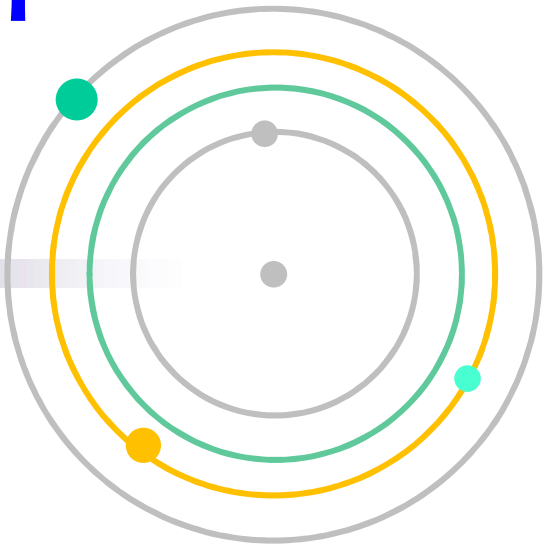
EMC Technical Seminar



Rev 7 – 07182023
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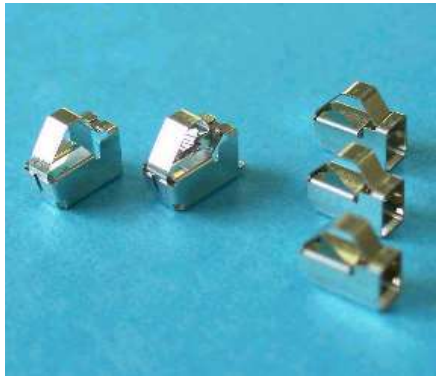
Contents

Grounding with Low Impedance Connection





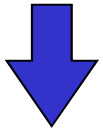



Grounding

Cause of Common Mode Noise:

- Common mode current causes radiated noise
- The potential difference of ground in a system causes common mode current

Solution: Make an ideal ground with zero potential difference

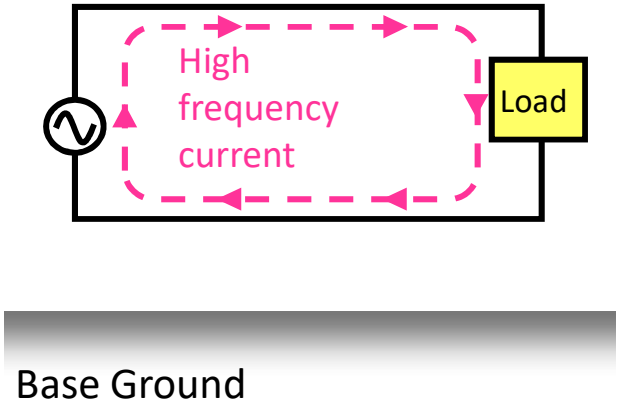


Key Consideration for EMC Grounding

Increasing ground area reduces impedance

Two Types of Noise Current

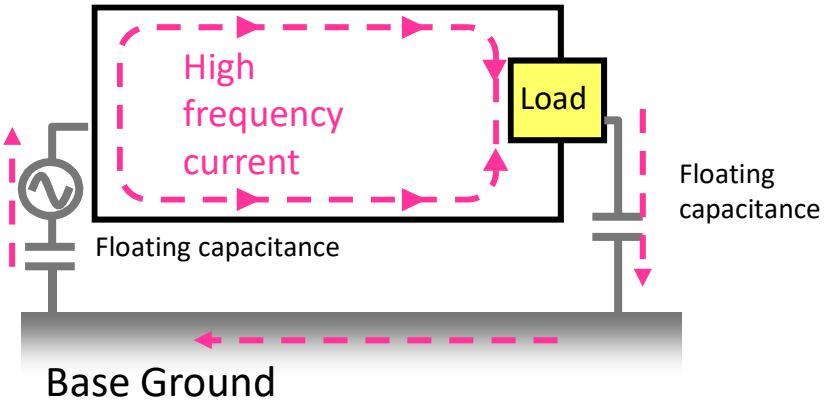
Normal (Differential) Mode Current



- Noise voltage occurs between lines
- Current flows in opposite directions between the power and load

→ Small EMI emissions

Common Mode Current



- Noise voltage occurs between ground
- Current flows in the same direction towards the load and returns through the ground

→ Large EMI emissions

Evaluation of Radiation Field Strength

Normal Mode Emission

$$E = 1.316 \times 10^{-14} \frac{|I_D| \times f^2 \times l \times s}{d}$$

I_D: normal mode current (A) f: frequency (Hz)

l: track length (m) s: conductor spacing (m)

d: distance (m) E: field strength (V/m)

Common Mode Emission

$$E = 1.257 \times 10^{-6} \frac{|I_C| \times f \times l}{d}$$

I_C: common mode current per track (A)

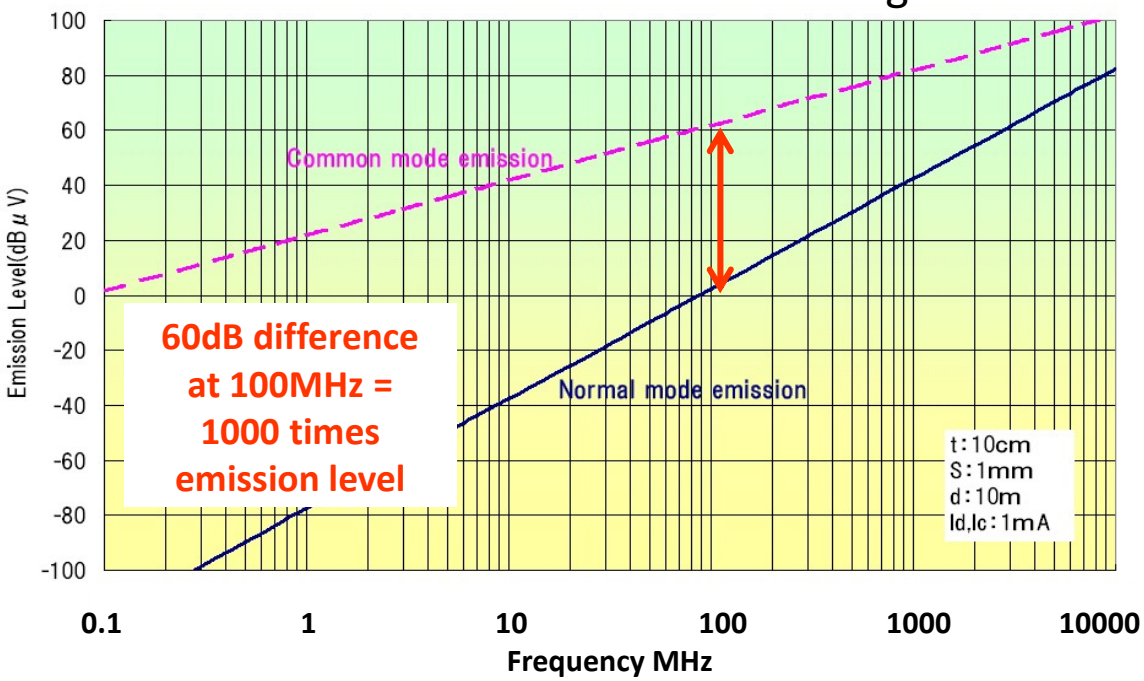
f: frequency (Hz) l: track length (m)

d: distance (m) E: field strength (V/m)

Above equation is valid when track length is small enough against a wavelength.

※ Citation: "Introduction to EMC" by C.R. Paul

Calculation of radiation field strength



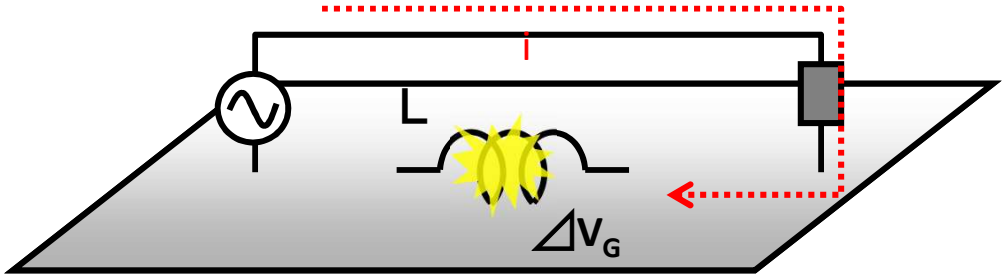
❖ Emission noise is dominated by common mode

Why does common mode noise occur?

Cause of Common Mode Noise

The Current Driven Model as an explanation of common mode current

Current Driven Model



self inductance

$$\Delta V_G = L\frac{di}{dt} = (L_G - L_M)\frac{di}{dt}$$

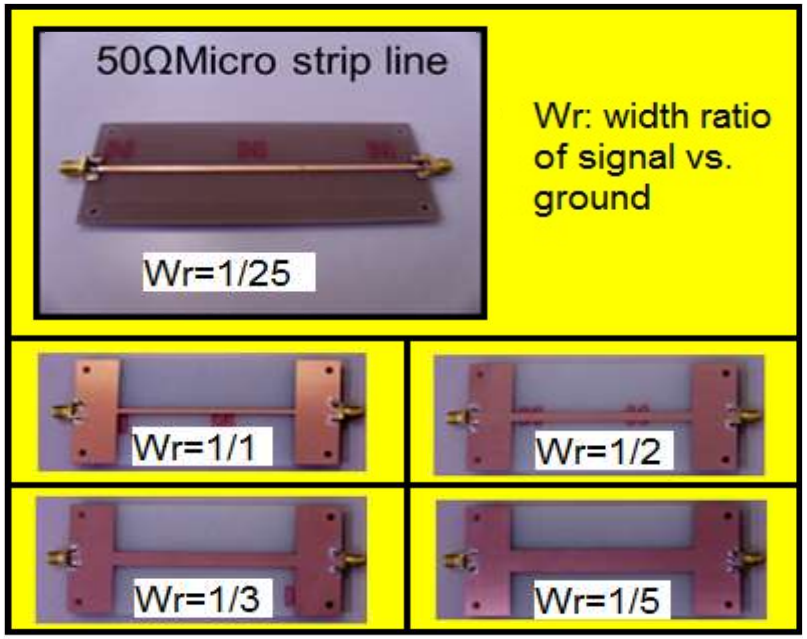
Common mode voltage

mutual inductance

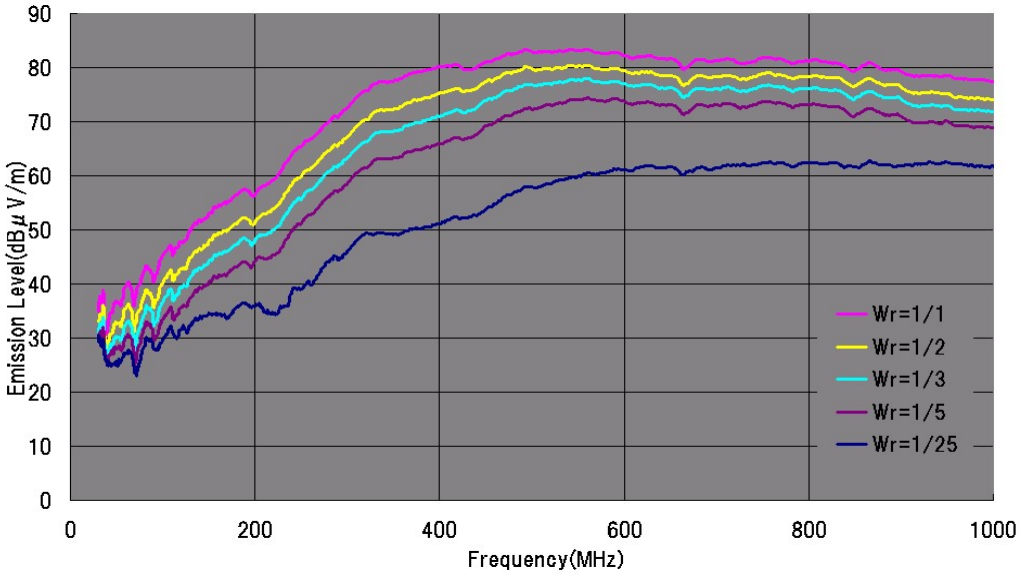
Reduction of self inductance and an increase of mutual inductance will reduce common mode voltage.

Ground Area and Grounding Effectiveness

Test boards with various ground widths



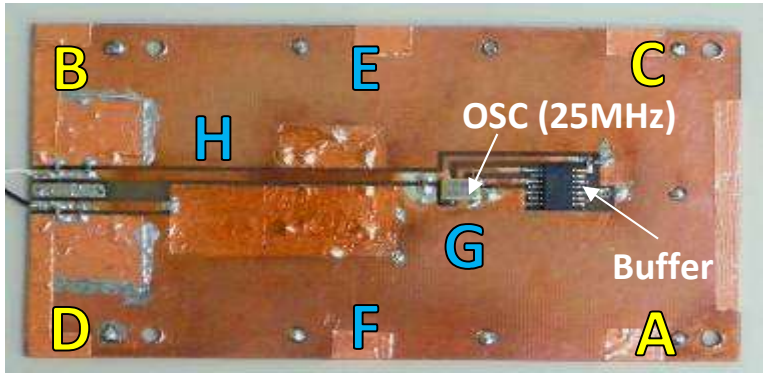
Emission from lines with varying ground widths



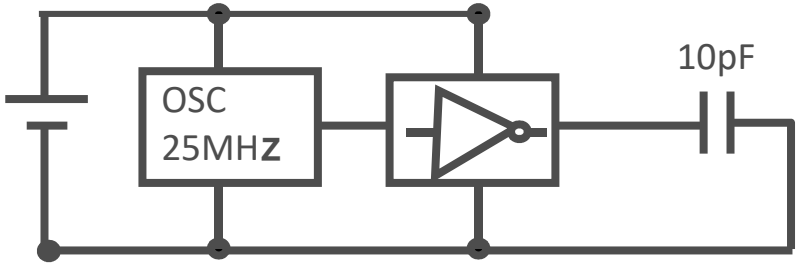
Larger ground area reduces self-inductance and increases mutual-inductance.

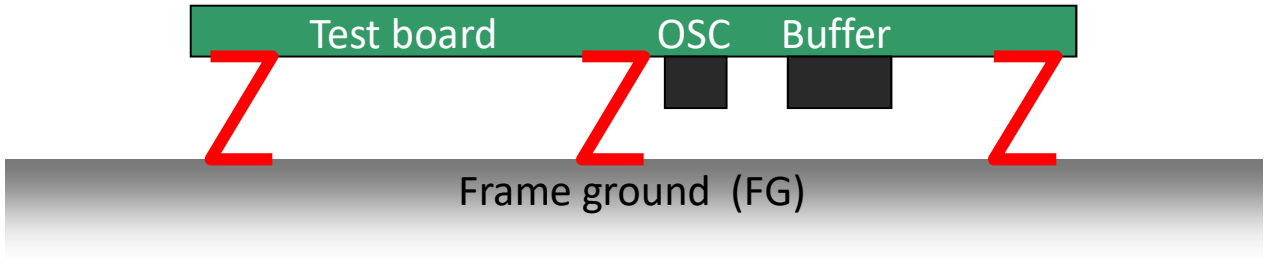
Increasing Ground Area

Multiple grounding points to the frame ground to reduce ground impedance



Grounding Points

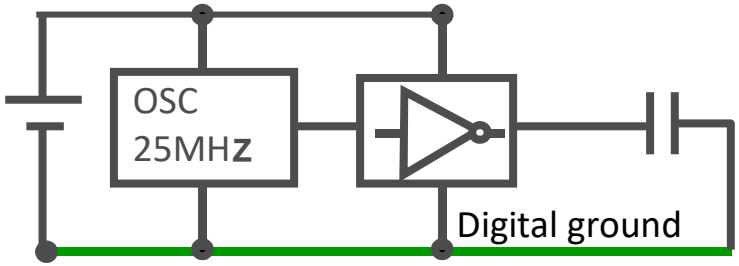




Radiated Emissions Test

- Test #1: PCB without any grounding
- Test #2: PCB + FG (4 points) at A, B, C, D
- Test #3: PCB + FG (8 points) at A, B, C, D, E, F, G, H

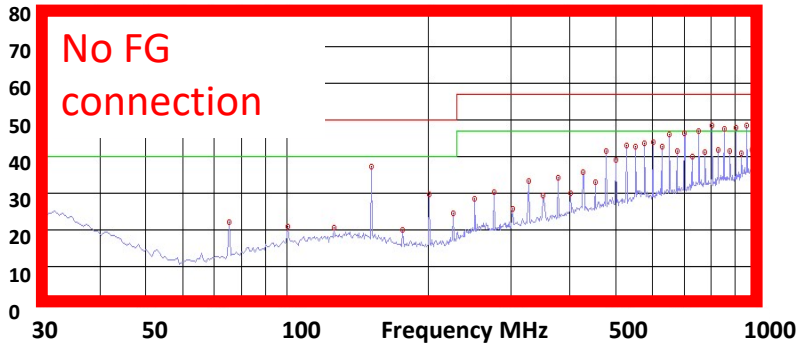
Multiple Connections to FG

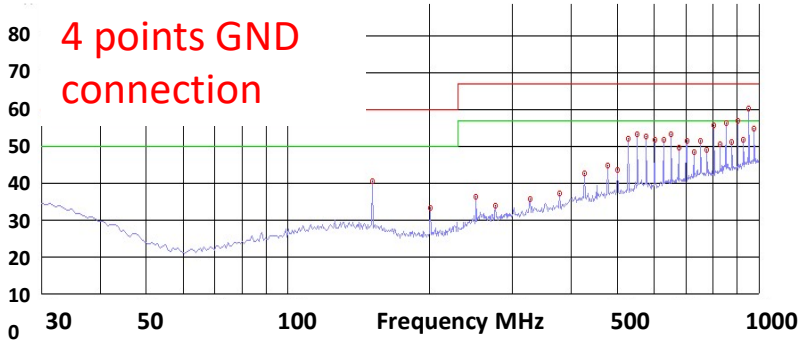


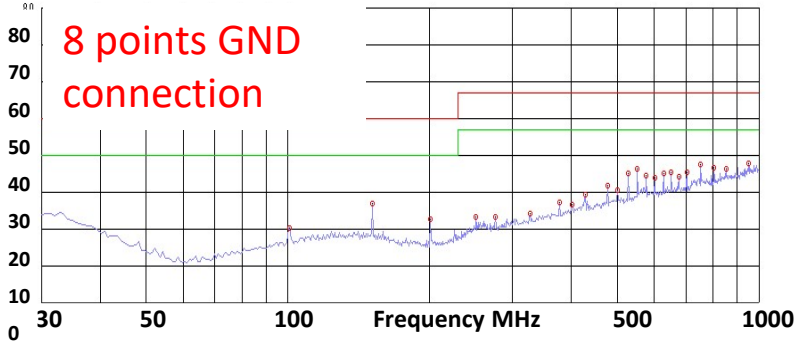
Frame ground (FG)

This is the level of radiation for no frame ground connection.

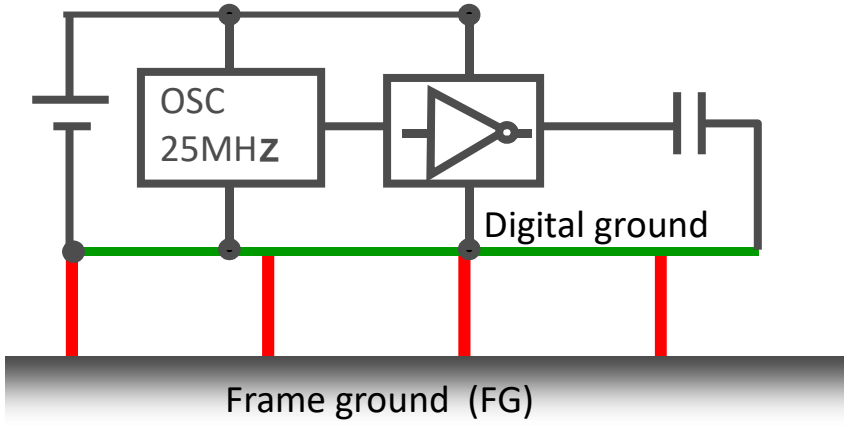
Horizontal Polarization





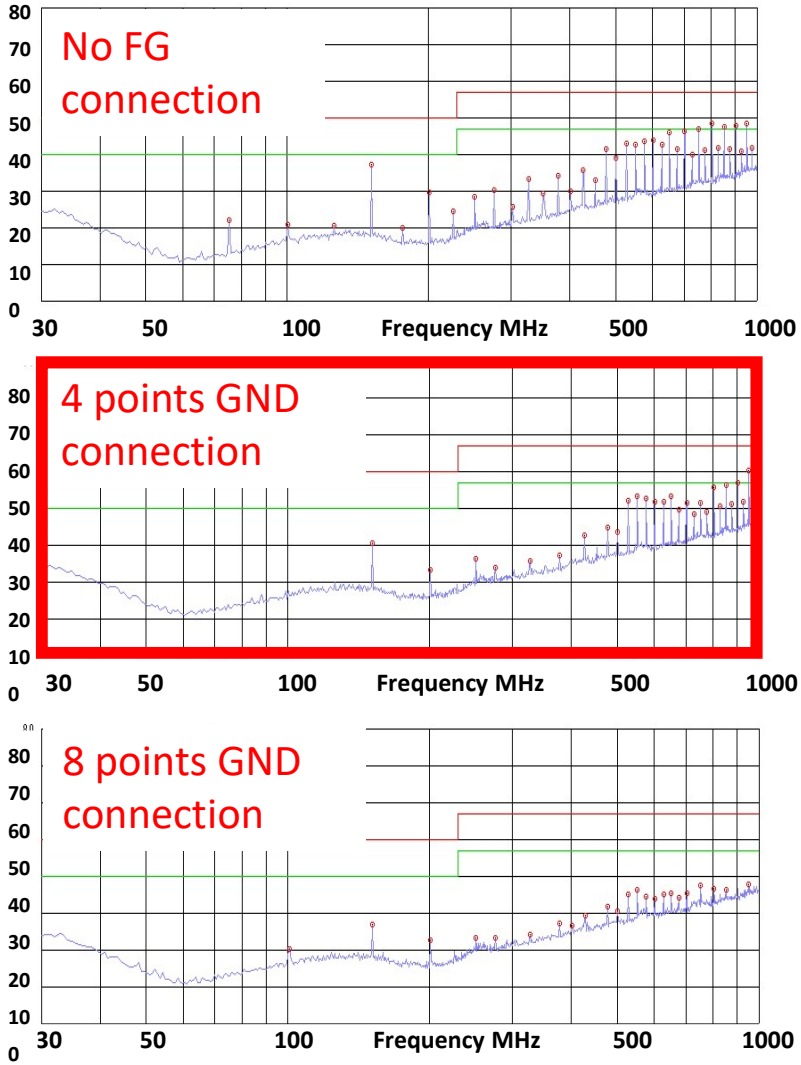


Multiple Connections to FG

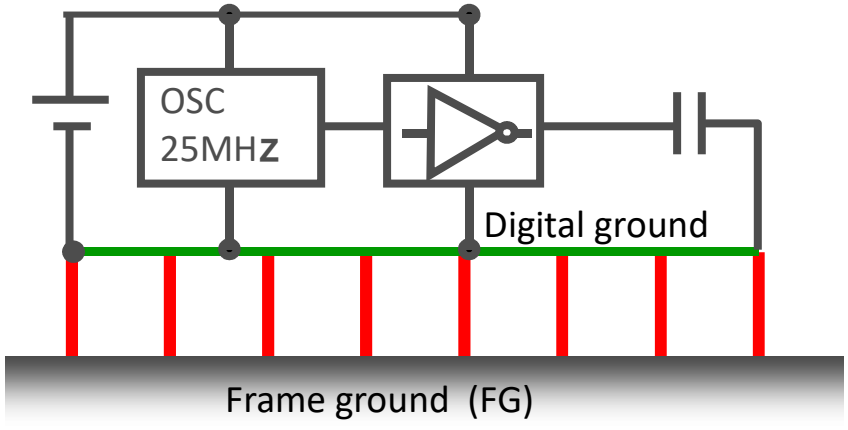


This is the level of radiation for connection at 4 points. The effect could be observed up to approximately 400 MHz.

Horizontal Polarization

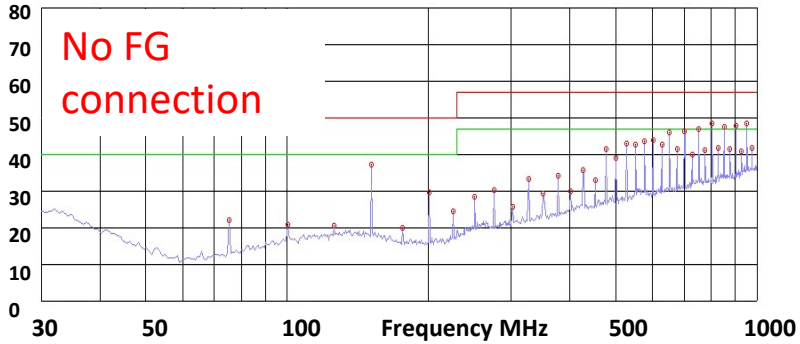


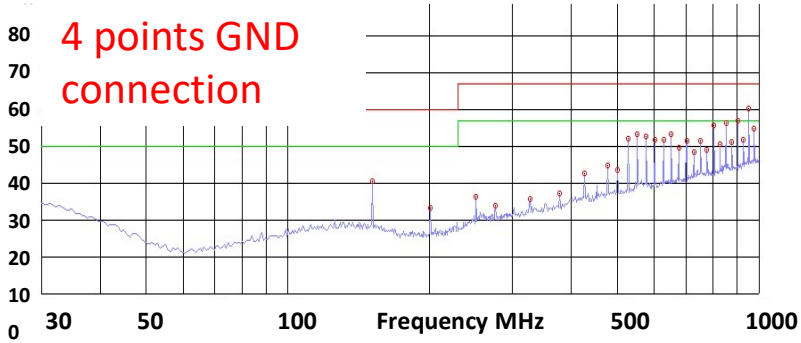
Multiple Connections to FG

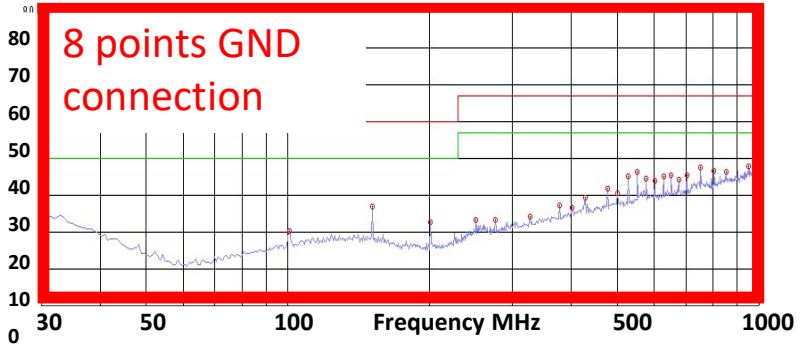


Improved suppression can be obtained by multi-point grounding.

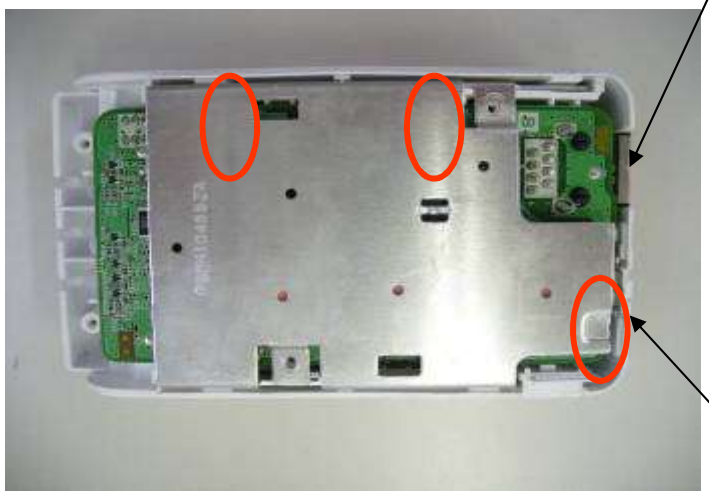
Horizontal Polarization

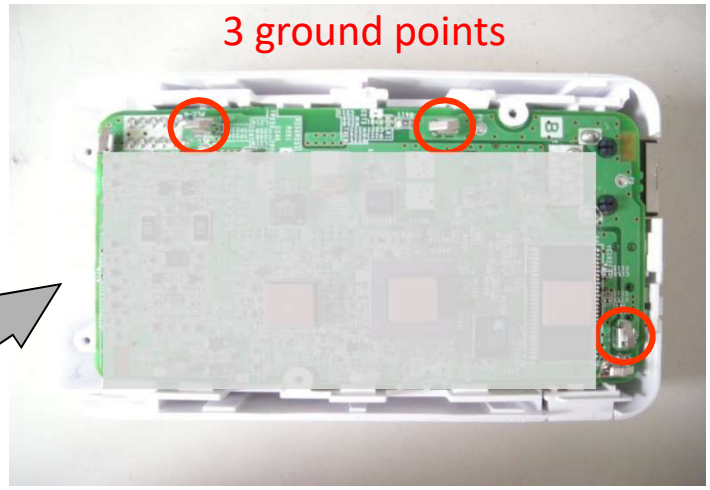


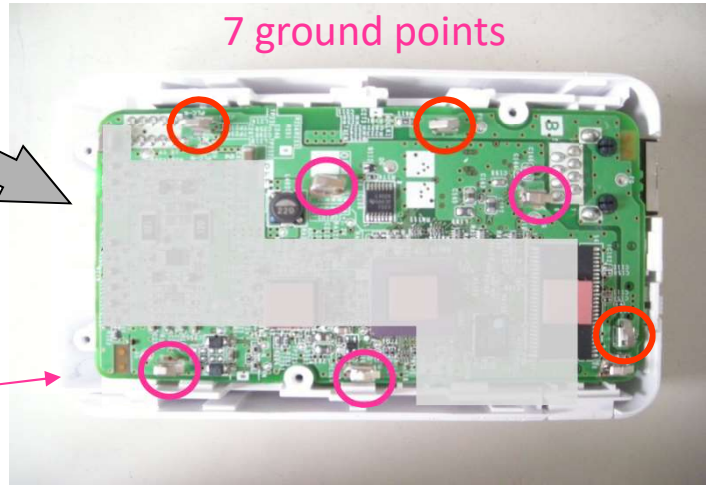




EMC Improvement with Additional Grounding Points

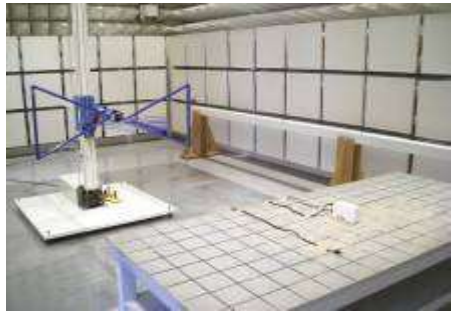




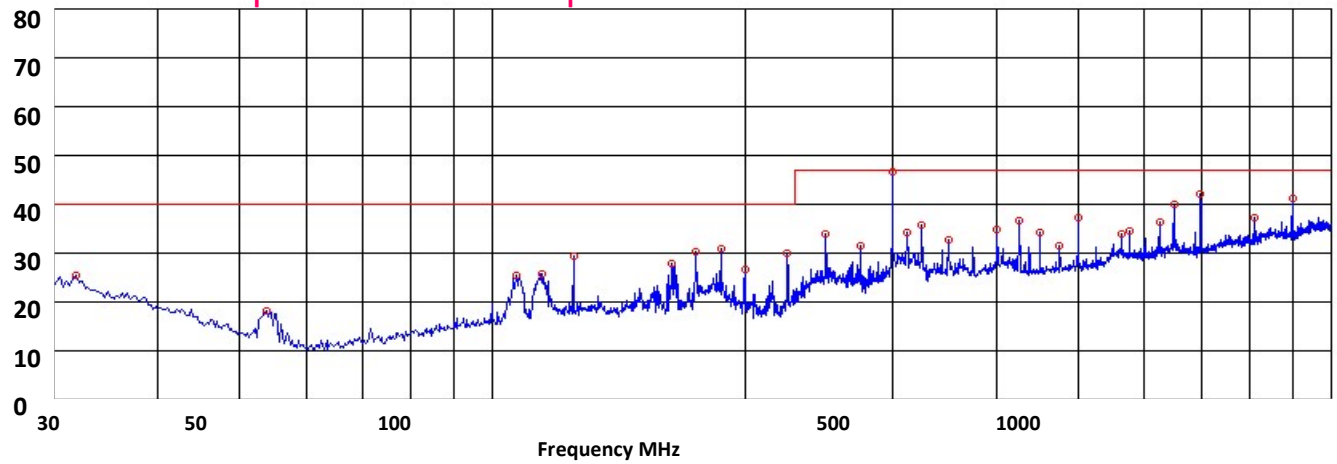


※ Grounding contact incorporated on PCB to touch the shield can to increase ground area.

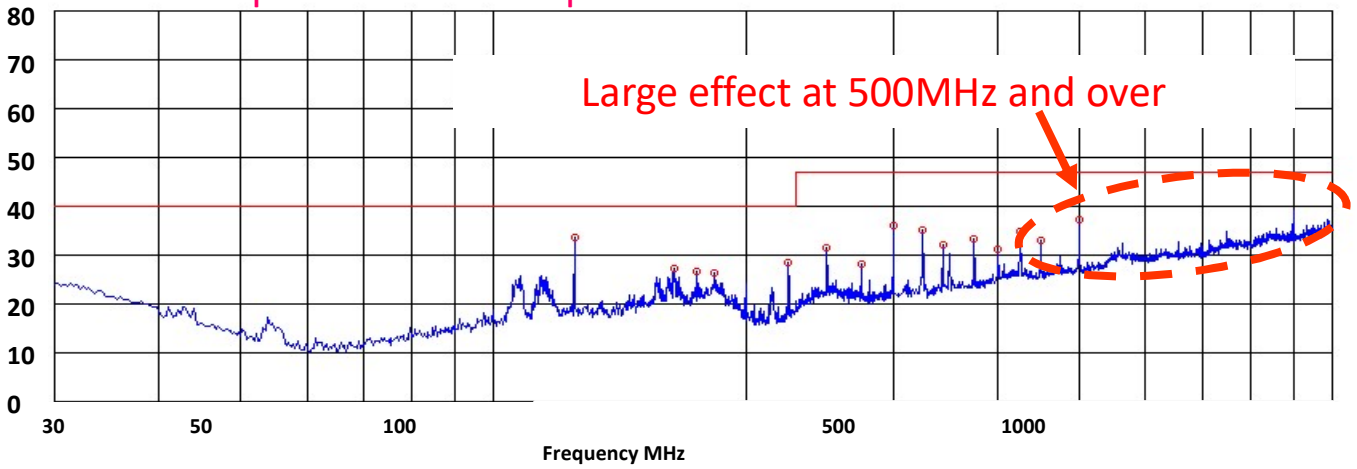
EMC Improvement with Additional Grounding Points



Horizontal polarization OG 3pcs

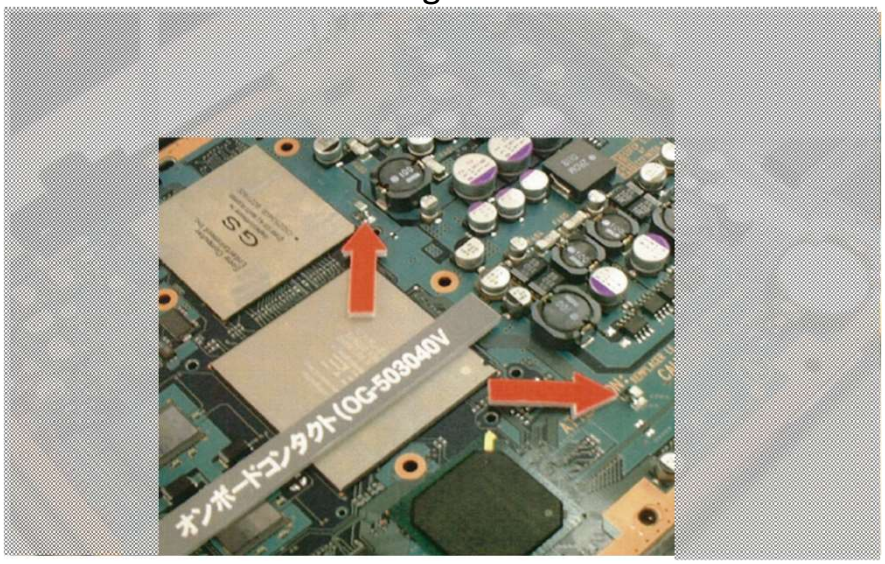


Horizontal polarization OG 7pcs



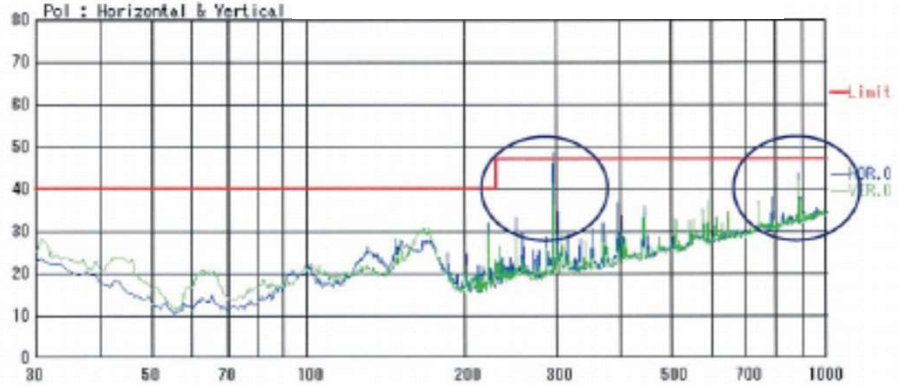
EMC Improvement using Grounding Contacts

Mounting on the PCB

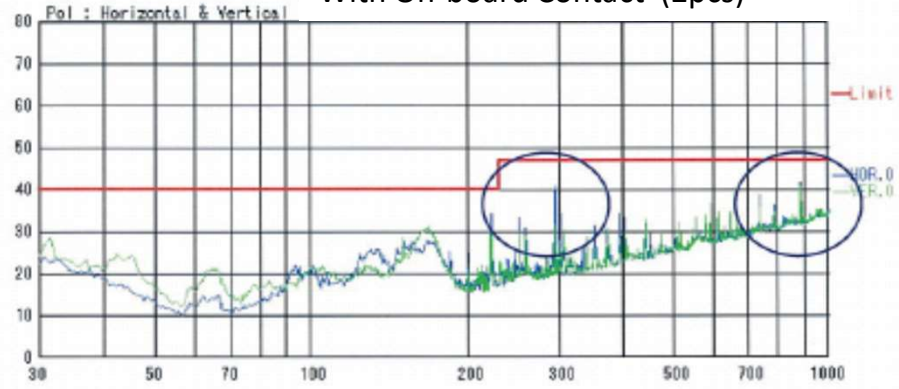


Ground connection around high speed IC with On-board Contact.

Without On-board Contact

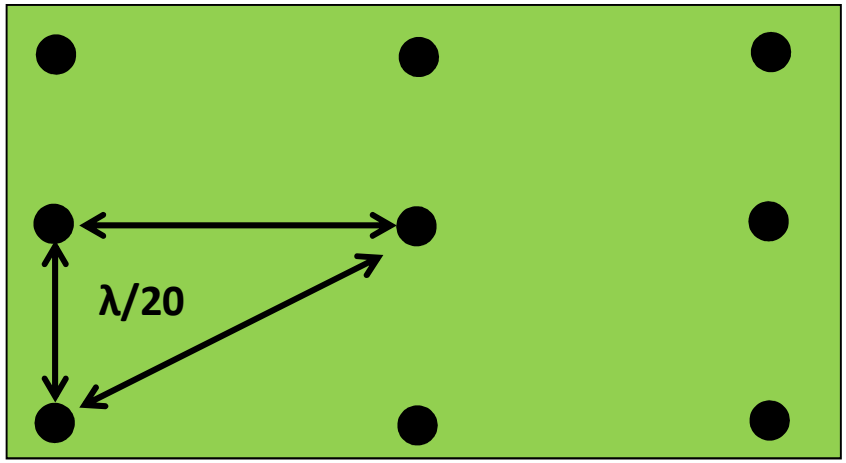


With On-board Contact (2pcs)

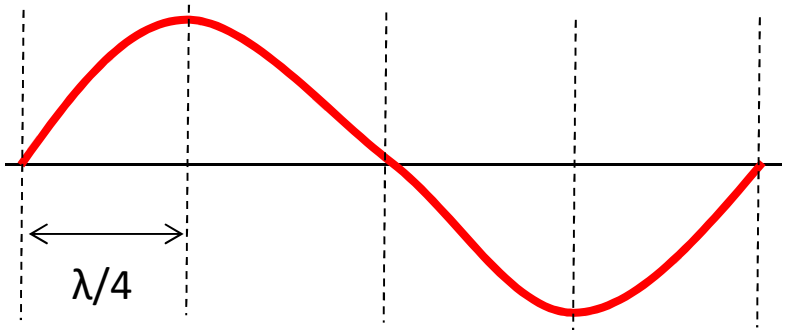


Recommended Number of Grounding Points

Ideal Placement Based on Theory



Voltage standing wave

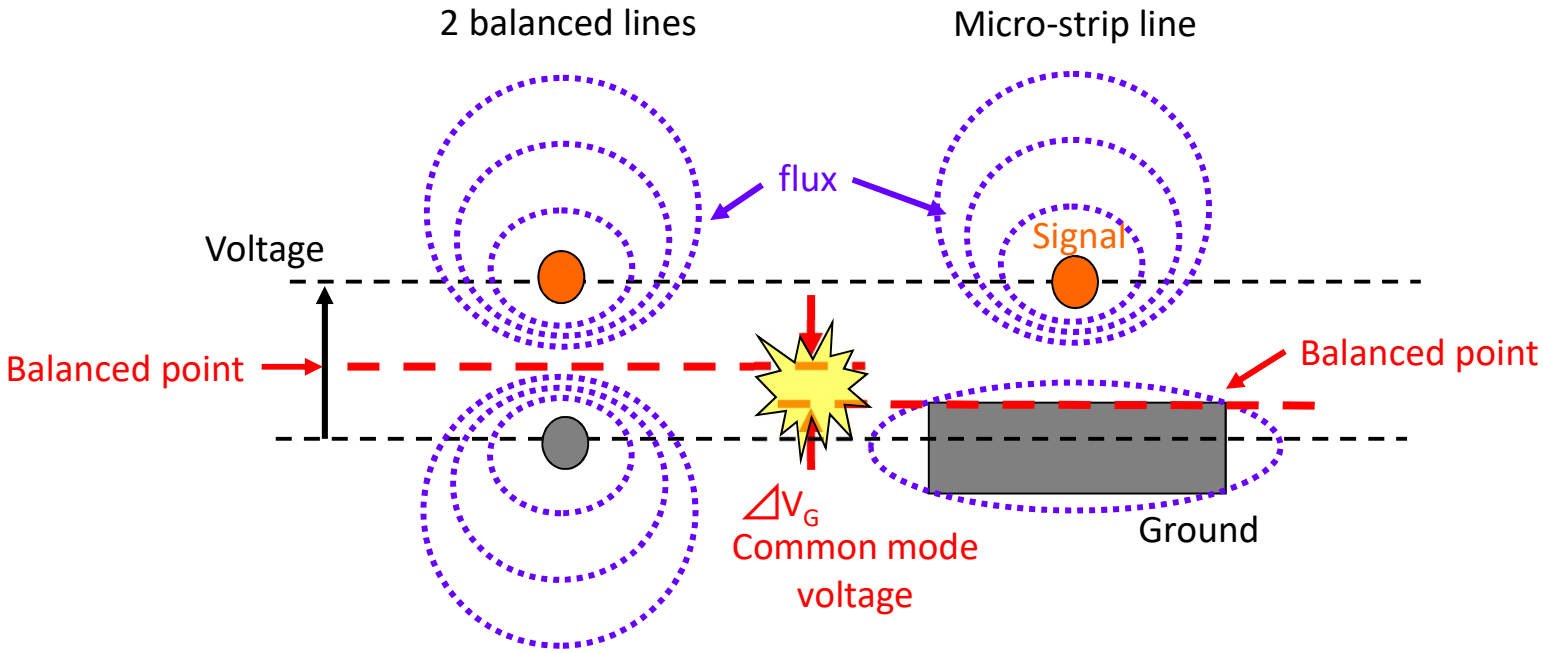


$$\lambda(m) = 300 / f(MHz)$$

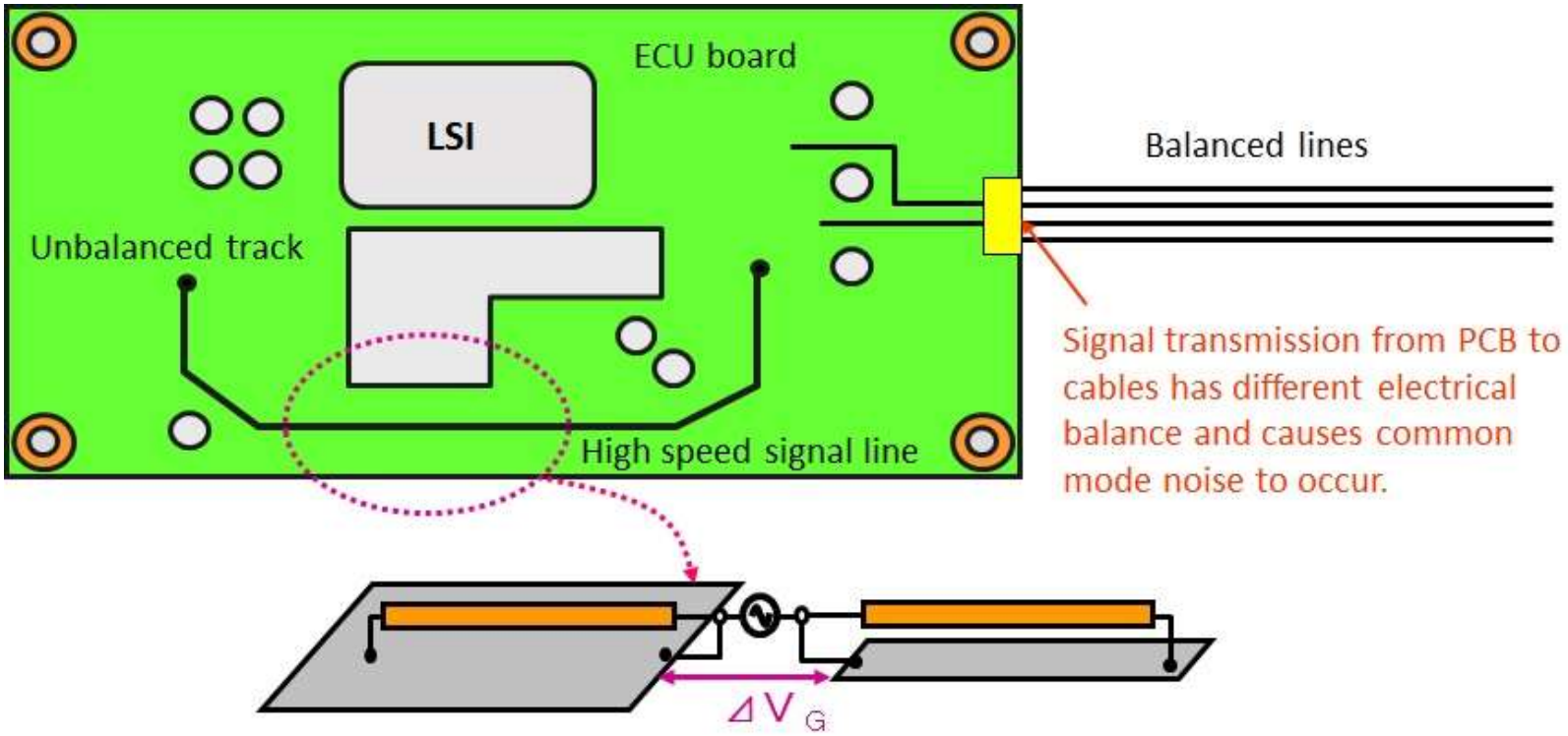
- Ideally 1/20 wavelength distance (FG used to increase area of the PCB ground)
- At least 1/8 wavelength distance (Prevents the increase of noise by resonance)

Mismatched Electrical Balance

Connecting tracks with different electrical balance causes a difference in voltage potential through the ground, creating common mode current.

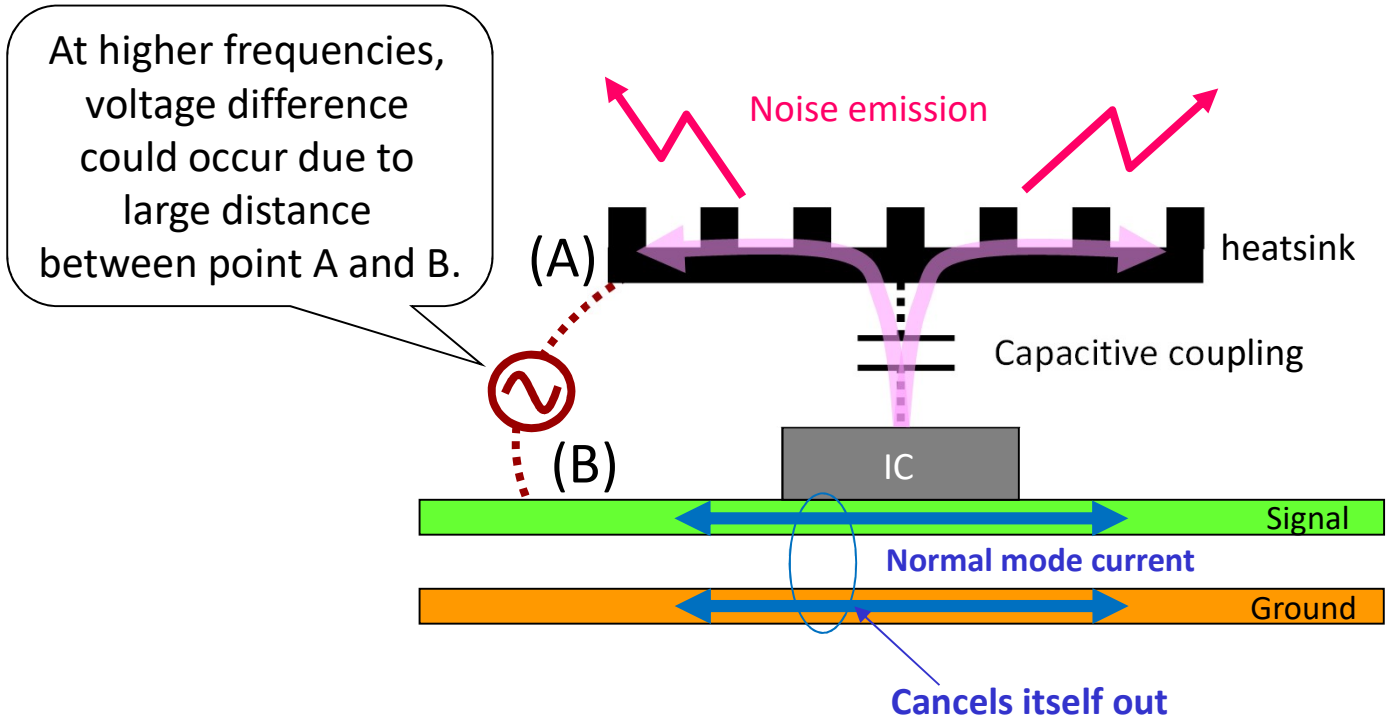


Example of Mismatched Electrical Balance



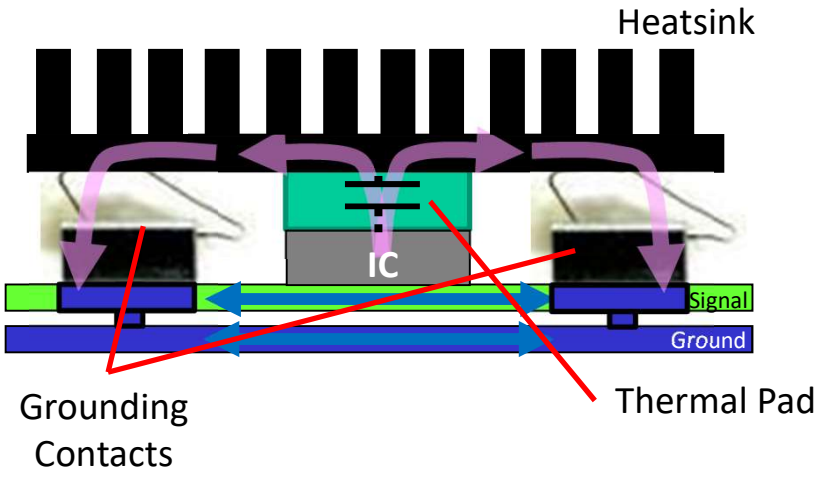
Even if micro-strip tracks are the same, if the ground width changes, so will the electrical balance.

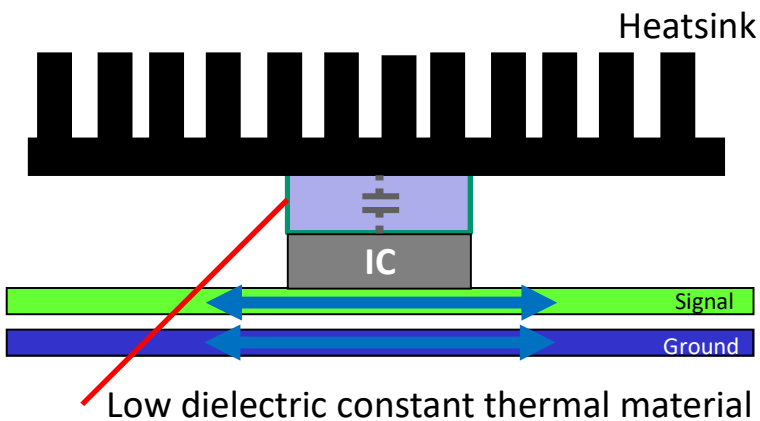
Voltage Driven Model

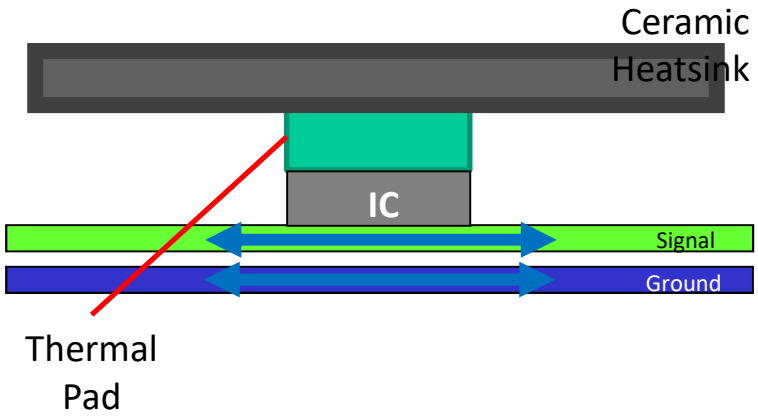


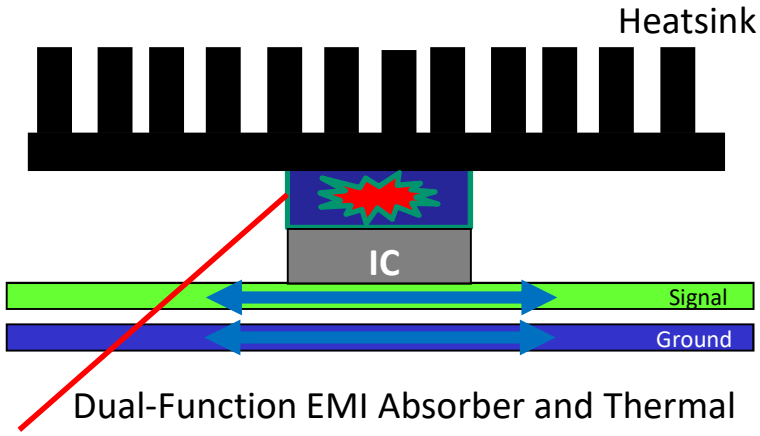
High frequency voltage difference and capacitive coupling generate common mode noise.

Potential Solutions to Address Noise Antenna

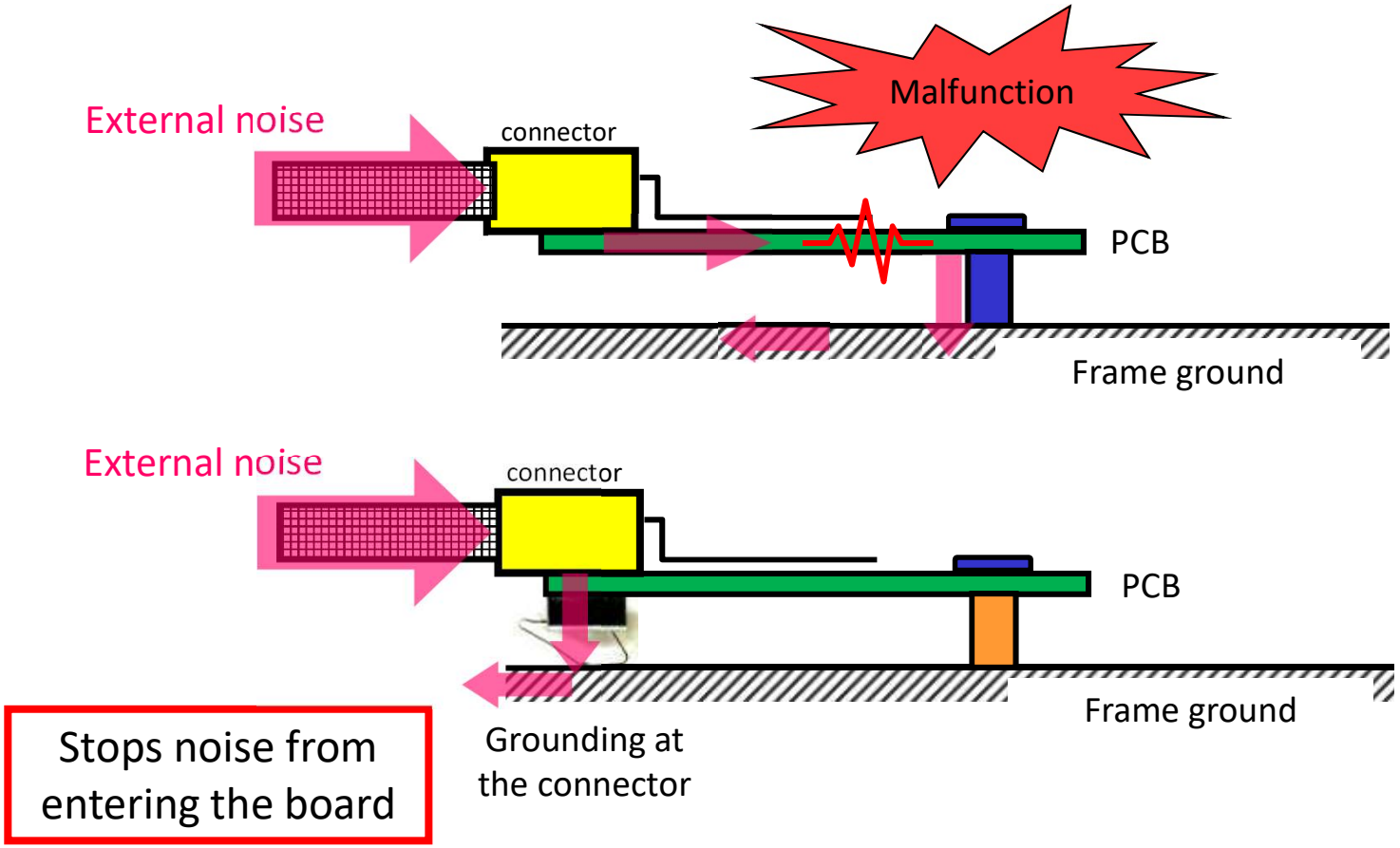






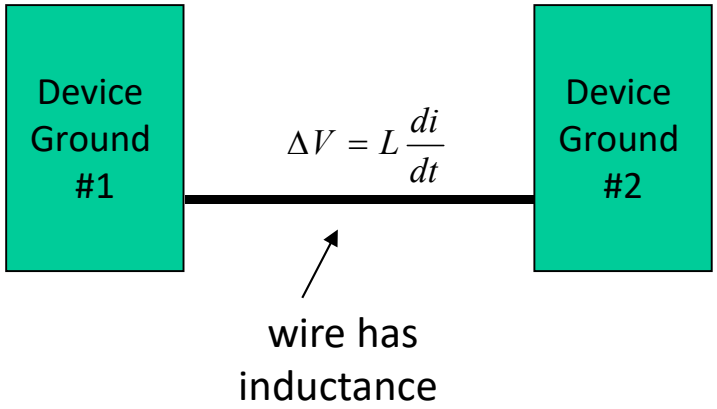


Grounding Around Connectors



Grounding High Frequency Noise

Noise caused by potential difference in ground



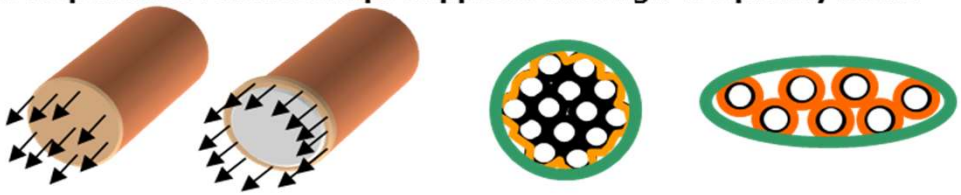
1cm ground wire has about 1nH inductance

Need to reduce wire inductance

Impedance characteristics - FG mesh

Frequency (MHz)	50	100	200	300	400	500
FG mesh (Ω)	13.2	26.2	54.9	88.1	135.1	201.8
AWG16 (Ω)	19.6	39.5	83.3	138.3	229.6	396.6

※**Low Impedance feature helps suppress the high-frequency noise**



①DC current ②AC current travels surface ③AWG16 cross section surfacial area SMALL ④FG mesh cross section surfacial area LARGE

Grounding Straps with Low Inductance

Key Points for Grounding

① Reduce ground impedance

- Reduce self inductance and increase mutual inductance
- Ground with low impedance

② Eliminate voltage potential difference (reduce balance mismatch)

- Increase ground surface
- Increase electrical contact to base ground

③ Consider the wavelength of the problem frequency

- λ (m) = 300 / f (MHz)
- Recommended minimum distance between ground points is $\lambda/8$