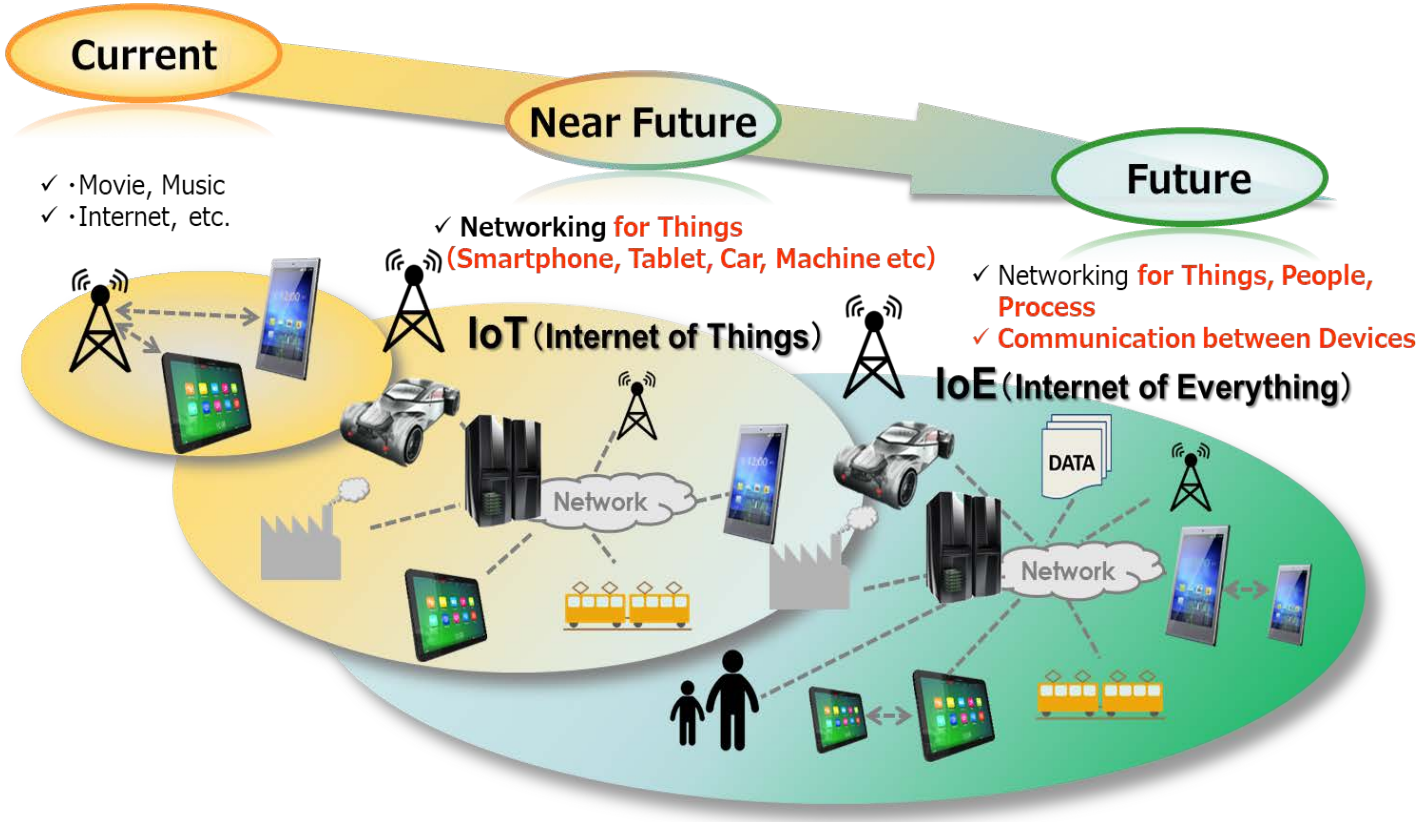
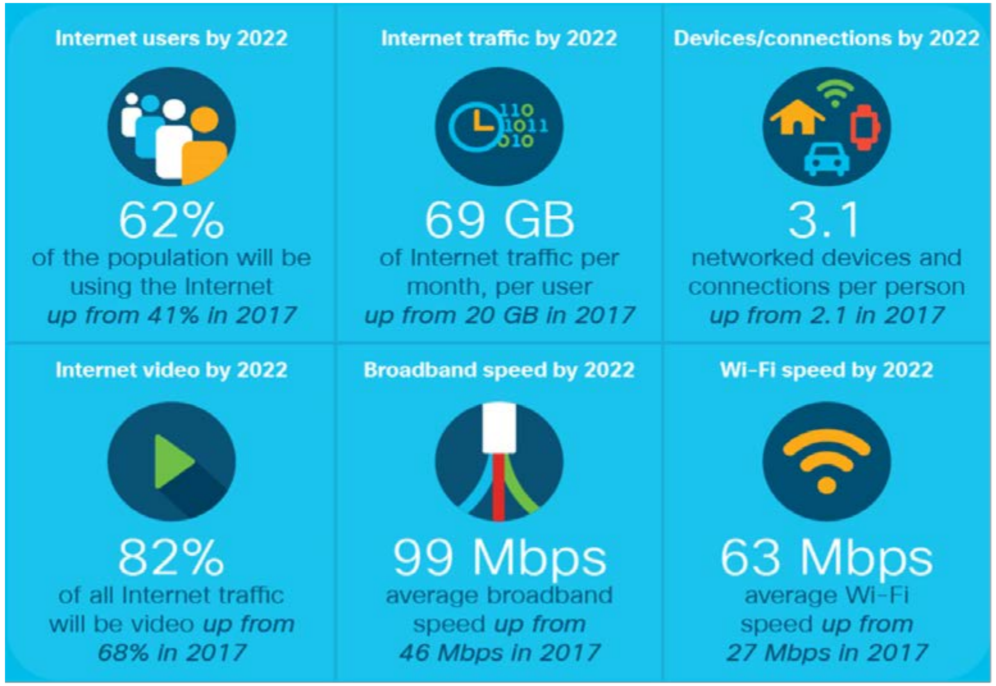
Trends for High Speed Applications

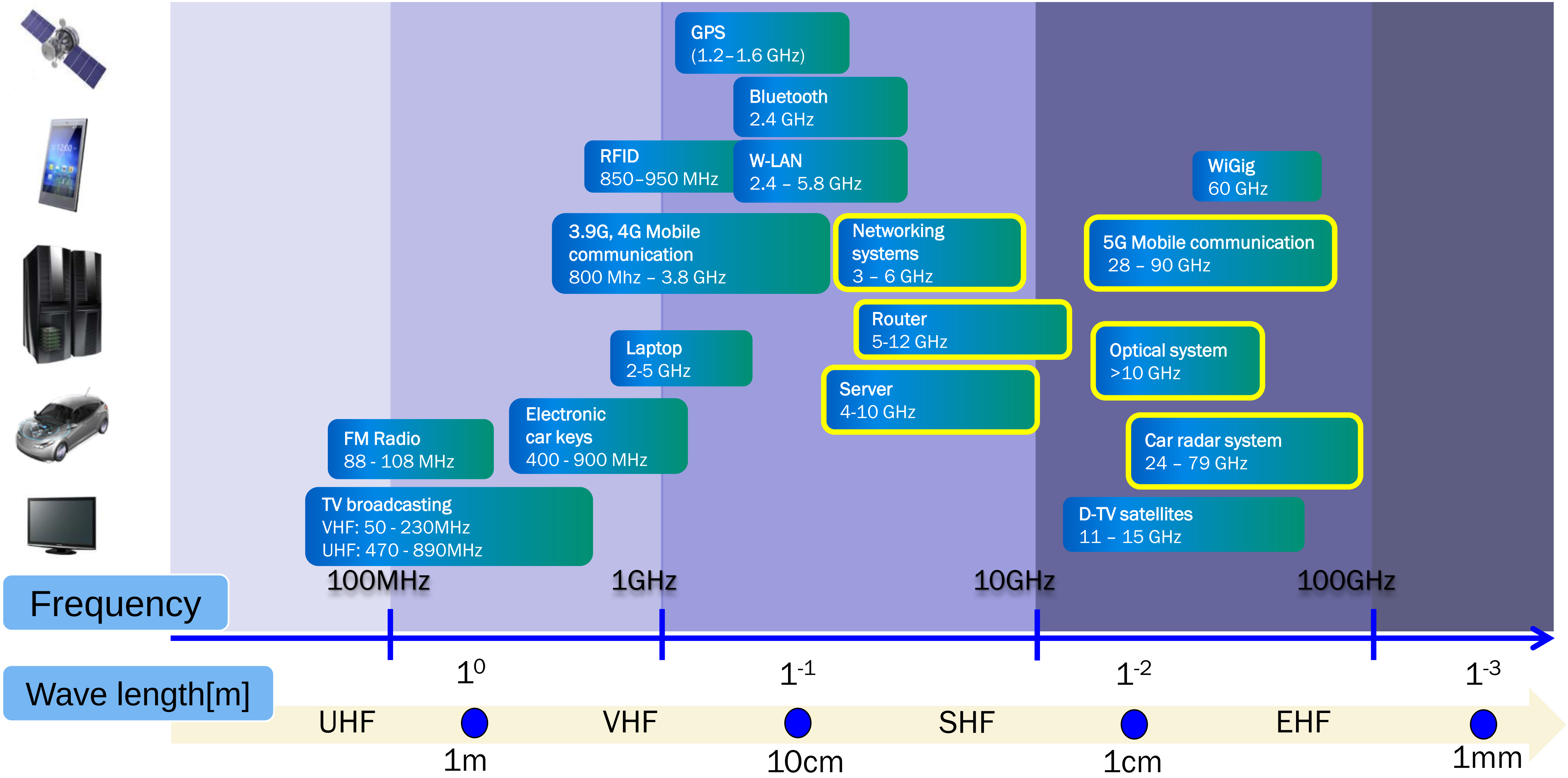
Internet environment will dramatically increase by 2022
(ie: number of devices and amount of traffic).



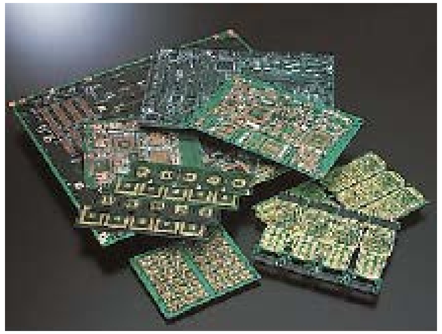


(Cisco Systems, Cisco Visual Networking Index (2018))

Trends for High Speed / High Frequency Applications



Technology Trends for PCB



ICT Infrastructure

TECHNOLOGY TRENDS

- ✓ High signal speed

- ✓ High density
- ✓ High layer count

- ✓ Environmentally friendly

Wireless

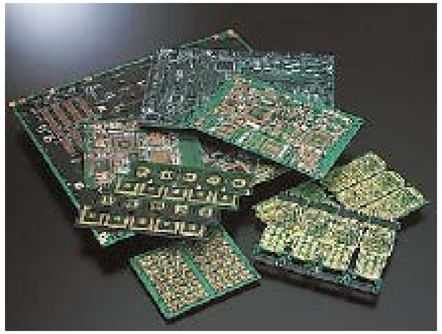
TECHNOLOGY TRENDS

- ✓ High Frequency

- ✓ Stability under high temperature

- ✓ Environmentally friendly

Technology Trends for PCB / FPC



Mobile

Cell Phone

TECHNOLOGY TRENDS

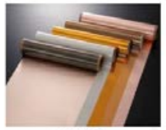
- ✓ High Signal Speed
- ✓ High Frequency (5G)

- ✓ High density
- ✓ Thinner PCB

- ✓ Environmentally friendly

Flexible Printed Circuit

Antenna FPC



FCCL

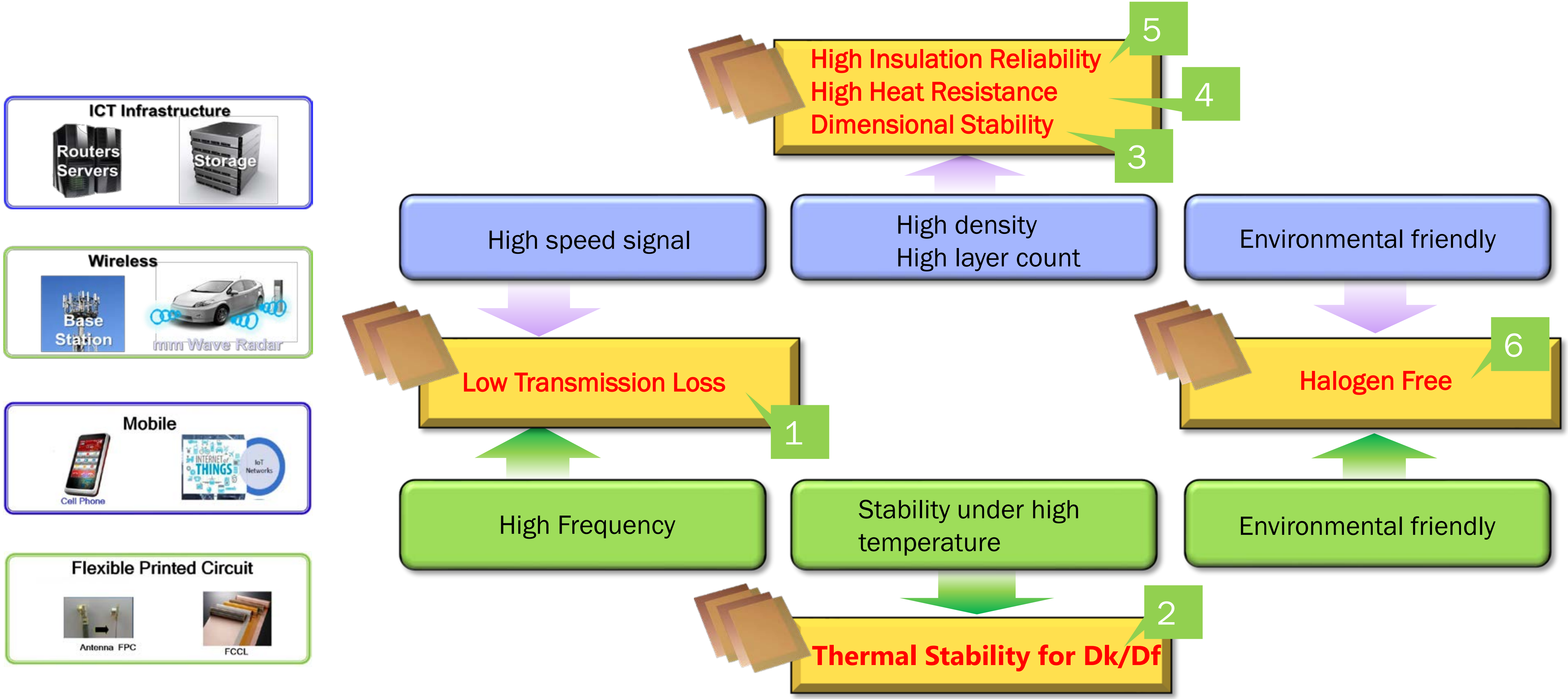
TECHNOLOGY TRENDS

- ✓ High Frequency

- ✓ Low Dk/Df – stable with temperature & humidity.

- ✓ Environmentally friendly

Trends for High Speed Applications



Requirements for Dk / Df of PCB / FPC Materials

Formula for transmission loss（by Edward A Wolff)

Transmission Loss (α_t) = Conductor Loss (α_c) + Dielectric Loss (α_d)

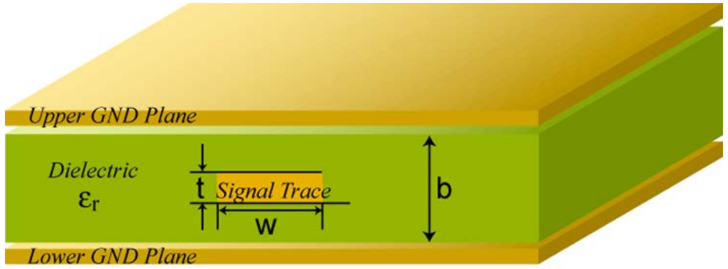
$$\alpha_c = \sqrt{\varepsilon r} * R(f)$$

$$\alpha_d = 27.3 * \sqrt{\varepsilon r} * \lambda o \quad * \tan\delta$$

R(f) : surface resistance
λo : wavelength

Conductor (Copper Foil)

Resin + Glass Cloth

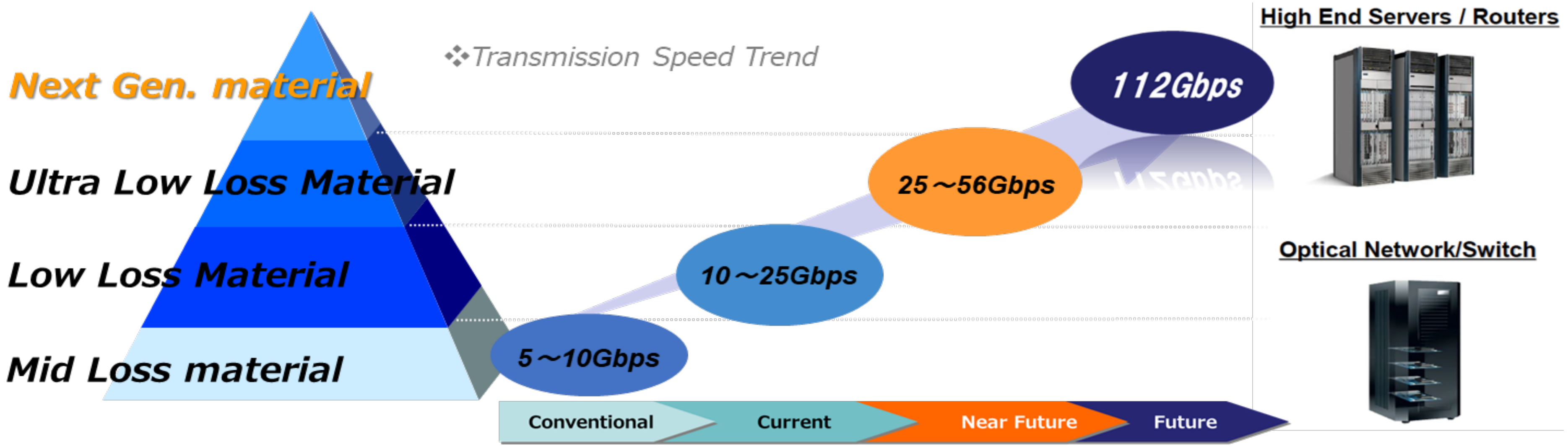


Reduction of αd : Lower Dk / Df Dielectric materials
Reduction of αc : Lower profile or Profile-free conductor

Signal transmission loss is sum of Conductor and Dielectric loss.
Dk and Df are both impacting on transmission loss.

High Speed Laminate Technical Trend

Next Generation High Speed Material

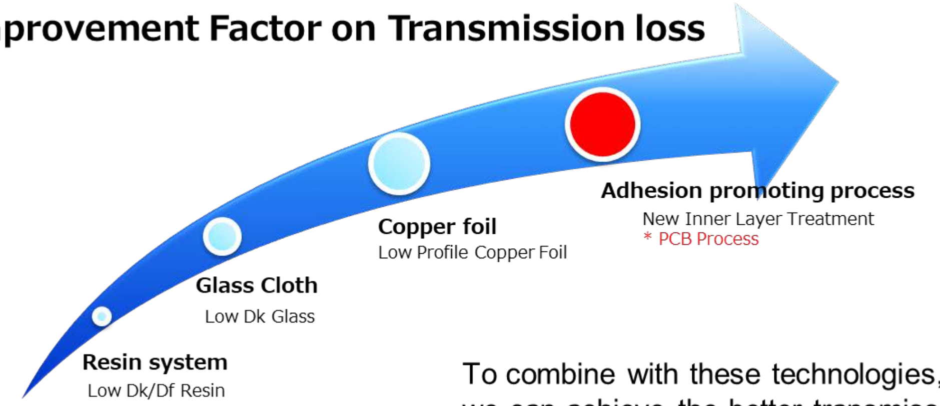


Future High Speed Material

Ultra low loss material for ICT equipment

- ✓ Lower transmission loss
- ✓ Suitable for higher layer count
- ✓ Good processability
- ✓ Lead free reflow applicable

Improvement Factor on Transmission loss



To combine with these technologies,
we can achieve the better transmission loss

High Speed Laminate Technical Trend

Glass Cloth: Electrical Properties (Dk / Df)

Dk/Df comparison data of glass itself

		E-glass	Low Dk glass
Dk	2GHz	6.62	5.02
	10GHz	6.43	4.70
Df	2GHz	0.0062	0.0038
	10GHz	0.0127	0.0078

By Cavity resonance method at Panasonic R&D

The other properties (by glass suppliers)

		E-glass	Low Dk glass
Density	g/cm3	2.63	2.30
CTE	ppm/℃	5.4	3.8
Elastic Modulus	GPa	77.2	62.1
Volume resistivity	Ω･cm	1E+15	1E+15
Surface resistivity	Ω	1E+14	1E+14

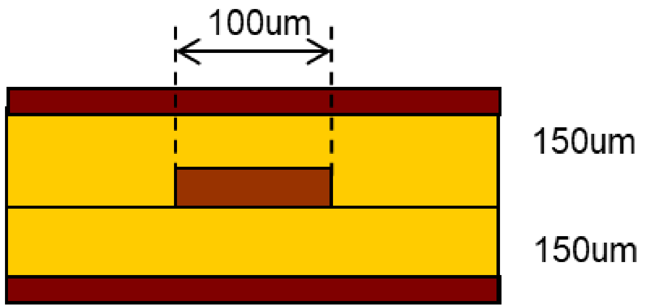
Reference from data sheet of Glass Cloth Suppliers

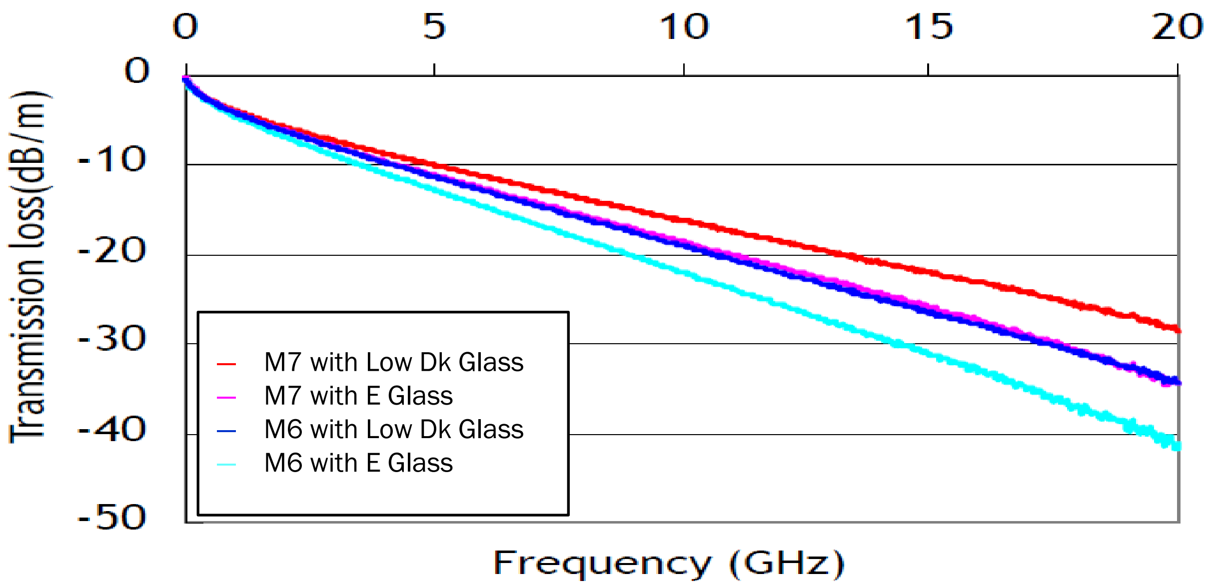
High Speed Laminate Technical Trend

Glass Cloth: Transmission Loss Property

Ex) M7 + H-VLP foil

Line length : 1000mm
Impedance : 50Ω
Copper thickness : 35um
Copper type : H-VLP
Inner Cu treatment : no-surface treatment
Core type : #1078(RC64~67%)*2ply
PP type : #1078*2ply

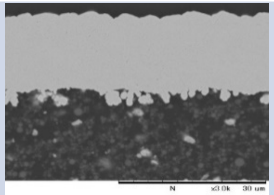
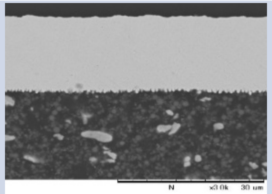
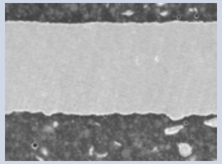


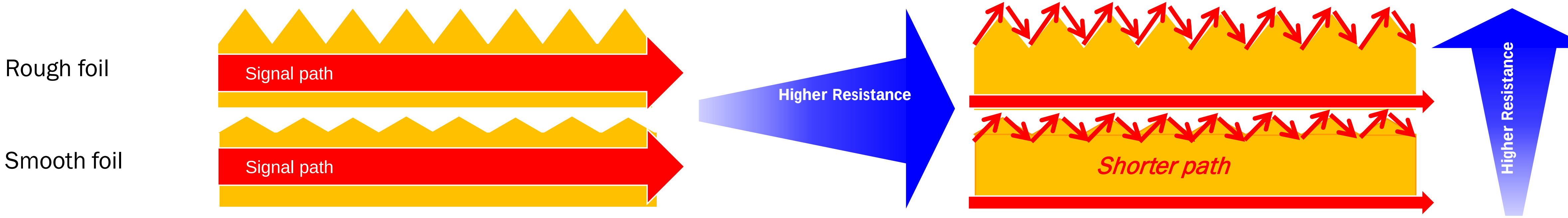


Low Dk glass offer better electrical performance for high speed PCBs due to lower Dk/Df.

Trends for High Speed Applications

Copper Foil: Copper Foil Roughness

Type	RTF	H-VLP	H-VLP2
X-section			
Rz (um) (JIS B 0601-2001)	2.5	1.3	1.8



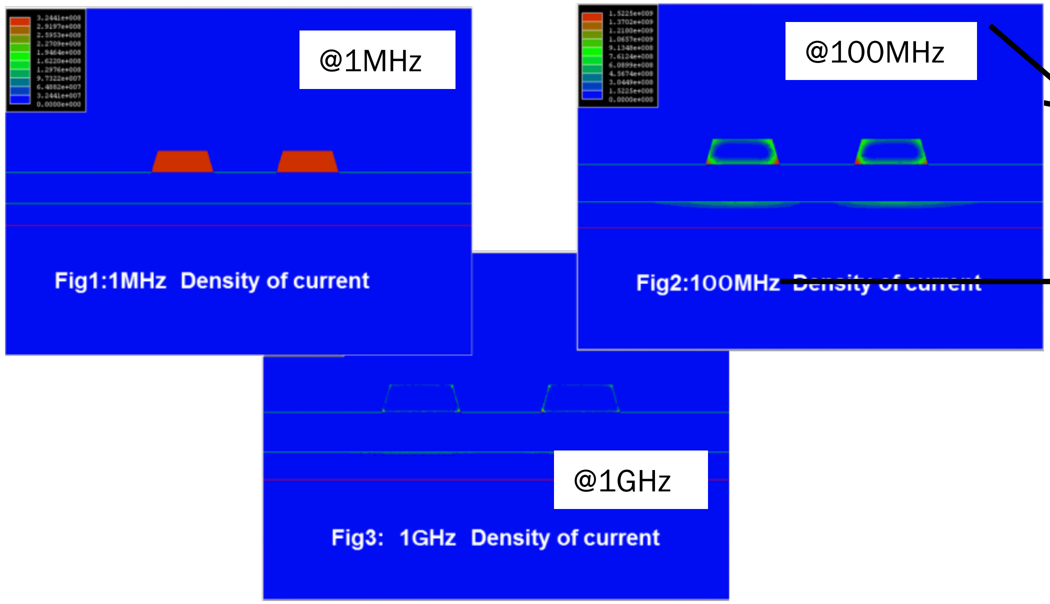
Copper profile is one of the main contributors for transmission loss for high frequency signals.

Trends for High Speed Applications

Copper Foil: Copper Foil Roughness / Skin Effect

$$d = \sqrt{2\rho / \omega\mu}$$

d : Skin effect depth
ρ : Electrical Resistivity
ω : Frequency
μ : Magnetic Transmission



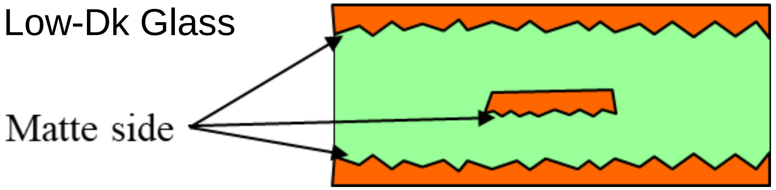
Frequency	Skin effect depth
10 kHz	660 μm
100 kHz	210 μm
1 MHz	65 μm
10 MHz	21 μm
100 MHz	6.6 μm
1 GHz	2.1 μm
10 GHz	0.7 μm

Higher the frequency – more significant impact of skin effect to transmission loss.

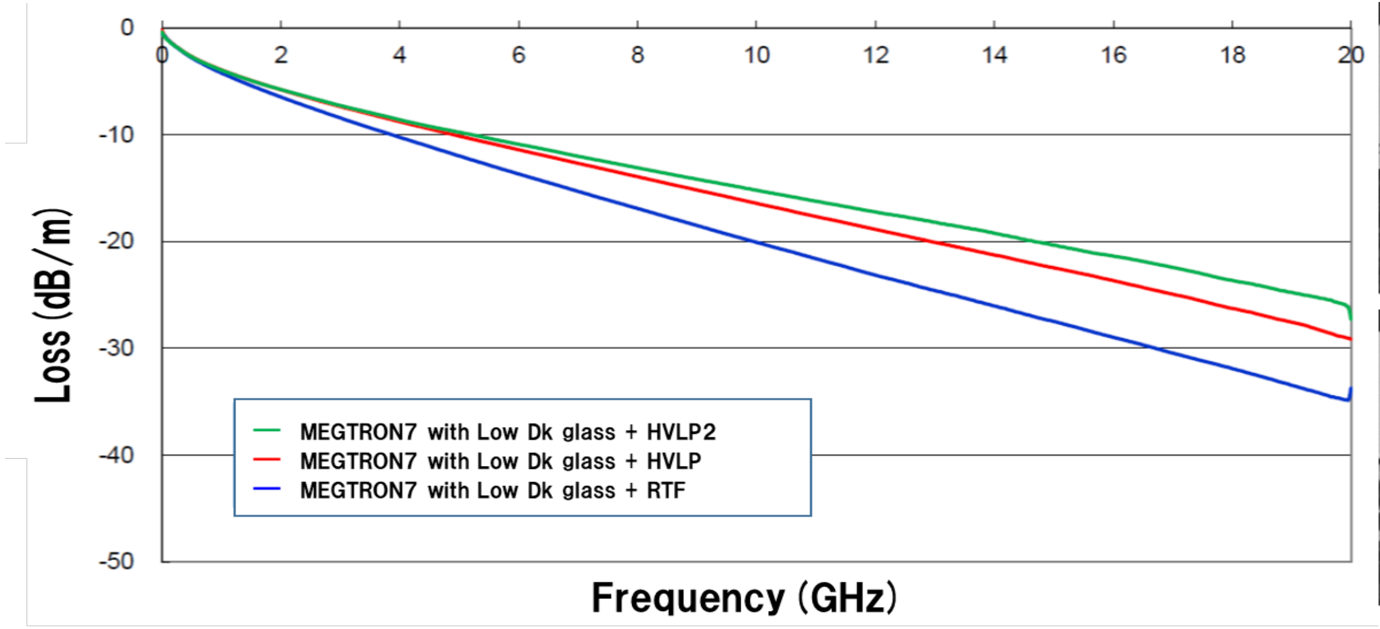
Trends for High Speed Applications

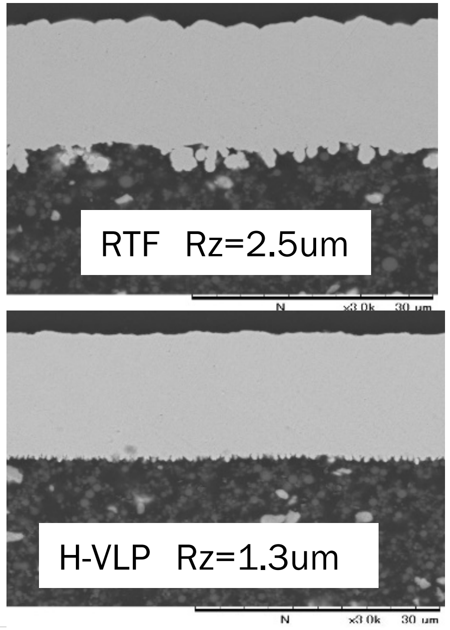
Copper Foil: Transmission Loss vs Copper Foil Type

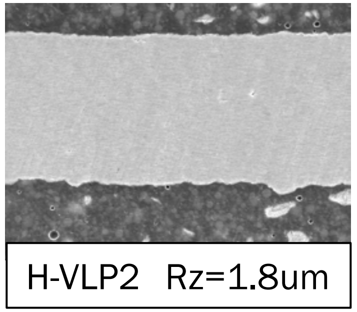
Ex) M7 + Low-Dk Glass



Line length : 1000mm	Inner Cu treatment : no-surface treatment
Impedance : 50Ω	Core type : #1078(RC67%)*2ply
Copper thickness : 18um	PP type : #1078*2ply





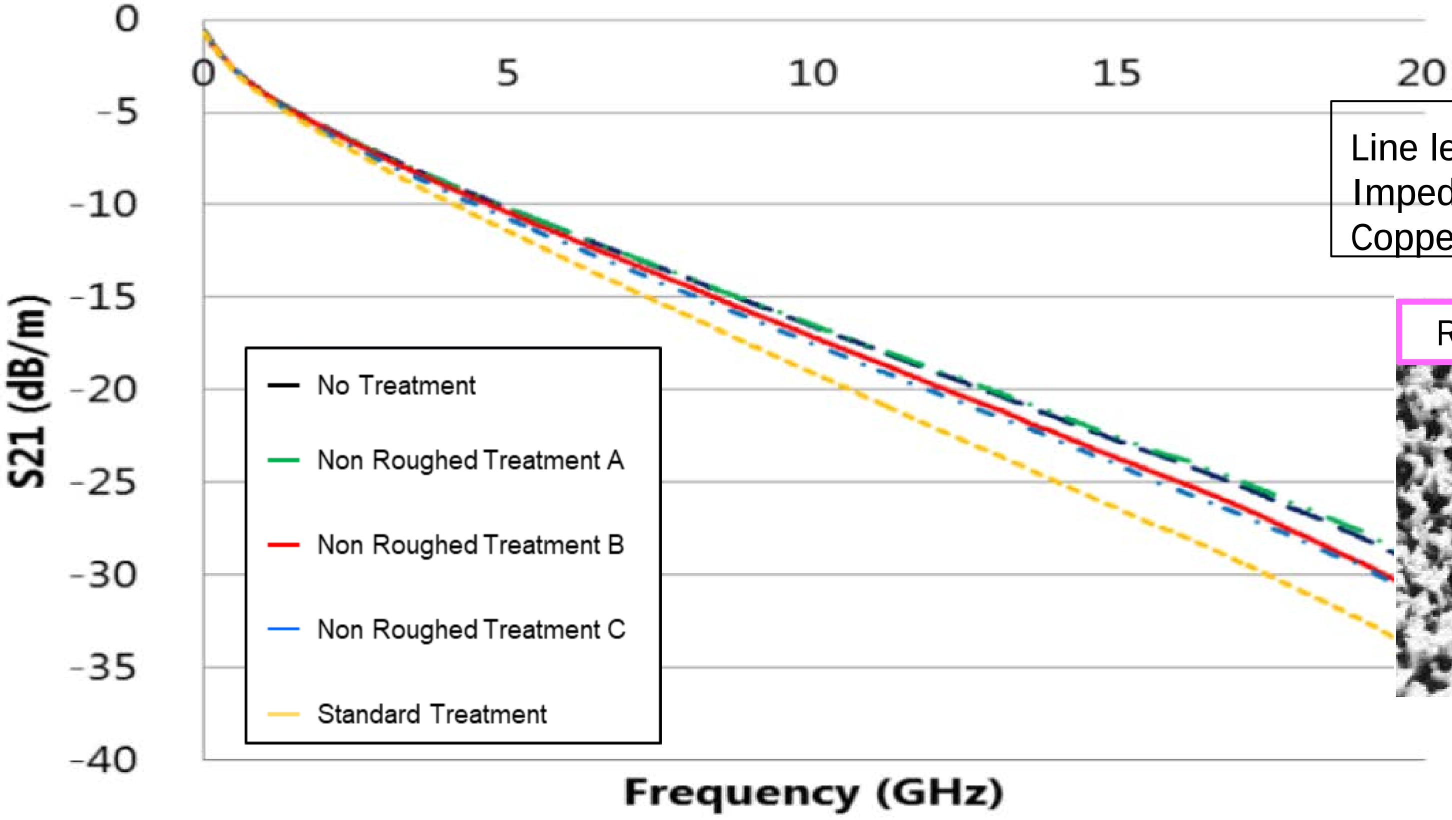


SEM x10000

SI performance is influenced by both copper foil roughness and shape of nodule.

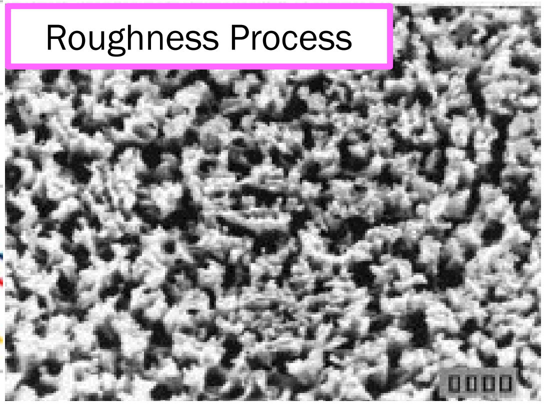
Trends for High Speed Applications

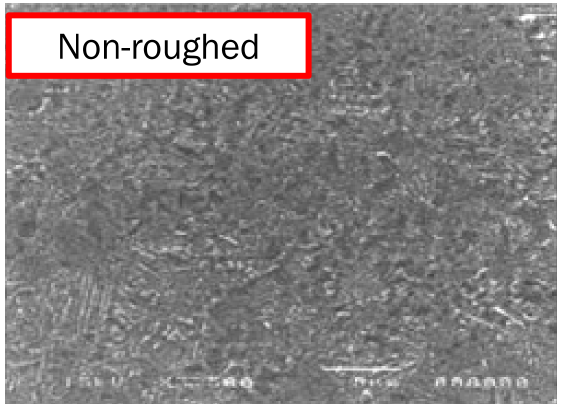
Copper Foil: Net Technology on Inner Layer Treatment



Line length：1000mm
Impedance：50Ω
Copper thickness：HVLP35um

Material：M7(N)
Core type：#1078(RC64～67%)*2ply
PP type：#1078*2ply



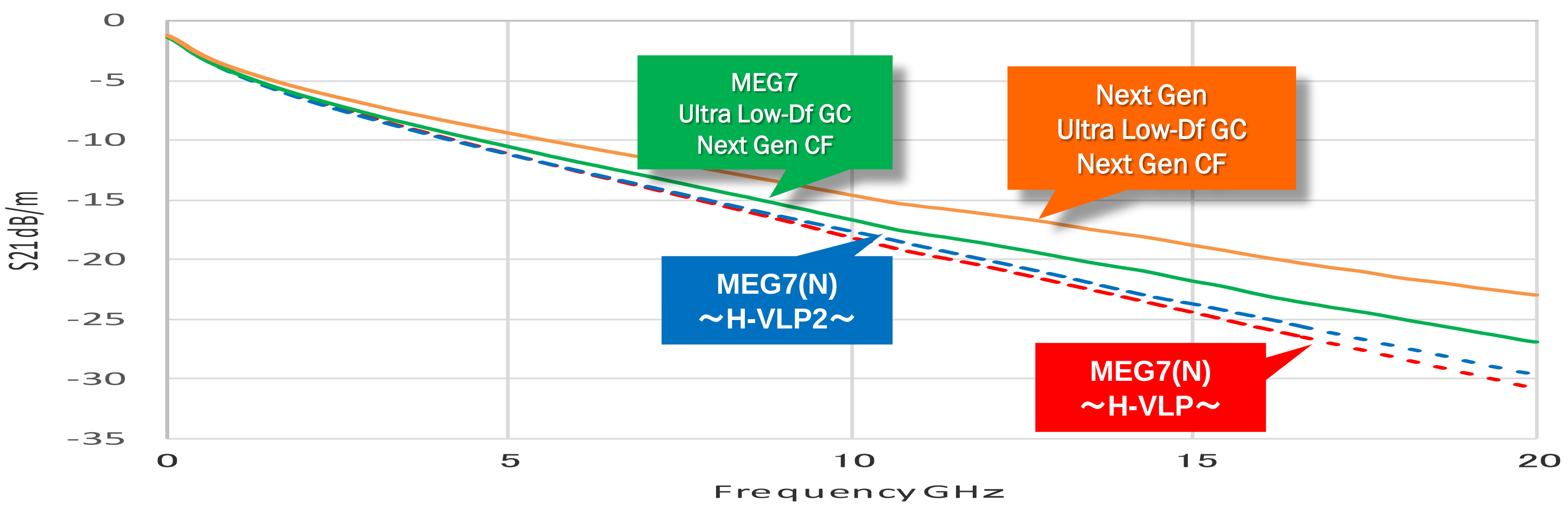


SI performance for new inner layer treatment is getting closer to no treatment.

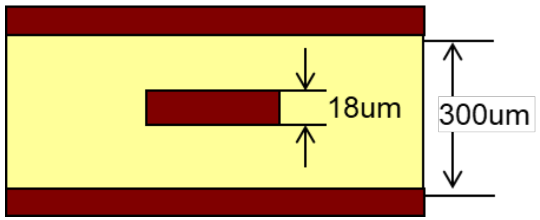
Trends for High Speed Applications

Next Generation Infrastructure Material

Resin	M7			Next Gen target
Glass Cloth	Low-Dk	Low-Dk	Ultra Low-Df	Ultra Low-Df
Copper Foil	H-VLP	H-VLP2	Next Gen CF	Next Gen CF
Dk@12GHz	3.4	3.4	3.3	3.2
Df@12GHz	0.002	0.002	0.0018	0.0015
Resin Contents(%)	2116 55%			



◆ **PCB Design**



Line length	1000 mm
Impedance	50Ω(±2)
Copper thickness	18 um
Inner Cu treatment	No-surface treatment

Trends for High Speed / High Frequency Applications

Mobile Materials – Trends

- Lower Dk / Lower Df
- Thinner material
- Low X/Y CTE
- Smooth Copper – good adhesion

Trends for High Speed / High Frequency Applications

FPC Materials for various applications

	Mobile	Network	Automotive Medical Avionics
FCCL (Polyimide)	Main board , Module (Camera, RF)		Gear BOX ECU
Thick PI	Impedance Control		Antenna Medical
Thick Cu	WPC		EV
Thin Cu	LCD module		Medical Equipment
FCCL (LCP)	Antenna module High speed cable (USB3.1 TypeC (Gen Ⅱ))	High speed cable Optical transceiver 5G Antenna	mm Wave Radar
FRCC	Camera Module		Medical Equipment

Trends for High Speed / High Frequency Applications

FPC Materials – Next Generation Requirements

- Lower loss dielectric material
- Smooth Copper foil – good adhesion
- Improved flexibility
- Low moisture absorption
- Substrate-Like

Trends for 5G / mmWave

Conclusion:

- Lower Dk / Df
- Smooth Copper
  - *Raw Foil*
  - *Innerlayer Adhesion Promotors*
- Dimensional Stability
- Low CTE
- High Tg
- Thermal Performance / Stability
- Moisture Absorption