Asian IBIS Summit (Tokyo)

Board Design for Low Loss

November 13, 2020

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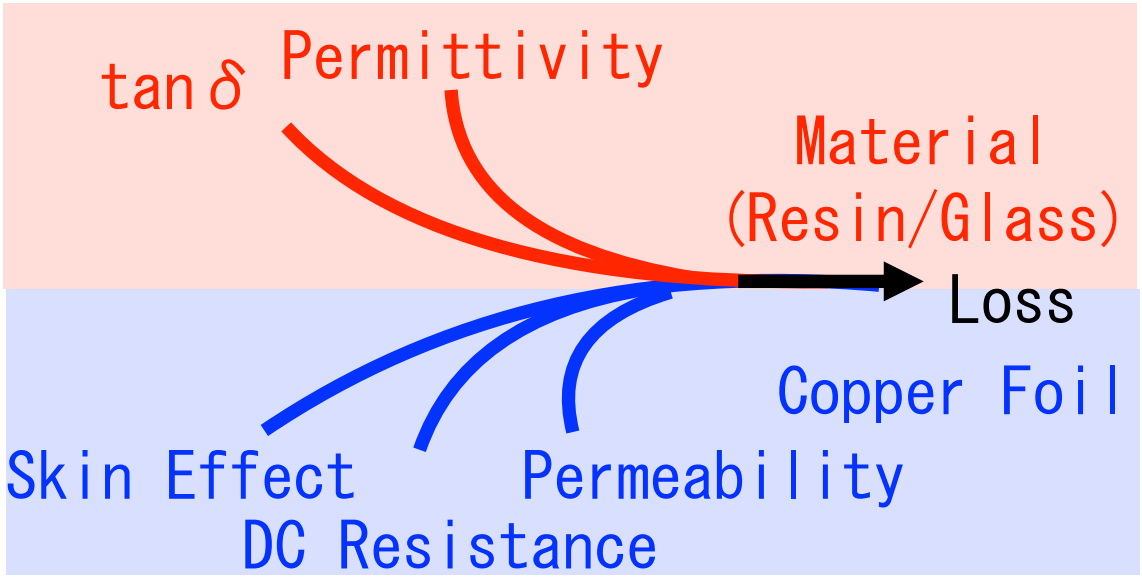
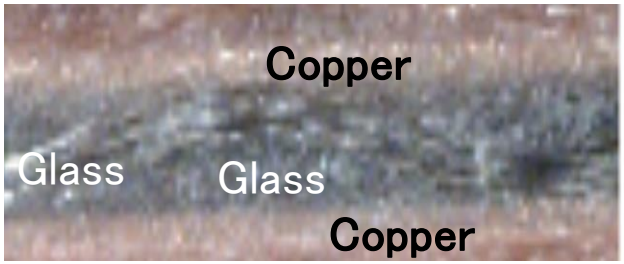
What is the loss

Dielectric Loss & Resistance Loss

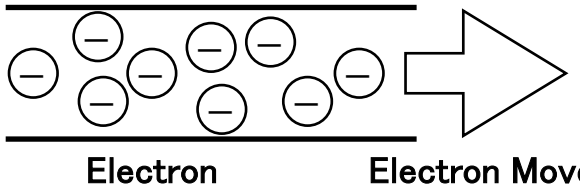


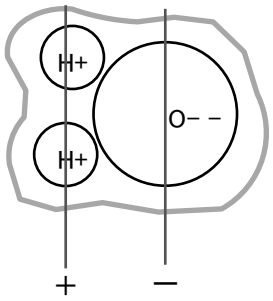


- Loss: Frequency and Etch Length
  - Dielectric Loss
    - Permittivity (ε) & Loss tangent (tan δ)
      - $D = K \cdot f \cdot \tan\delta \cdot \sqrt{\varepsilon}$
  - Resistance Loss
    - Skin Effect (Skin Depth : d)
      - $d = \sqrt{\rho / \pi f \mu}$

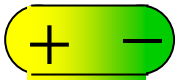
Dielectric Loss

- Conductor : Free Electron
- Dielectric : Electric Dipole

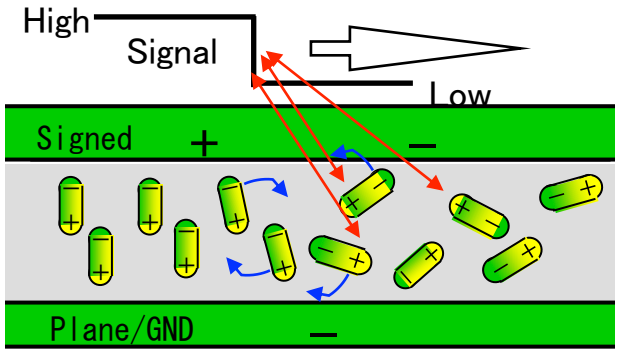




Water Molecule

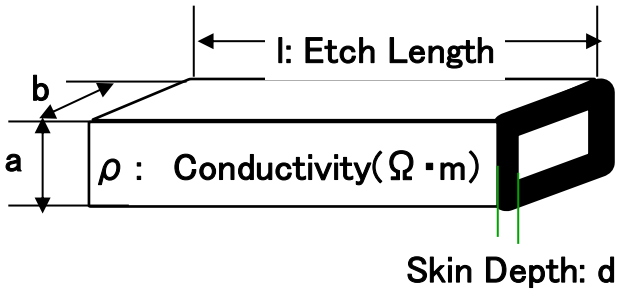


- When the potential between two layers change, the electric dipole spin by electric field changing
  - Permittivity : Energy loss by repulsive force between signal and dipole
  - tangent loss : Energy loss by spin dipole



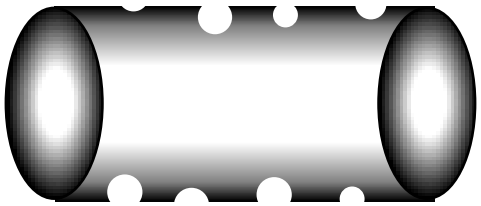
Resistance Loss

- Conductor (Copper) has small resistance
  - Resistance : $R = l \times \rho / S$
    (S: Cross-section area (a x b)

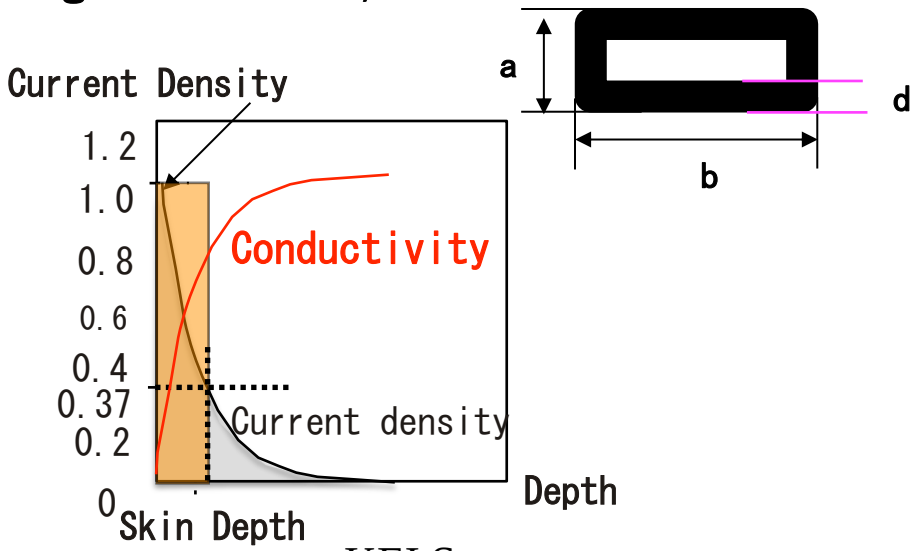


- Skin Effect
  - When the current changes quickly, magnetic field is generated inside of conductor. This magnetic field generate current inside the conductor. Density of signal current becomes high of skincare, low of inside.
- Skin Depth : $d = \sqrt{\rho / \pi f \mu}$
- Effective cross-section area: S1

  S1 = a x b – (a-2d) x (b-2d)



Surface Roughness



Loss Simulation

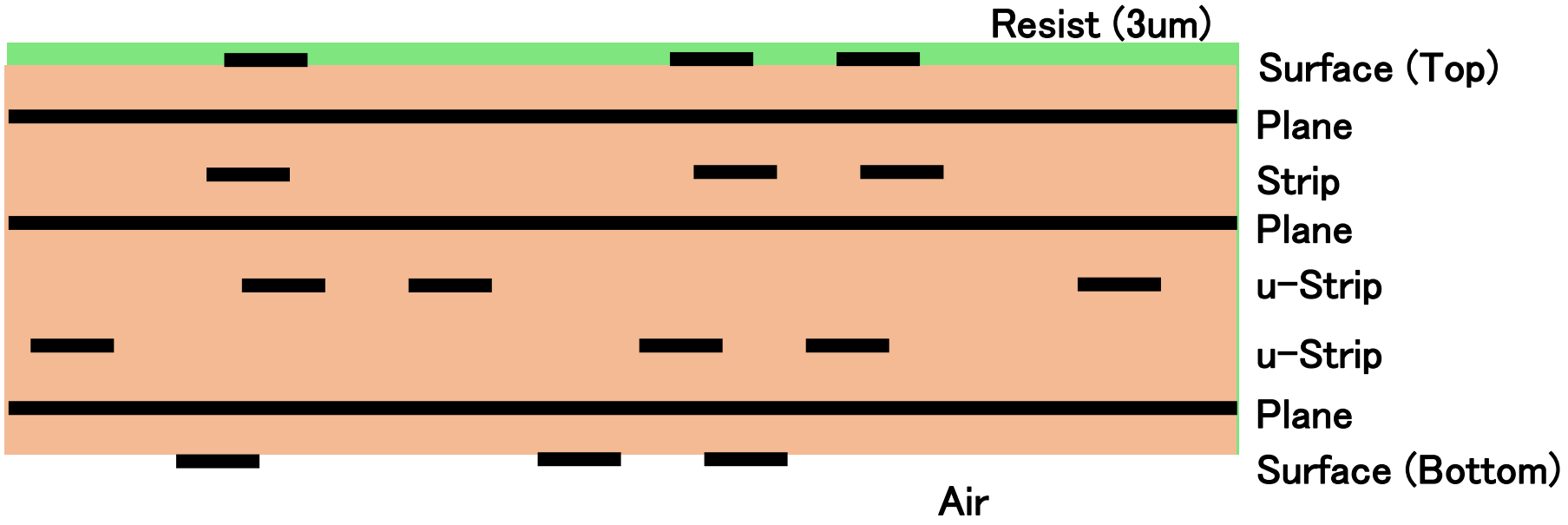
Material

- Simulate three cases
  - General Use FR-4
  - Low Loss for High Frequency PCB
  - Super Low Loss for over 12GHz
- Resist Ink
  - Low Loss Ink (Most Resists are more lossy)
- Copper surface roughness is average of 4-sides

	FR-4	Low Loss	Super Low Loss	Resist Ink (Low Loss)
Dk(1GHz)	4.8	3.8	3.4	3.0
Dk(10GHz)		3.8	3.4	
Df(1GHz)	0.015	0.005	0.002	0.01
Df(10GHz)		0.007	0.004	
Cu Surface	3um	1um	1um	-

Stack-up

- The Thickness of each layer is different to keep same single etch width (100 um) and same impedance (50 ohm) of each condition.
- Etch Length = 30 cm (12”)



Simulation Case

- Single Line
  - Line width: 100 um, Impedance: 50 ohm
- Diff. Line
  - Line Width: 100 um, Single Line Impedance: 50 ohm
  - Diff. Line Space: 250um/100um/75um
  - Structure: u-Strip (Surface)/u-Strip (Inner)/Strip

	FR-4	Low Loss	Super Low Loss
Single	50	50	50
100/250	94~100	96~100	98~100
100/100	76~86	81~87	83~88
100/75	69~80	74~81	77~82

  - High-Speed Serial Signal

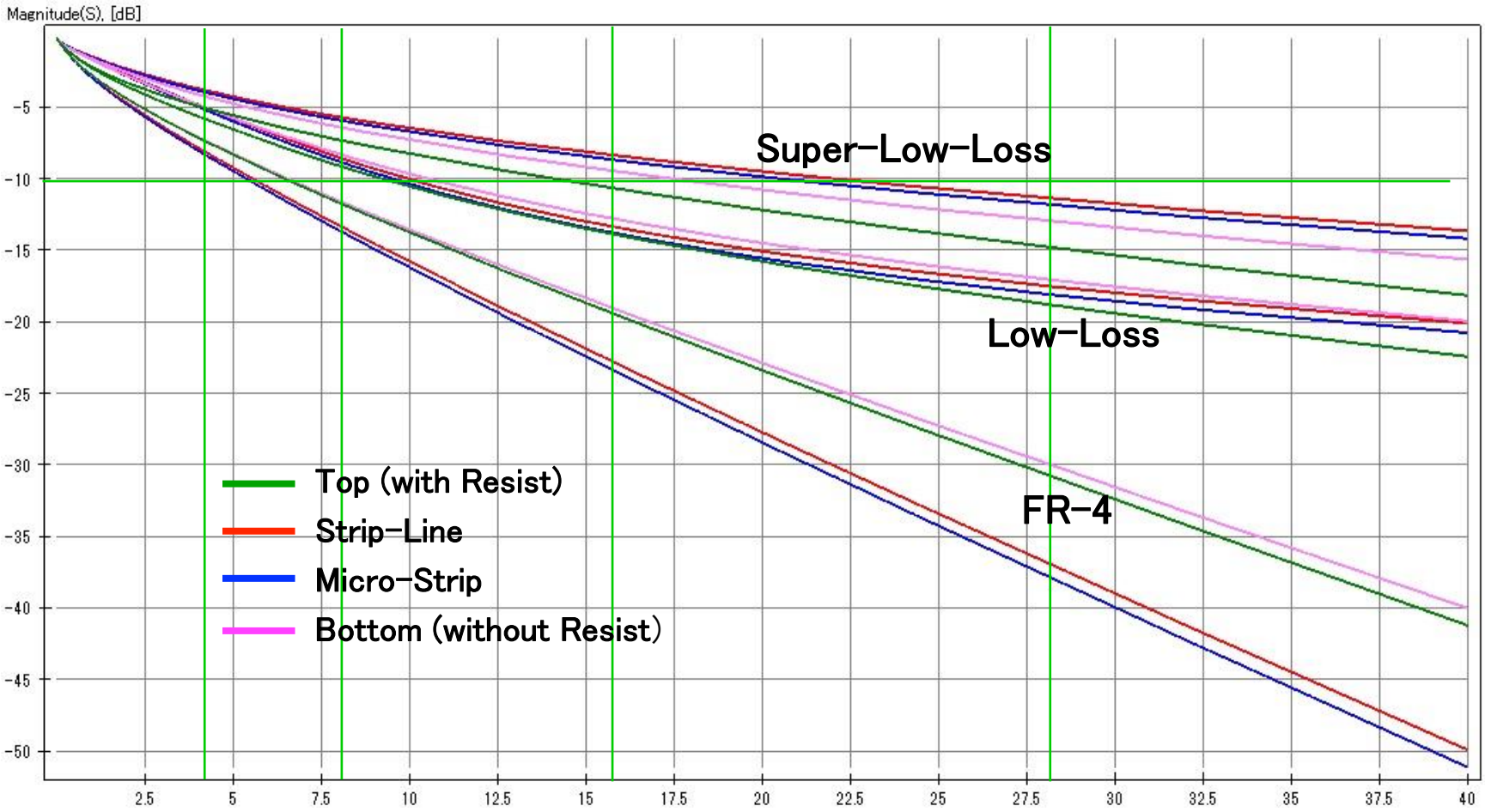
	PCIe 3	PCIe 4	28Gbis	PCIe 5	*PCIe 6*	*56 Gbps*	*112 Gbps*
Signal Speed	4 GHz	8 GHz	14 GHz	16 GHz	*16 GHz*	*14 GHz*	*28 GHz*
	NRZ	NRZ	NRZ	NRZ	*PAM4*	*PAM4*	*PAM4*

Simulation Results

Single Line

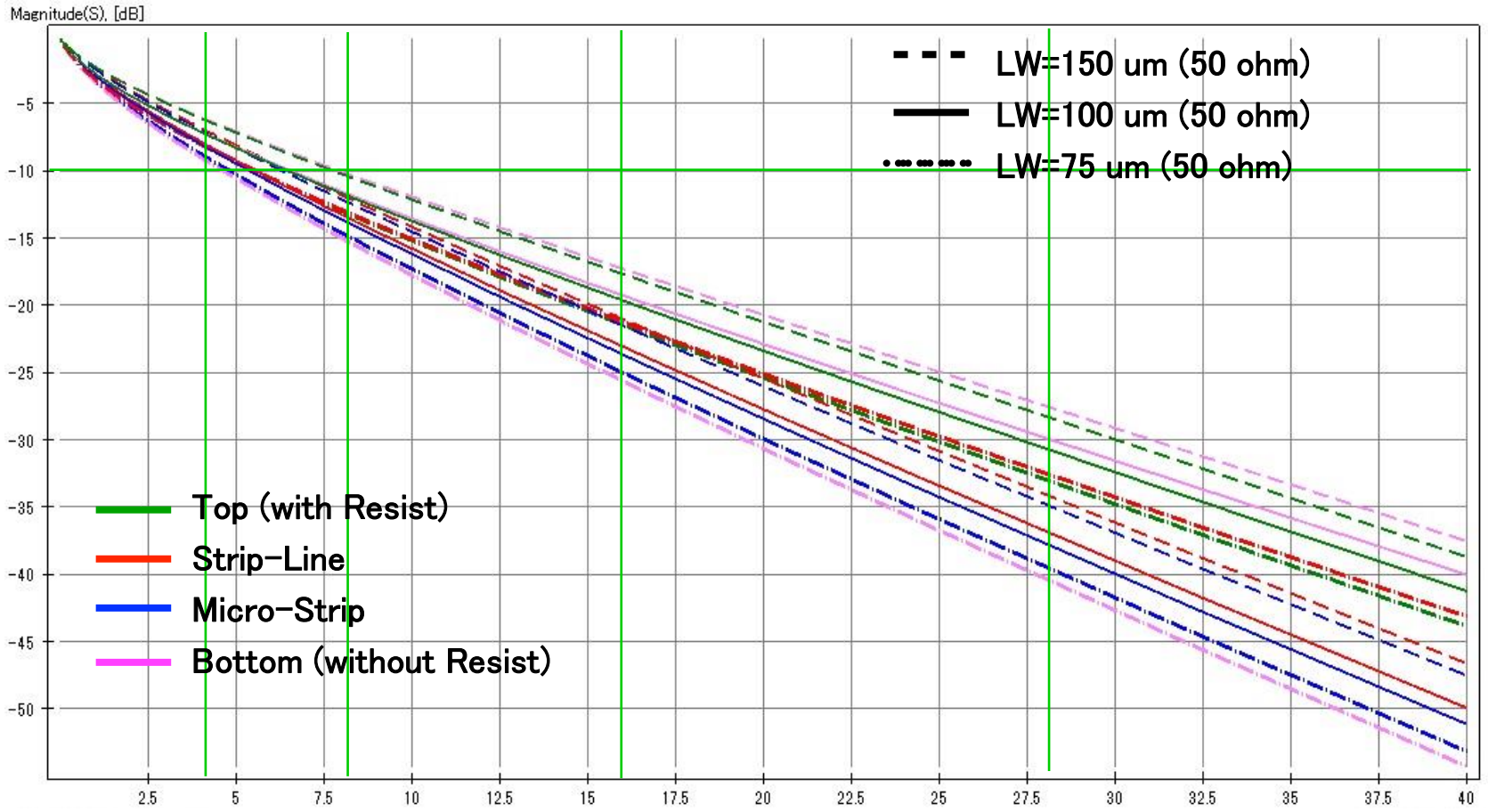
Single 50 ohm

- Three Materials



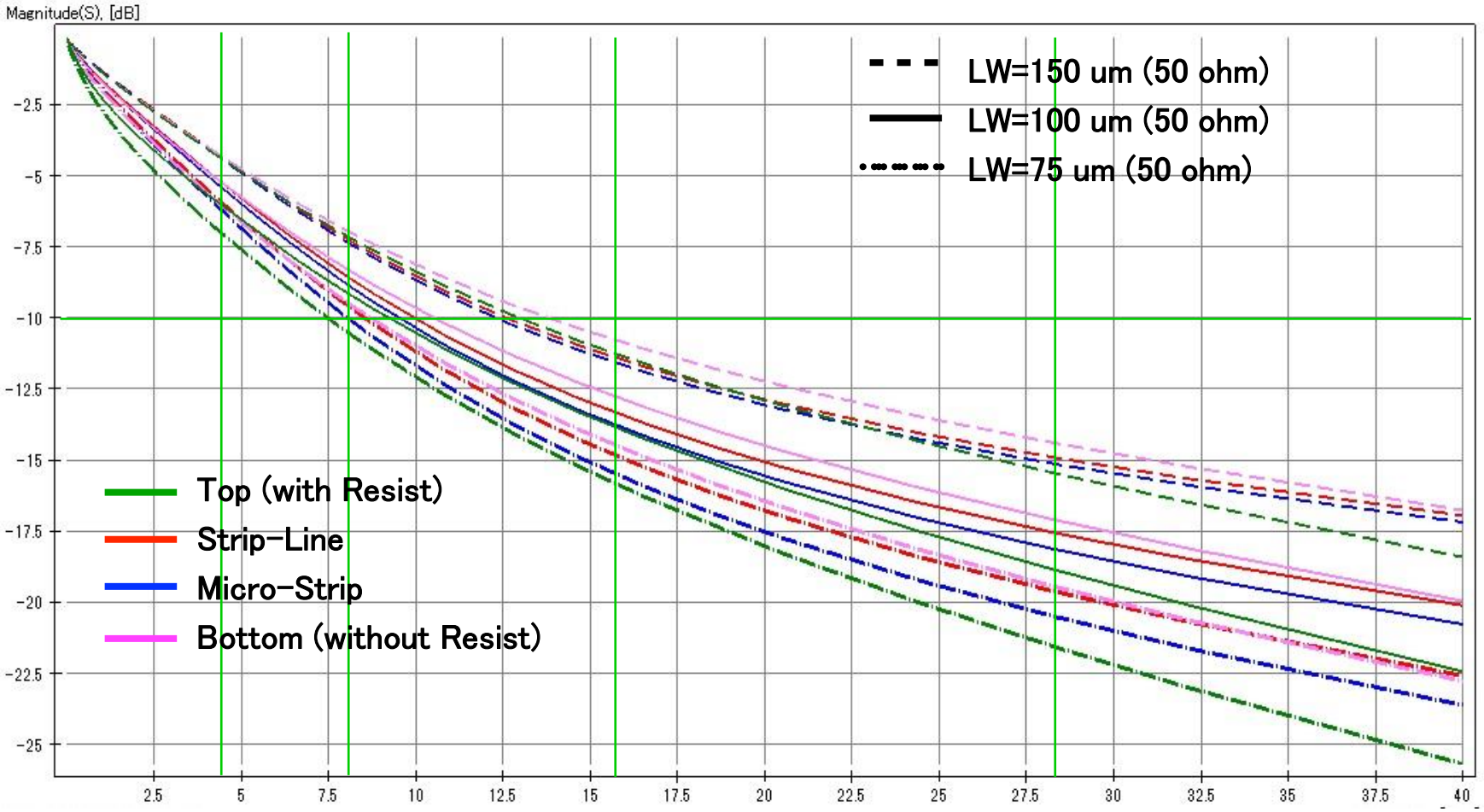
FR-4 Material (Single 50 ohm)

- Different Line Width



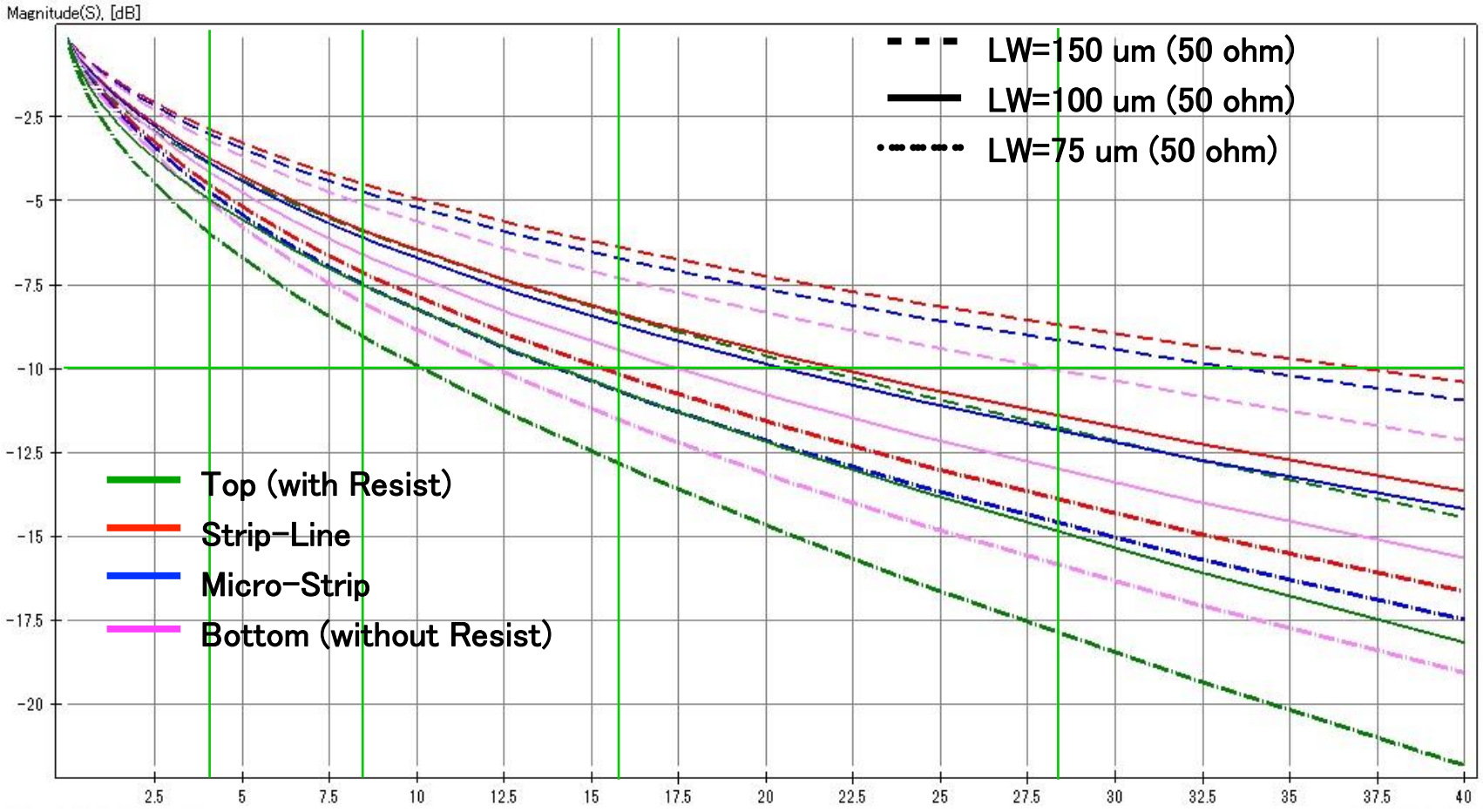
Low-Loss Material (Single 50 ohm)

- Different Line Width



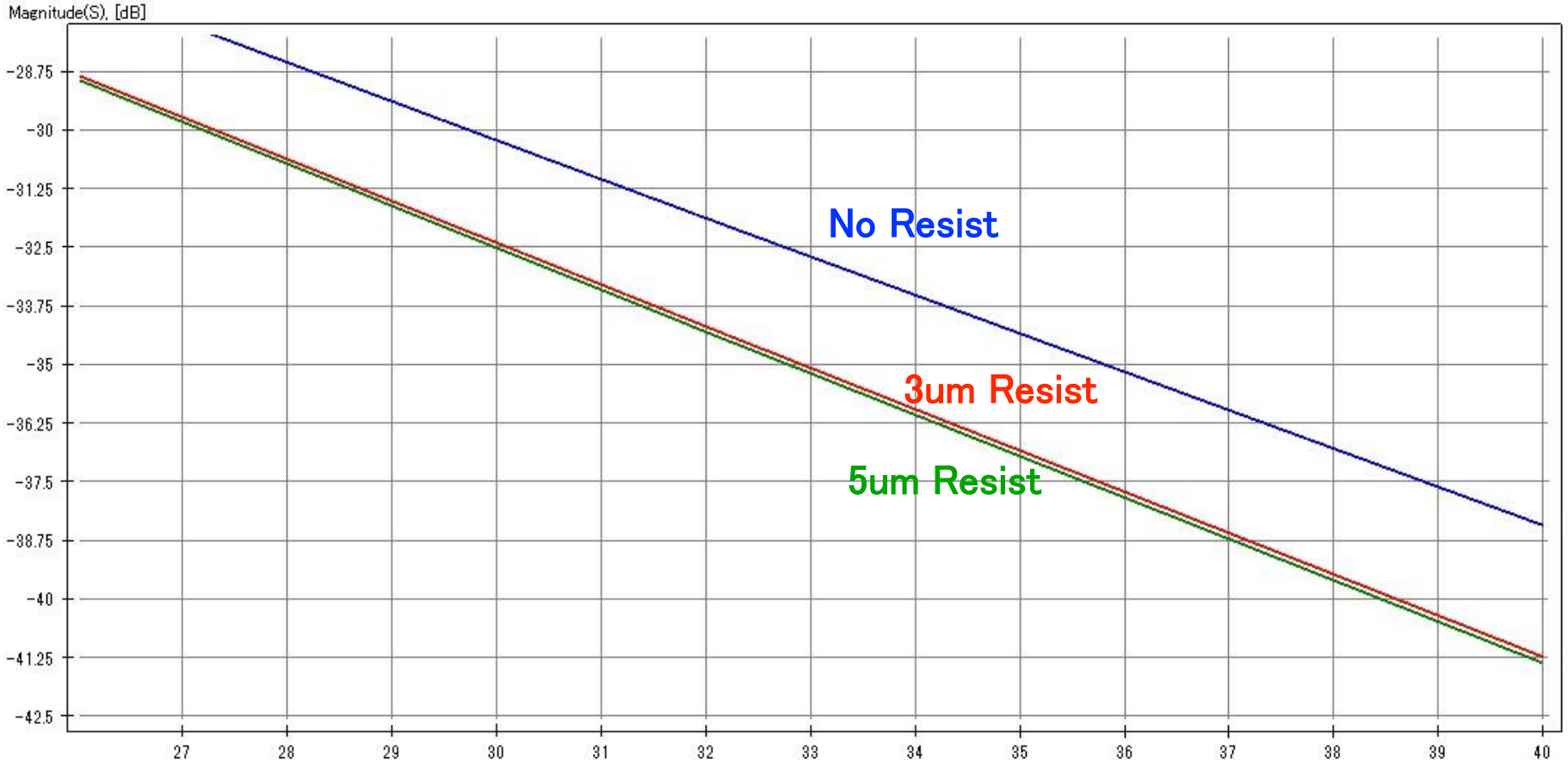
Super-Low-Loss Material (Single 50 ohm)

- Different Line Width



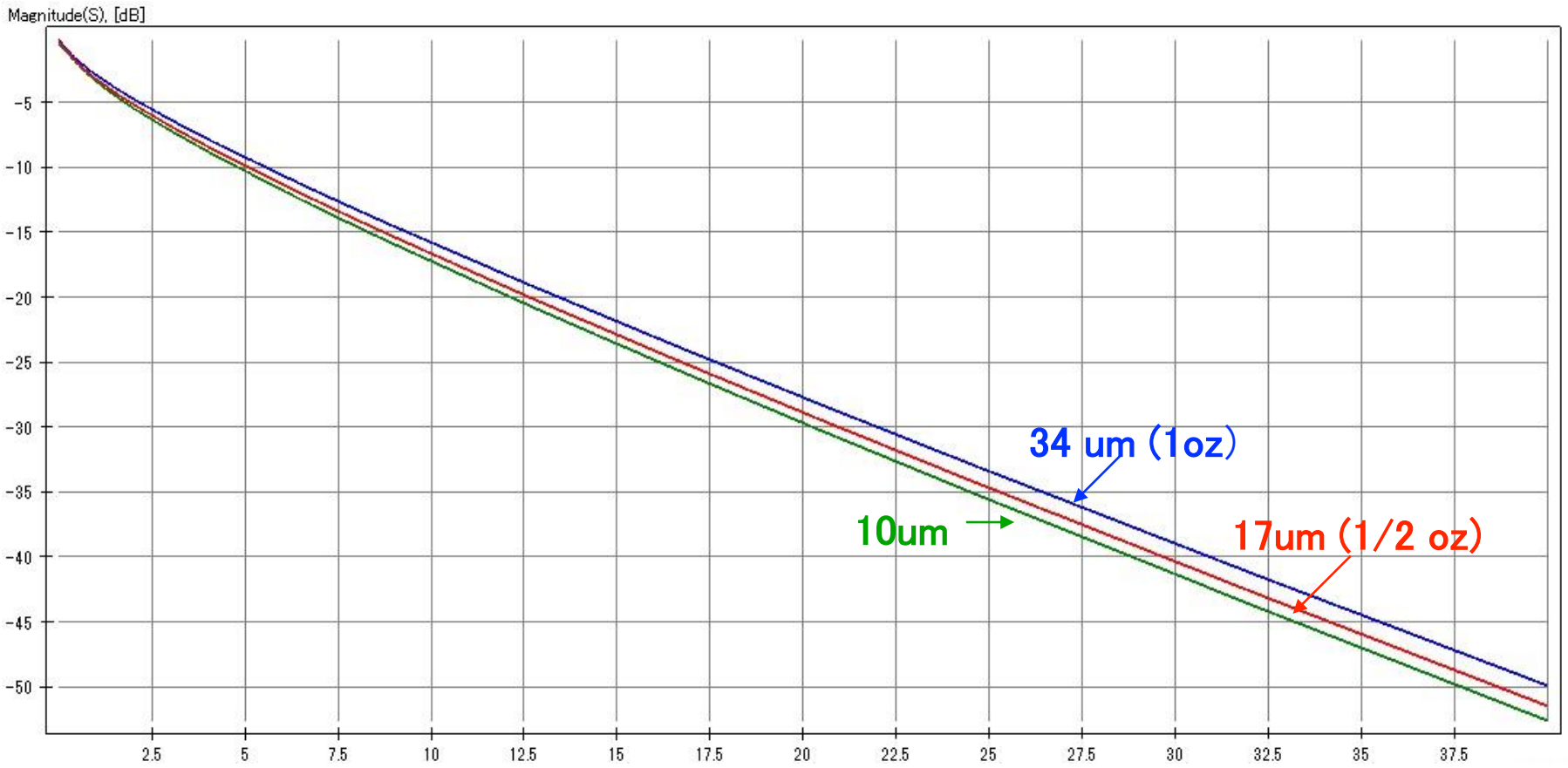
Effect of Resist ink

- FR-4 Top
- LW = 100 um



Effect of Copper Thickness

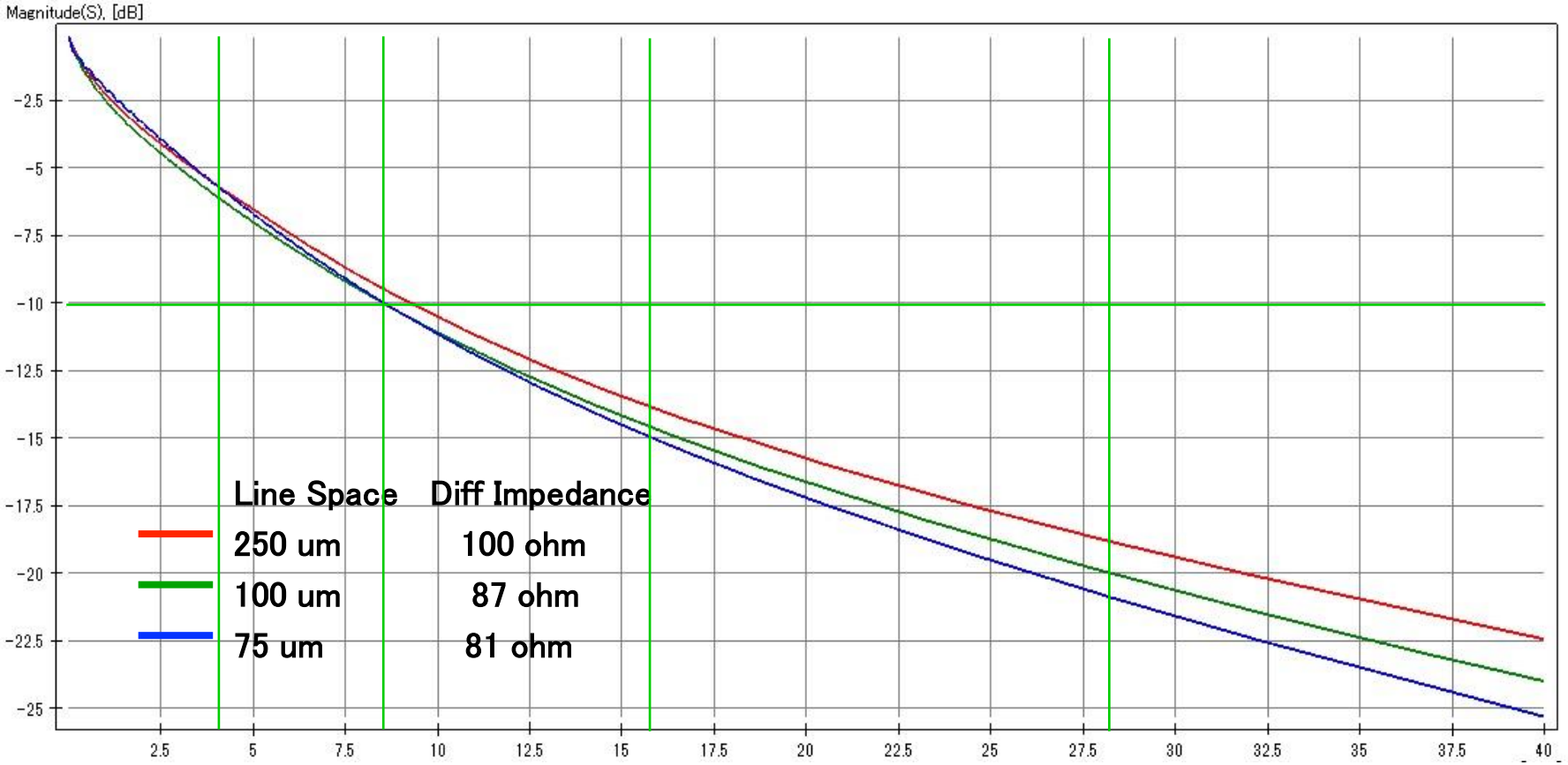
- FR-4 Strip Line
- LW = 100 um



Differential Line

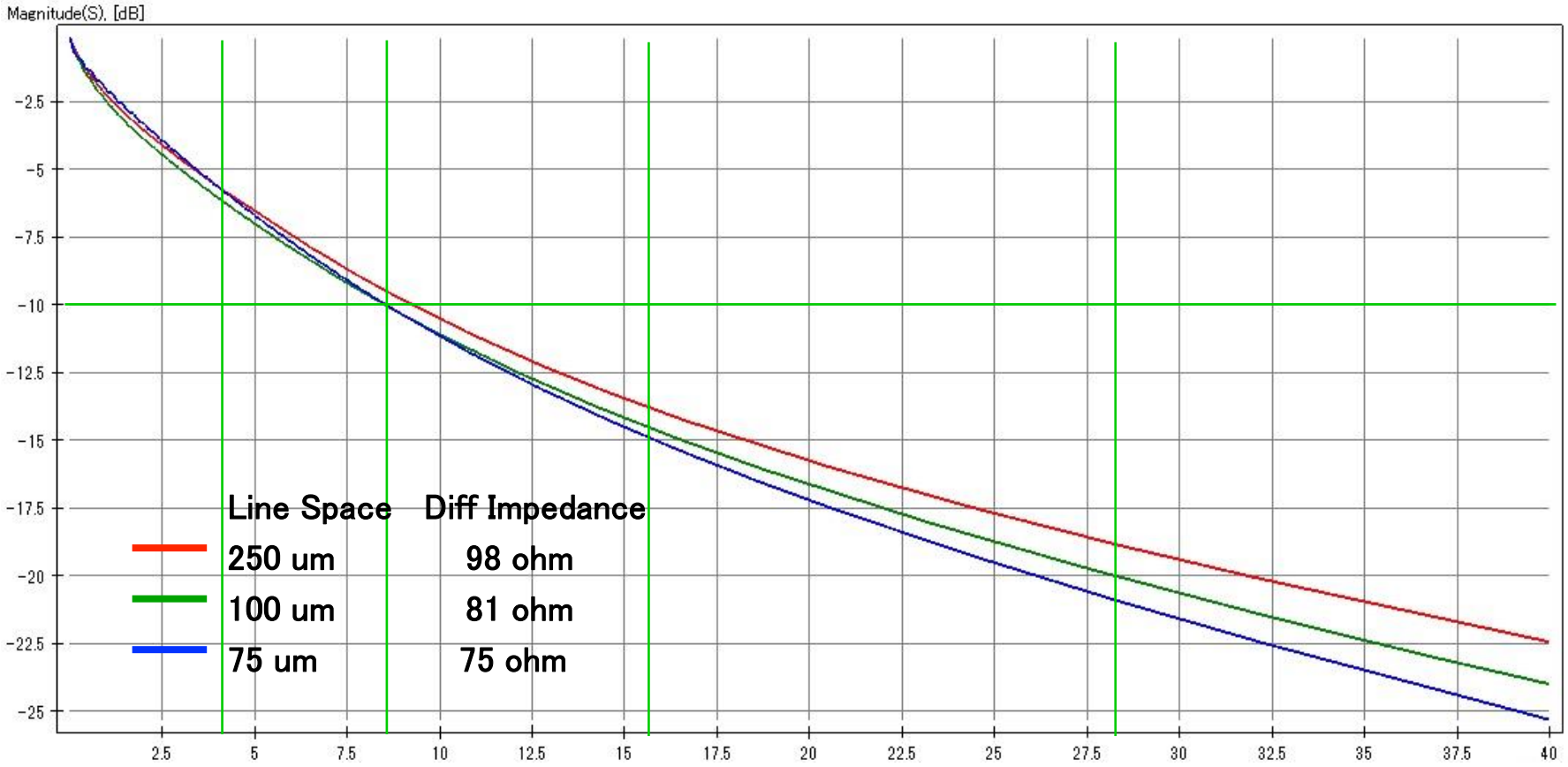
Differential Line Space

- Low Loss Material, Top Layer
  - Line Width: 100um (Single Line Impedance = 50 ohm)



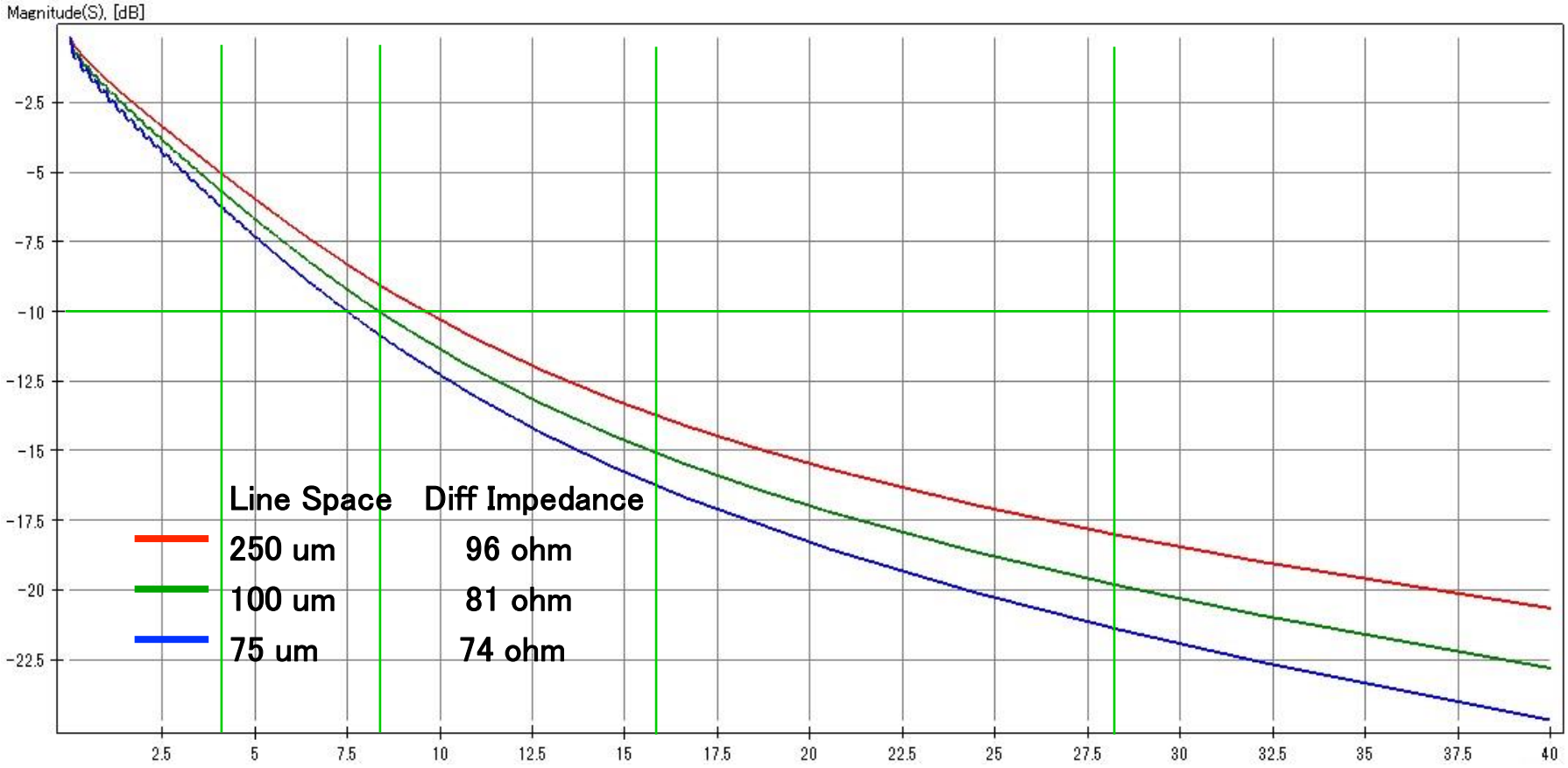
Differential Line Space

- Low Loss Material, Strip-line
  - Line Width: 100um (Single Line Impedance = 50 ohm)



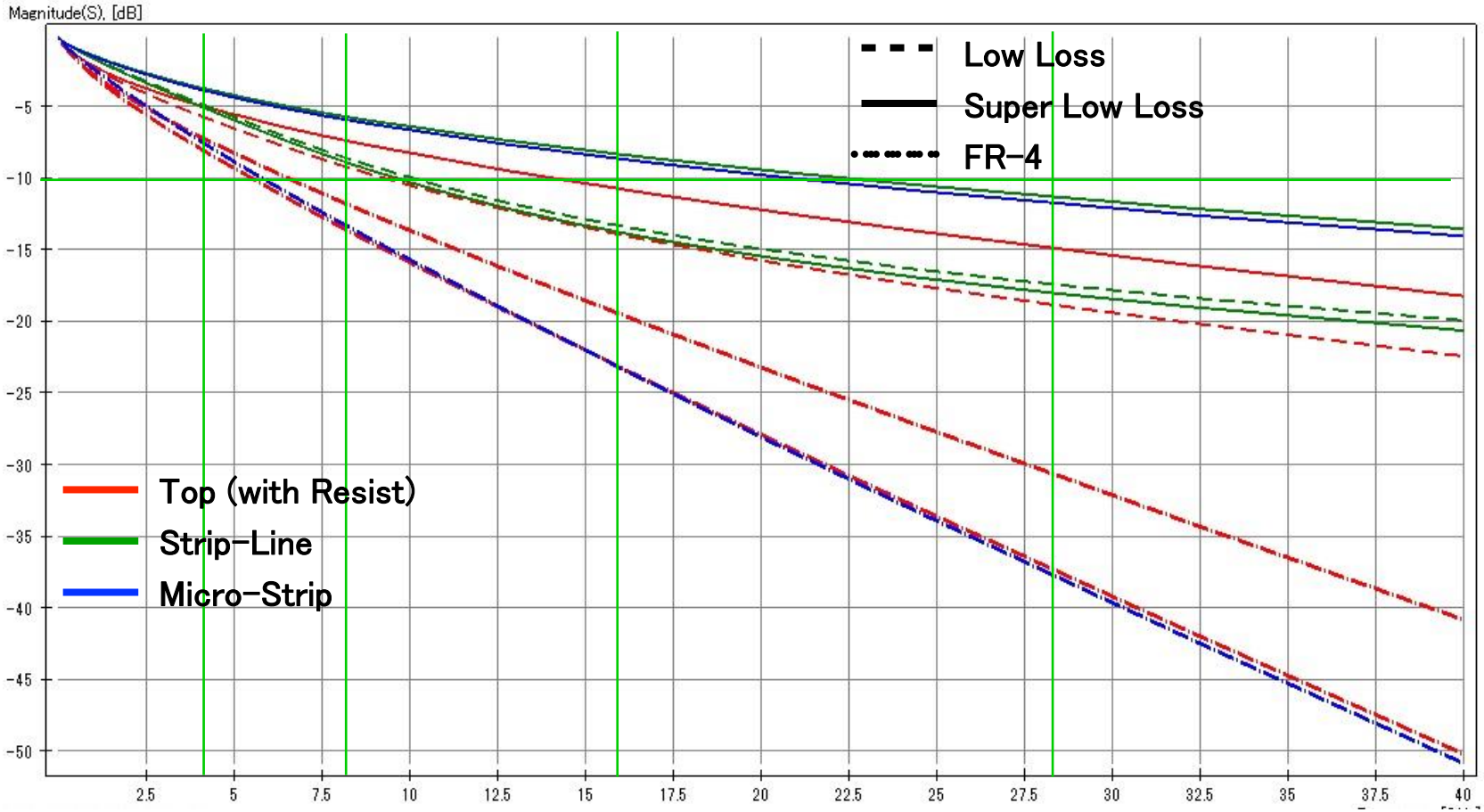
Differential Line Space

- Low Loss Material, Micro-Strip-line
  - Line Width: 100um (Single Line Impedance = 50 ohm)



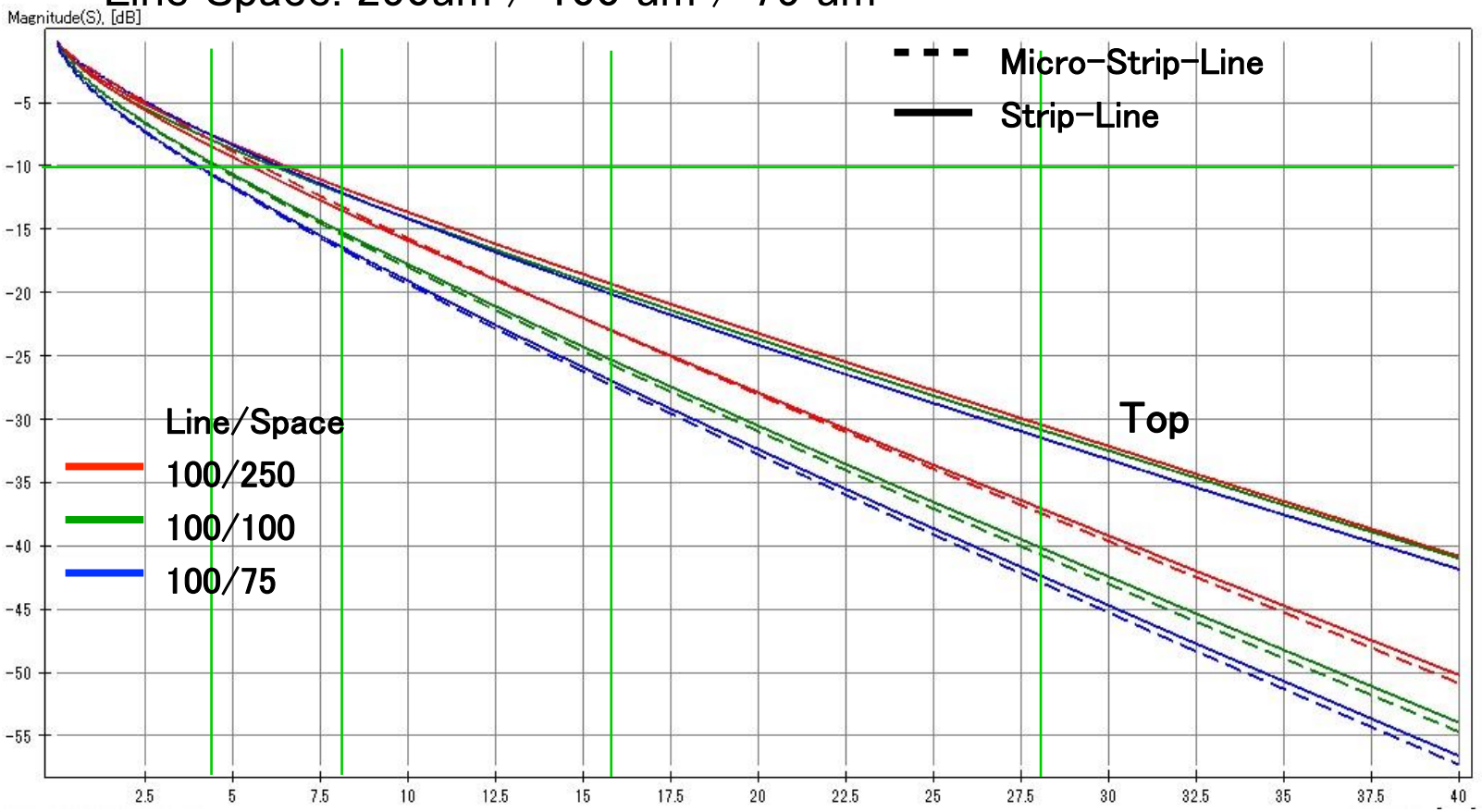
Differential Line

- Different Materials
  - L/S = 100 um/250 um Zdiff ≒ 100 ohm



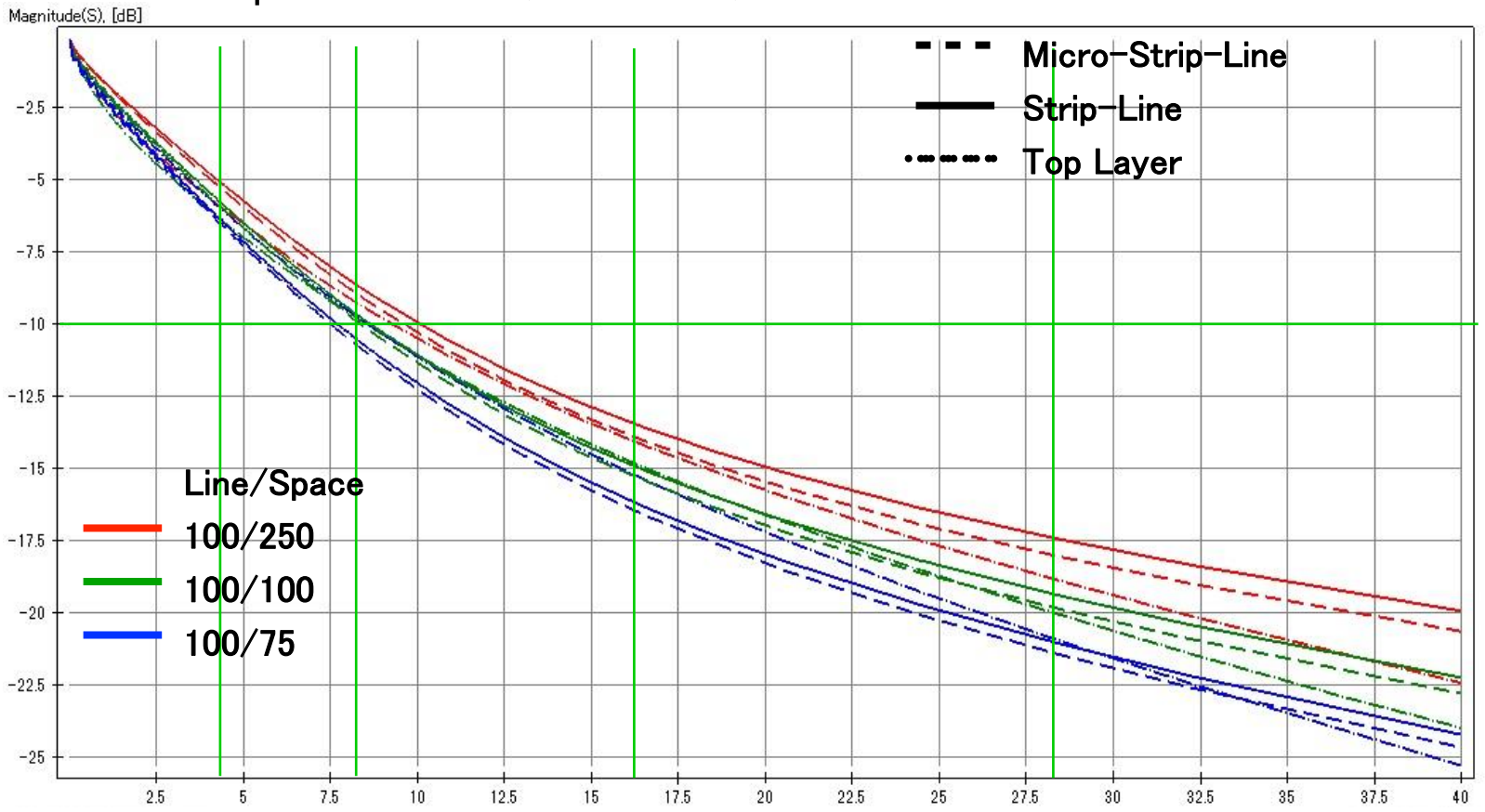
Differential Line (FR-4)

- Different Space
  - Line Width 100 um (Single 50 ohm)
  - Line Space: 250um / 100 um / 75 um



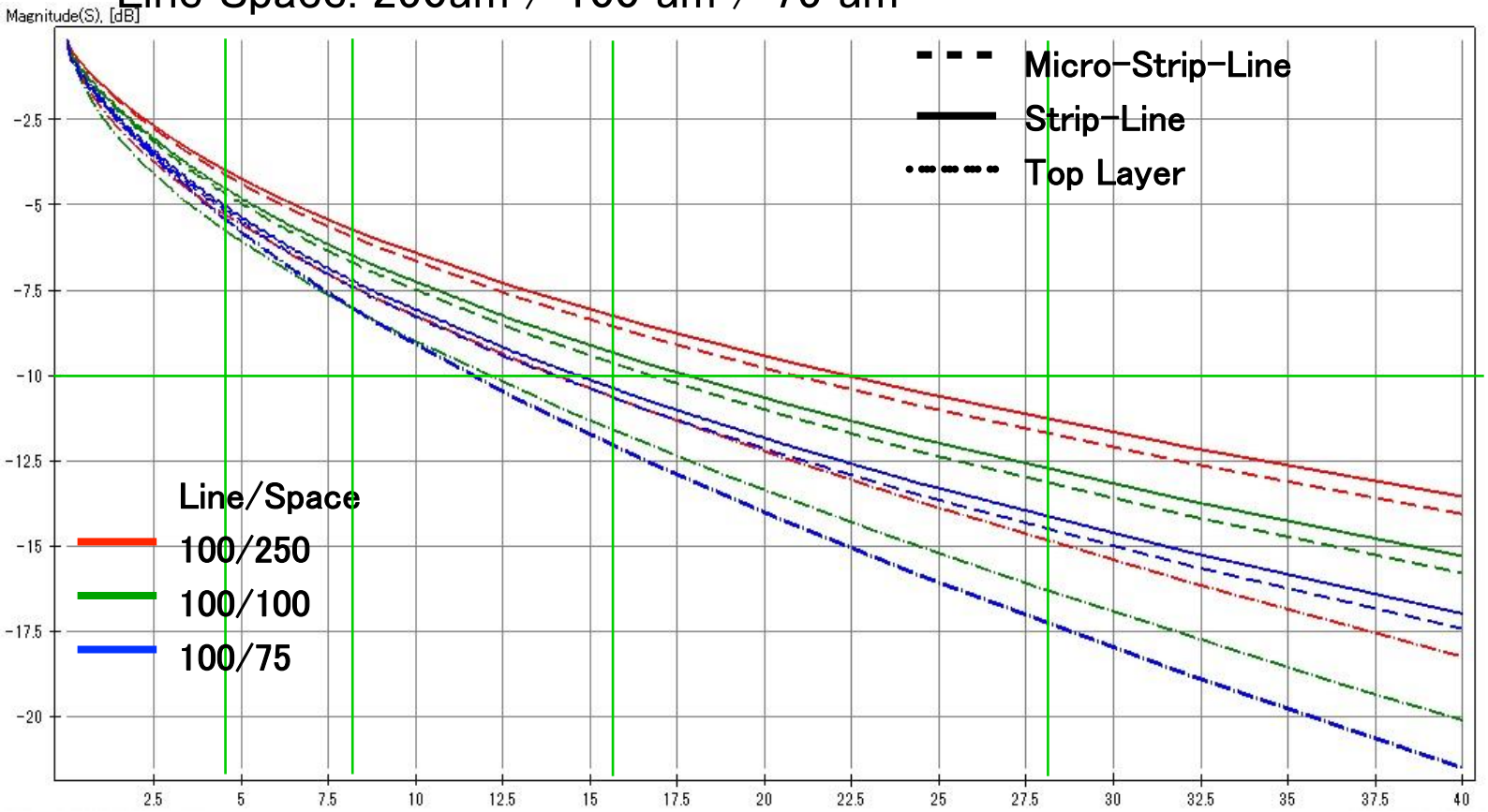
Differential Line (Low-Loss)

- Different Space
  - Line Width 100 um (Single 50 ohm)
  - Line Space: 250um / 100 um / 75 um



Differential Line (Super-Low-Loss)

- Different Space
  - Line Width 100 um (Single 50 ohm)
  - Line Space: 250um / 100 um / 75 um



Conclusion

- Line Width vs. Loss
  - Narrow Etch has advantage for Dielectric Loss
    - Less efficient Dipole
  - Wide Etch has advantage for Resistance Loss
    - Larger effective cross-section area
- Thick Copper has advantage for Resistance Loss
- Wide Differential Space is stable but low etch density
- Resist-Ink has effect for surface etch