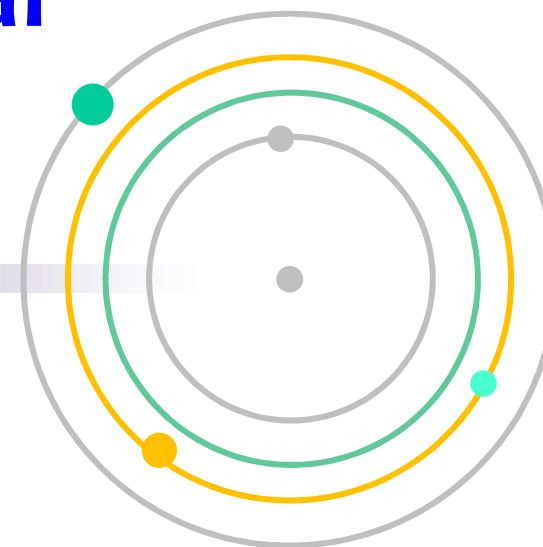


# EMC Technical Seminar



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G2024-003E

# Contents

1. Fundamentals of EMC
2. Shielding Techniques and Components
- 3. Grounding Techniques and Components**
4. Filtering Techniques with Ferrite Cores

# Grounding with Low Impedance Connection

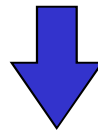


# Grounding

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

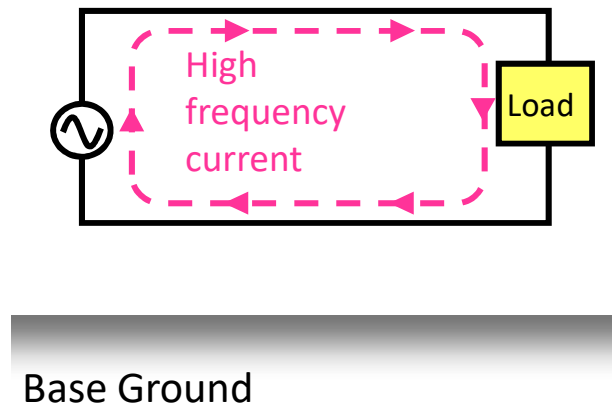


Key Consideration for EMC Grounding

Increasing ground area reduces impedance

# Two Types of Noise Current

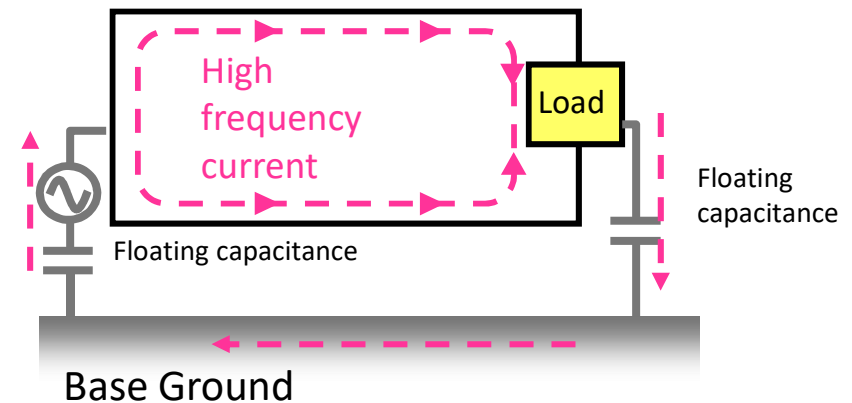
## Normal (Differential) Mode Current



- 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

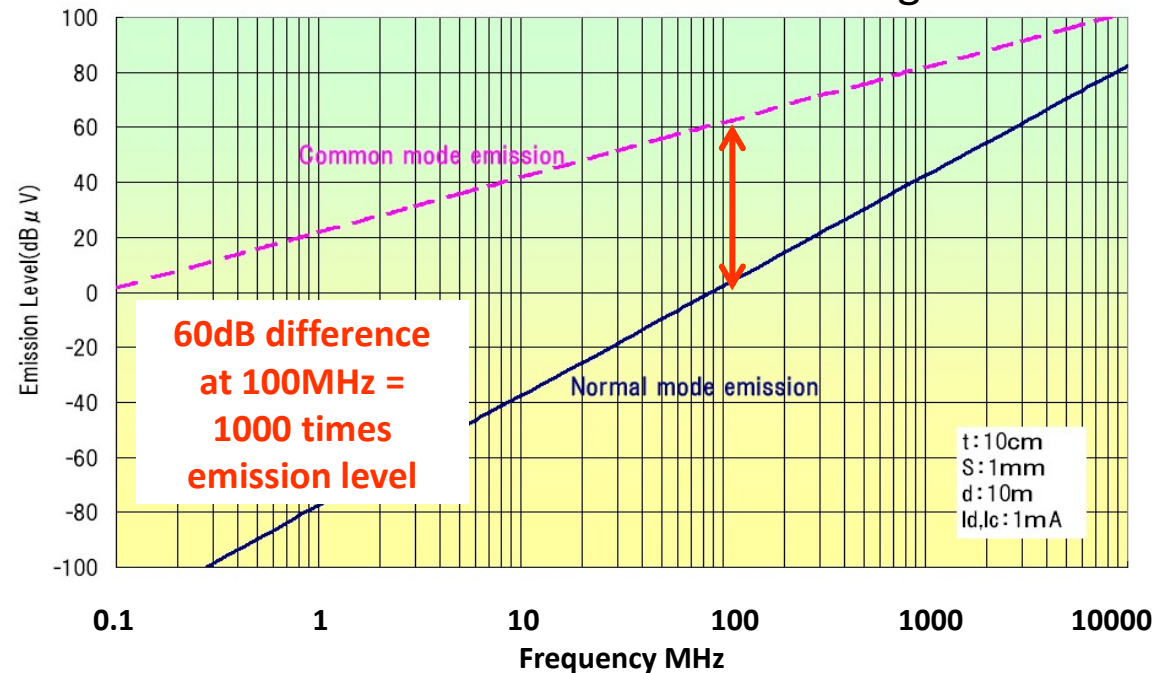
$$E = 1.257 \times 10^{-6} \frac{|I_C| \times f \times l}{d}$$

$I_C$ : 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



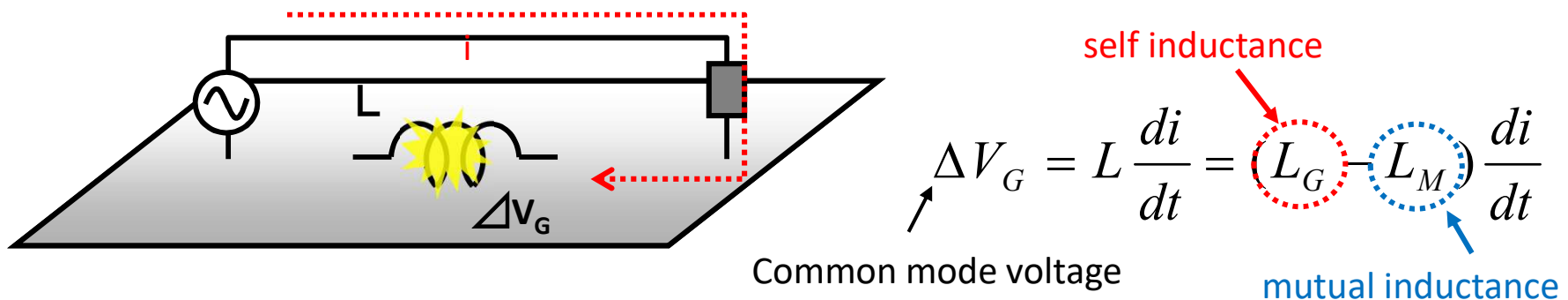
❖ Emission noise is dominated by common mode

Why does common mode noise occur?

# Cause of Common Mode Noise

The **Current Driven Model** as an explanation of common mode current

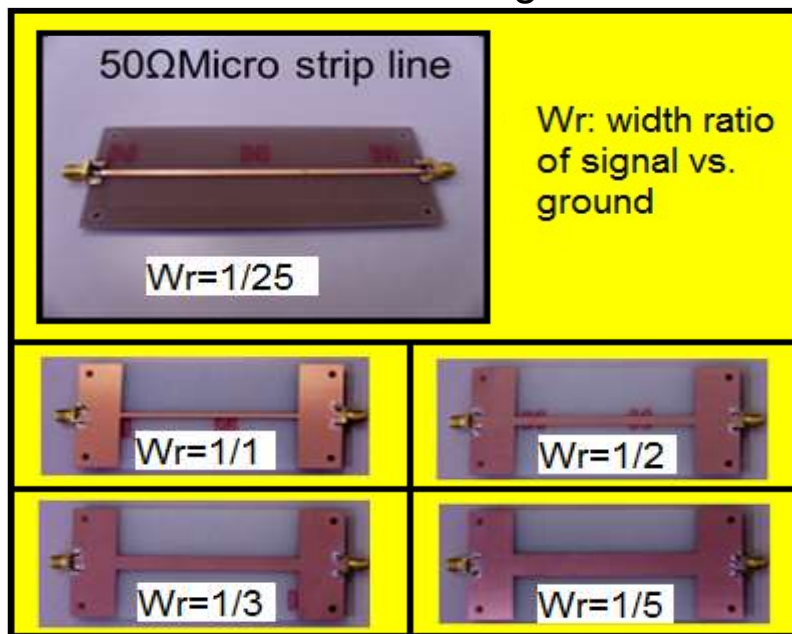
Current Driven Model



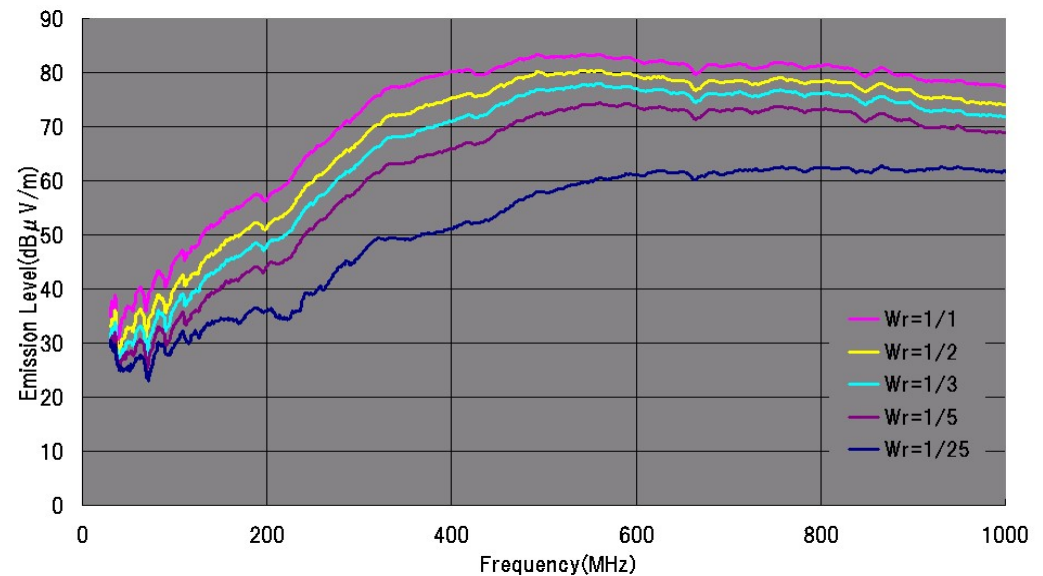
Reduction of **self inductance** and an increase of **mutual inductance** will reduce common mode voltage.

# Ground Area and Grounding Effectiveness

Test boards with various ground widths



Emission from lines with varying ground widths

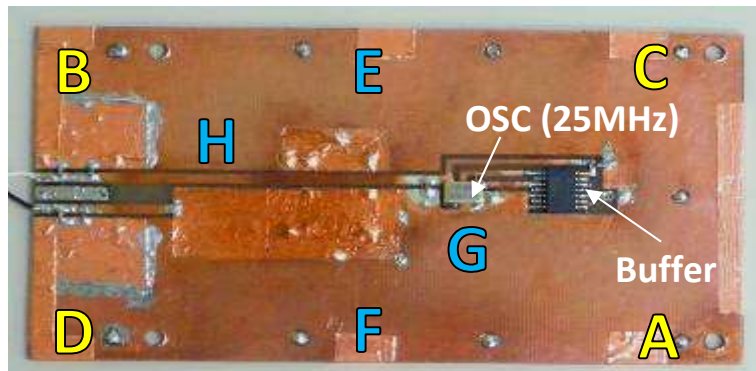


Larger ground area reduces self-inductance and increases mutual-inductance.

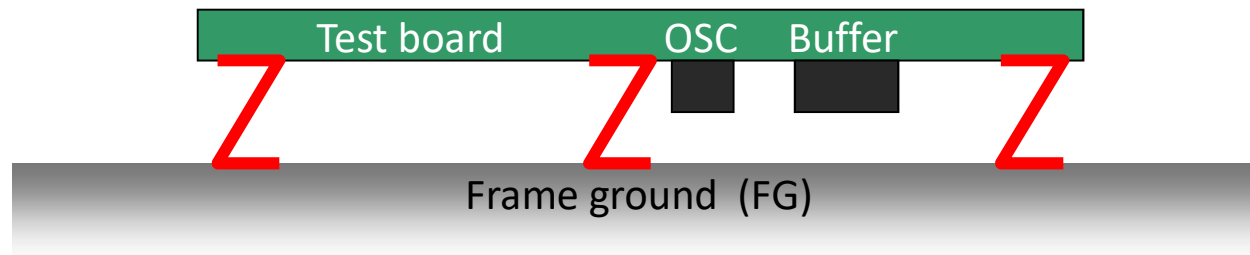
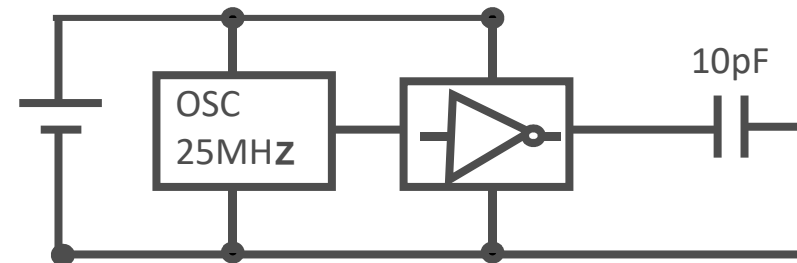


# Increasing Ground Area

Multiple grounding points to the frame ground to reduce ground impedance



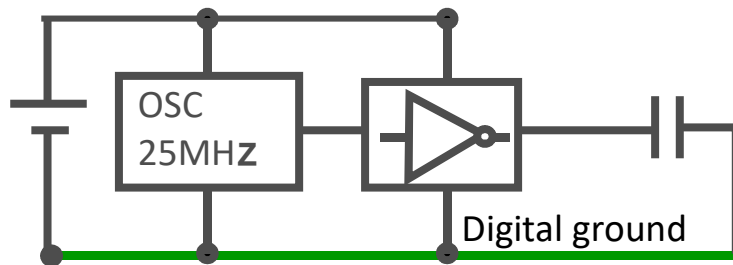
Grounding Points



## 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**

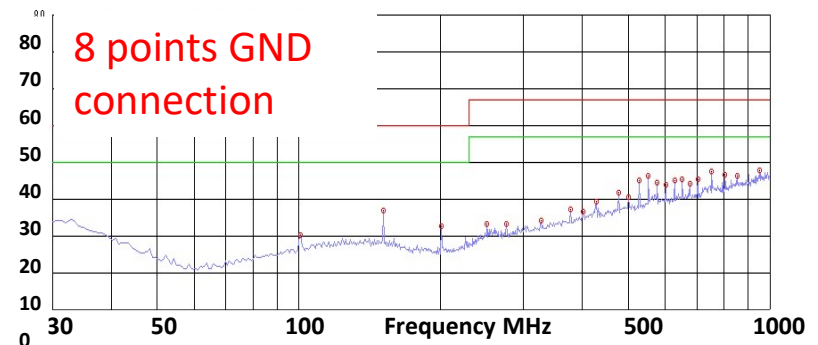
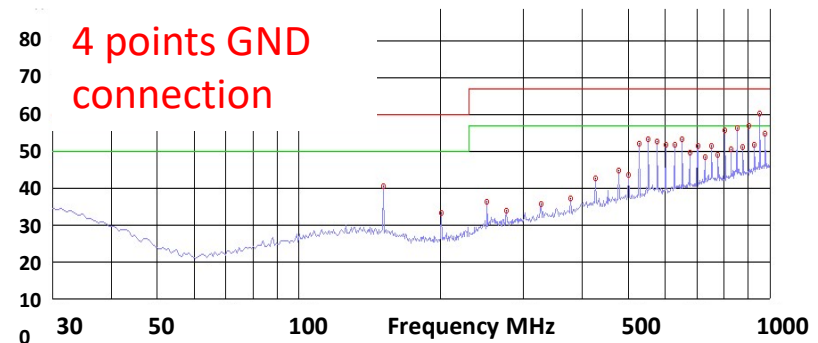
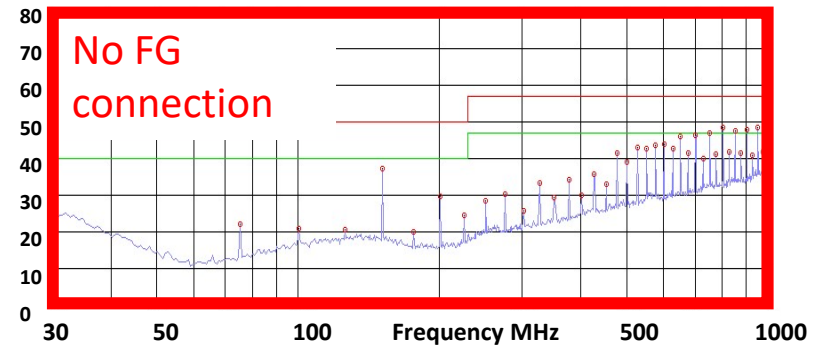
# Multiple Connections to FG



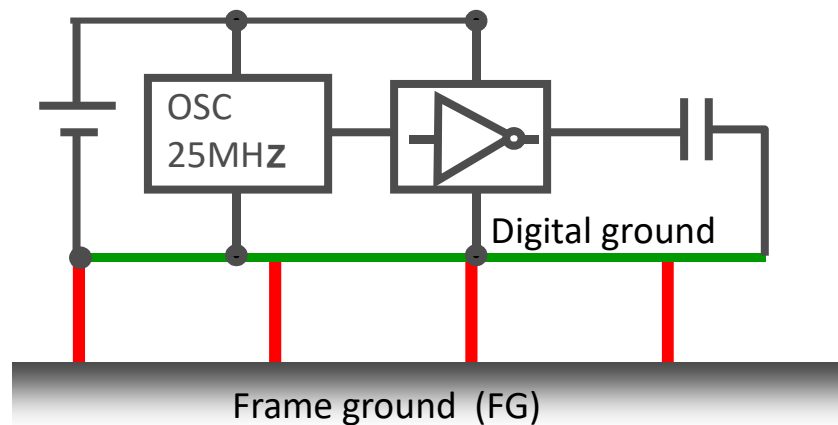
Frame ground (FG)

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

Horizontal Polarization

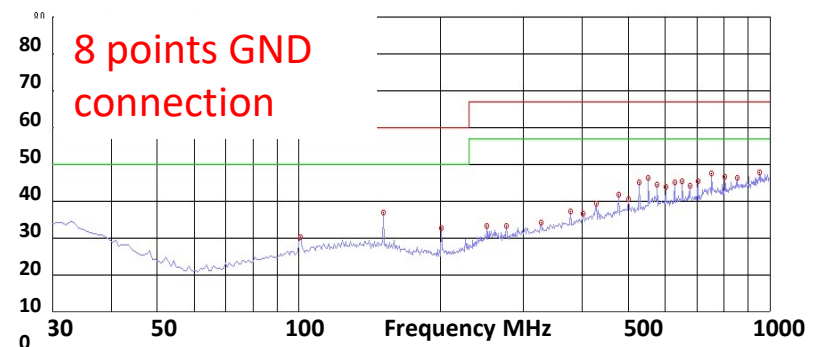
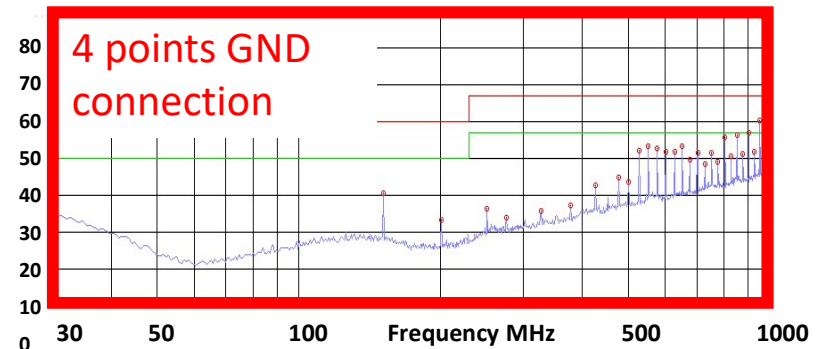
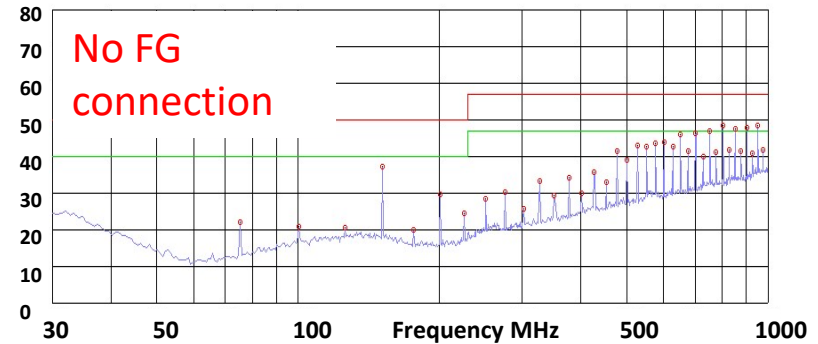


# Multiple Connections to FG

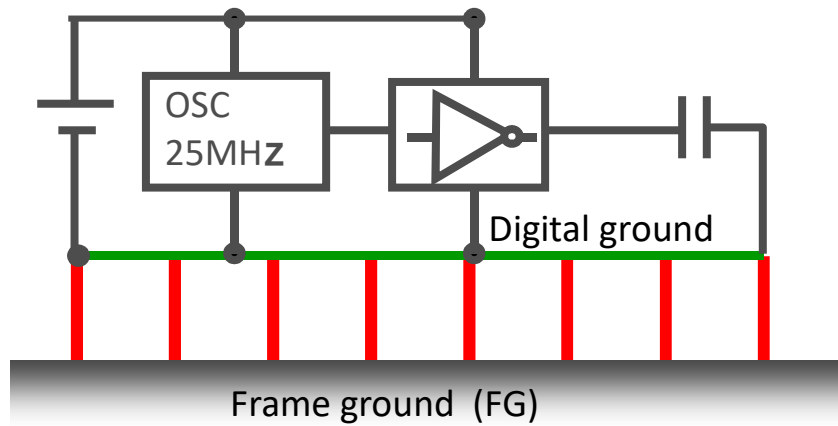


This is the level of radiation for connection at 4 points. The effect could be observed up to approximately 400 MHz.

Horizontal Polarization

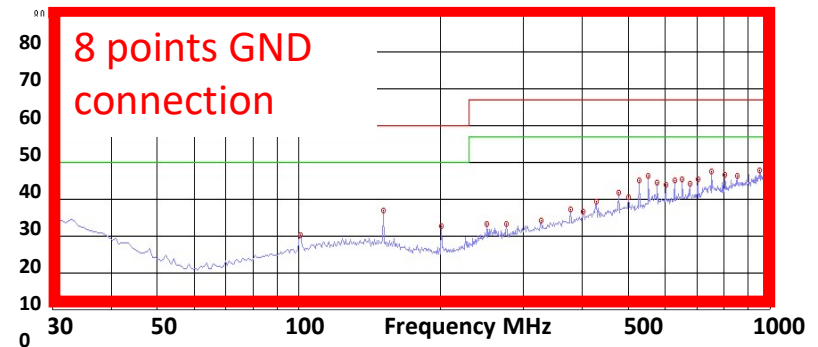
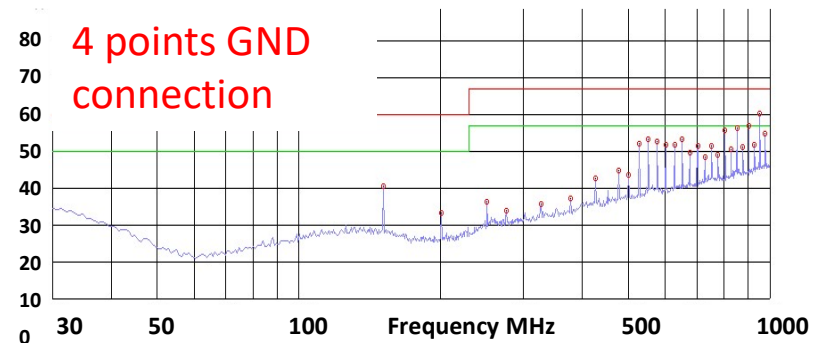
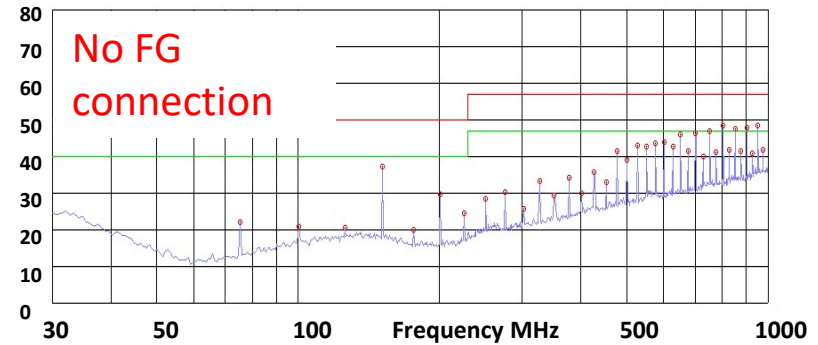


# Multiple Connections to FG

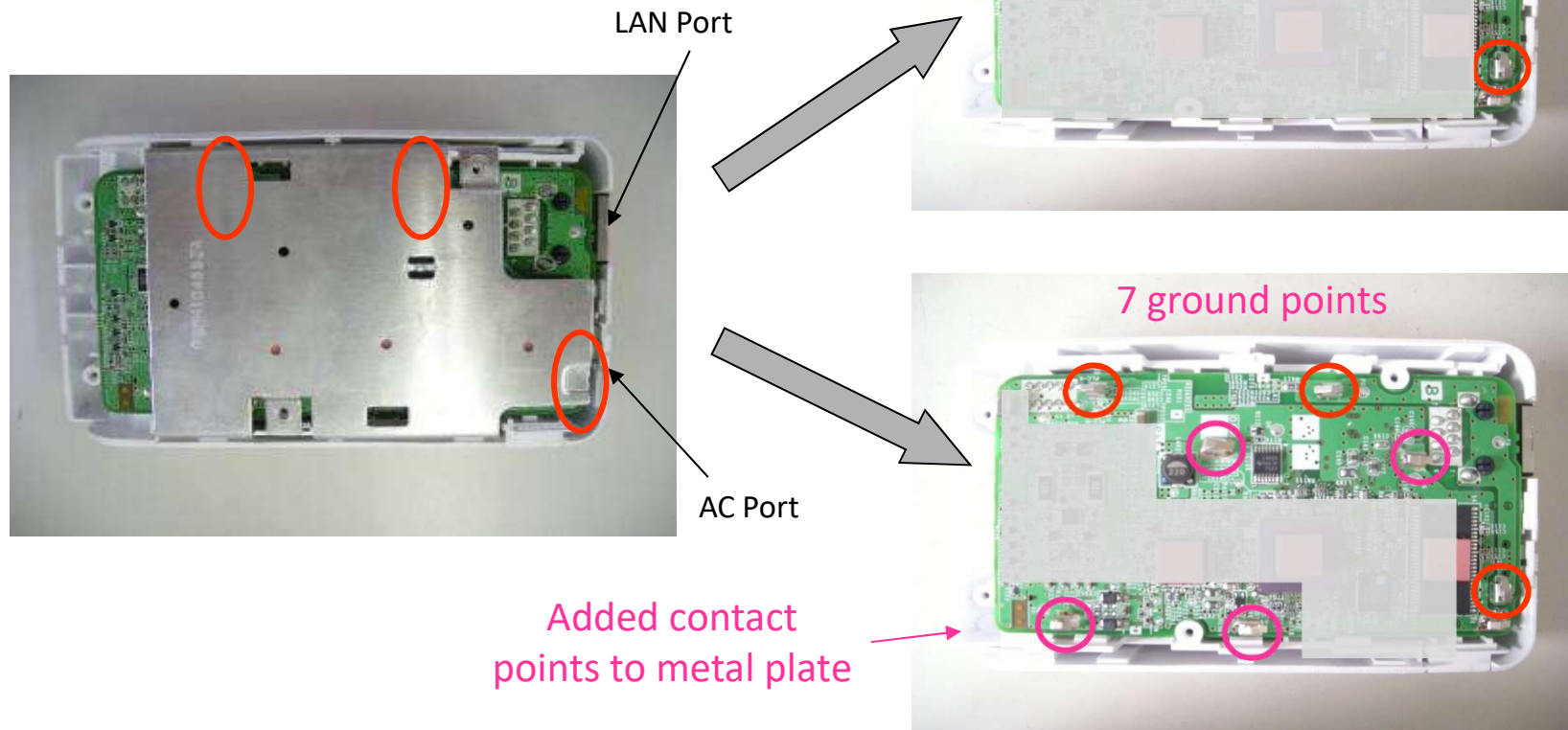


Improved suppression can be obtained by multi-point grounding.

Horizontal Polarization



# EMC Improvement with Additional Grounding Points

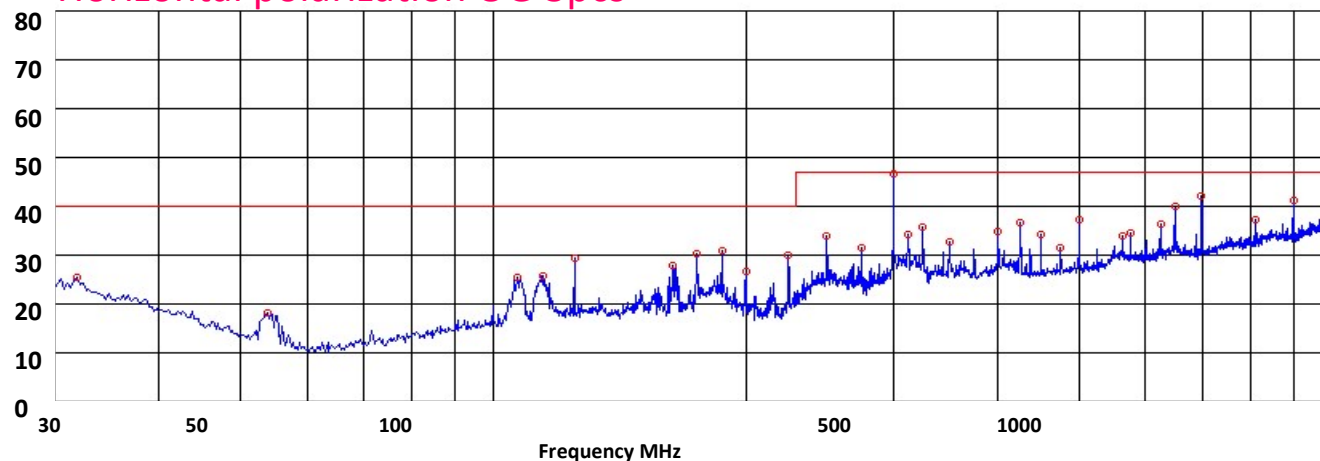


※ Grounding contact incorporated on PCB to touch the shield can to increase ground area.

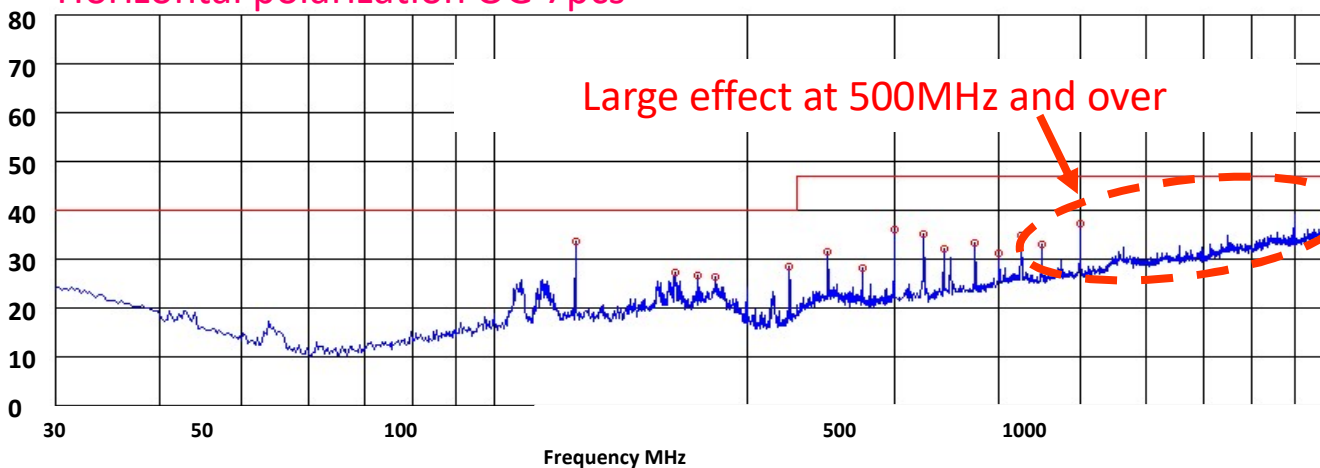
# EMC Improvement with Additional Grounding Points



Horizontal polarization OG 3pcs

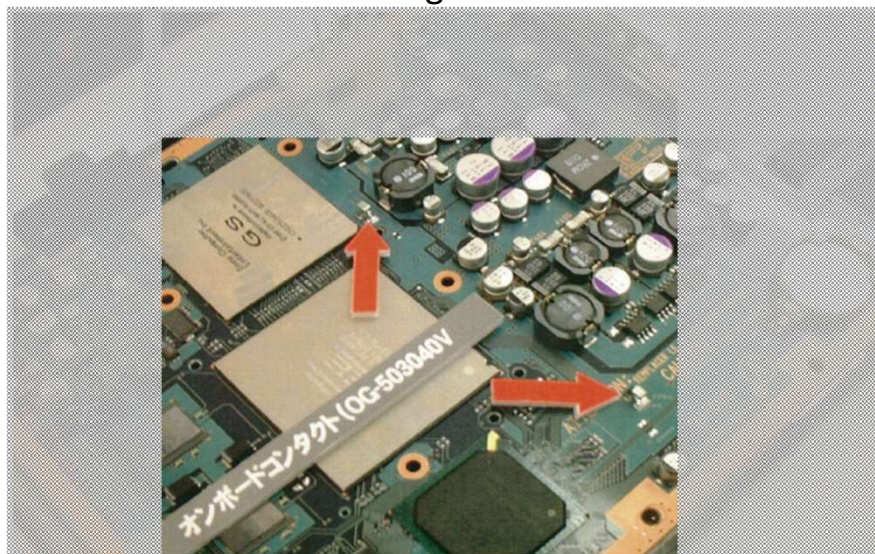


Horizontal polarization OG 7pcs



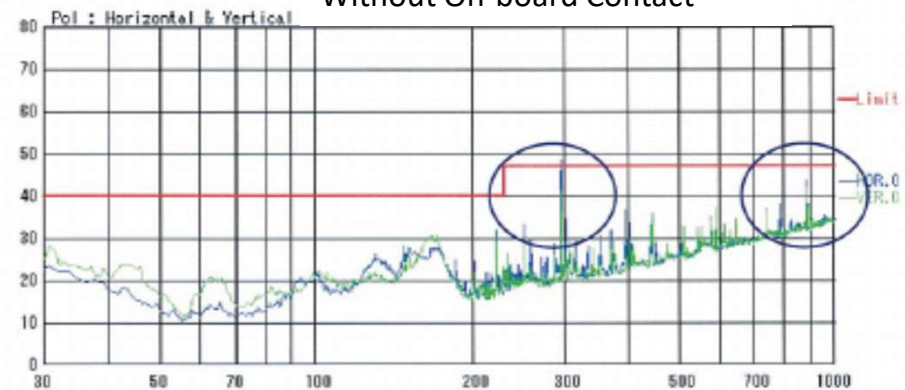
# EMC Improvement using Grounding Contacts

Mounting on the PCB



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

Without On-board Contact

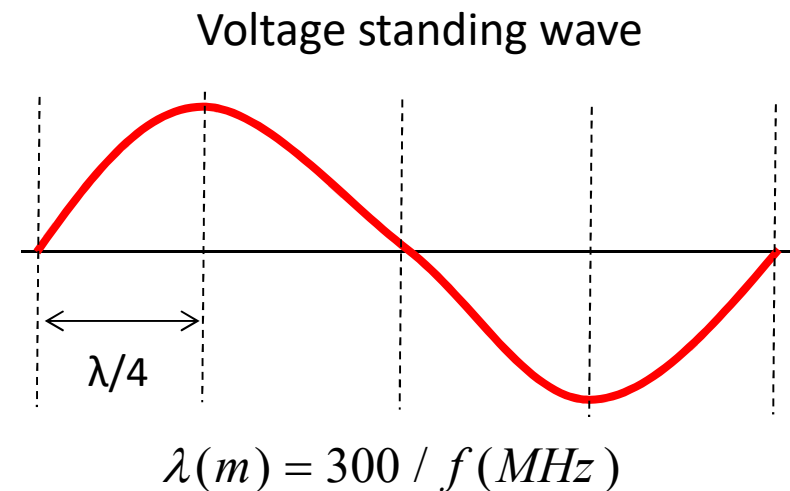
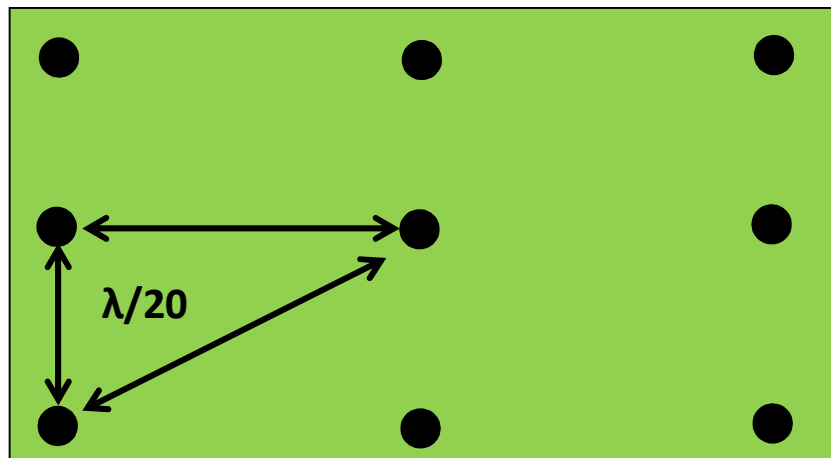


With On-board Contact (2pcs)



# Recommended Number of Grounding Points

## Ideal Placement Based on Theory

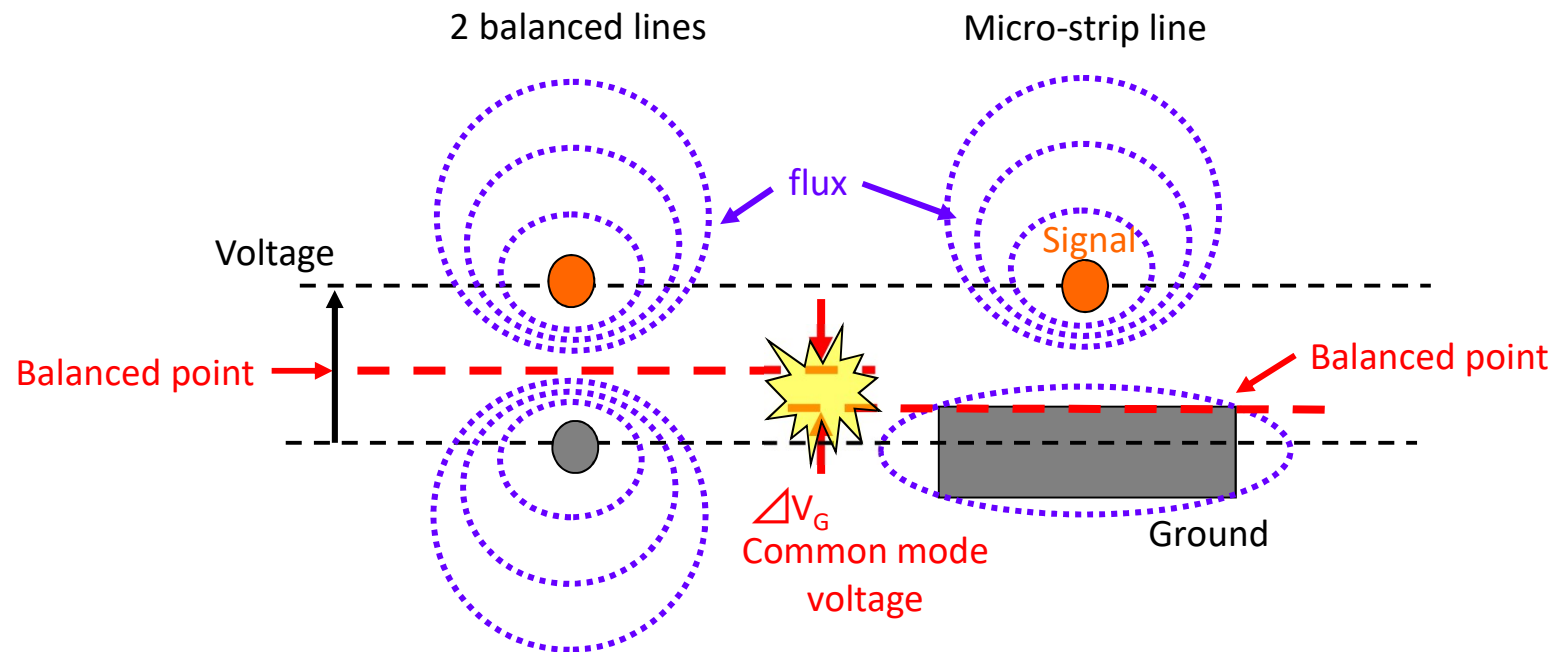


- Ideally 1/20 wavelength distance (FG used to increase area of the PCB ground)
- At least 1/8 wavelength distance (Prevents the increase of noise by resonance)

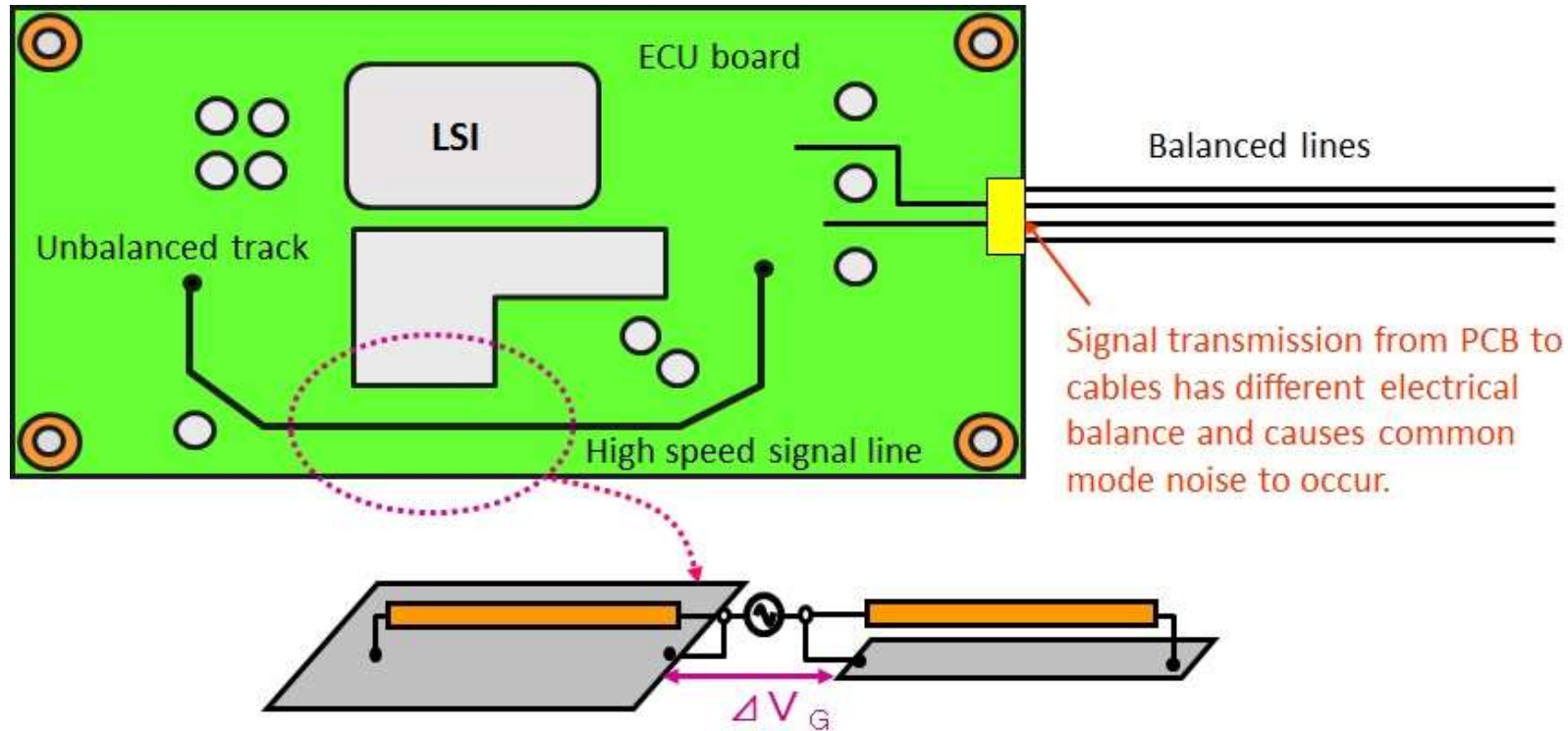


# Mismatched Electrical Balance

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

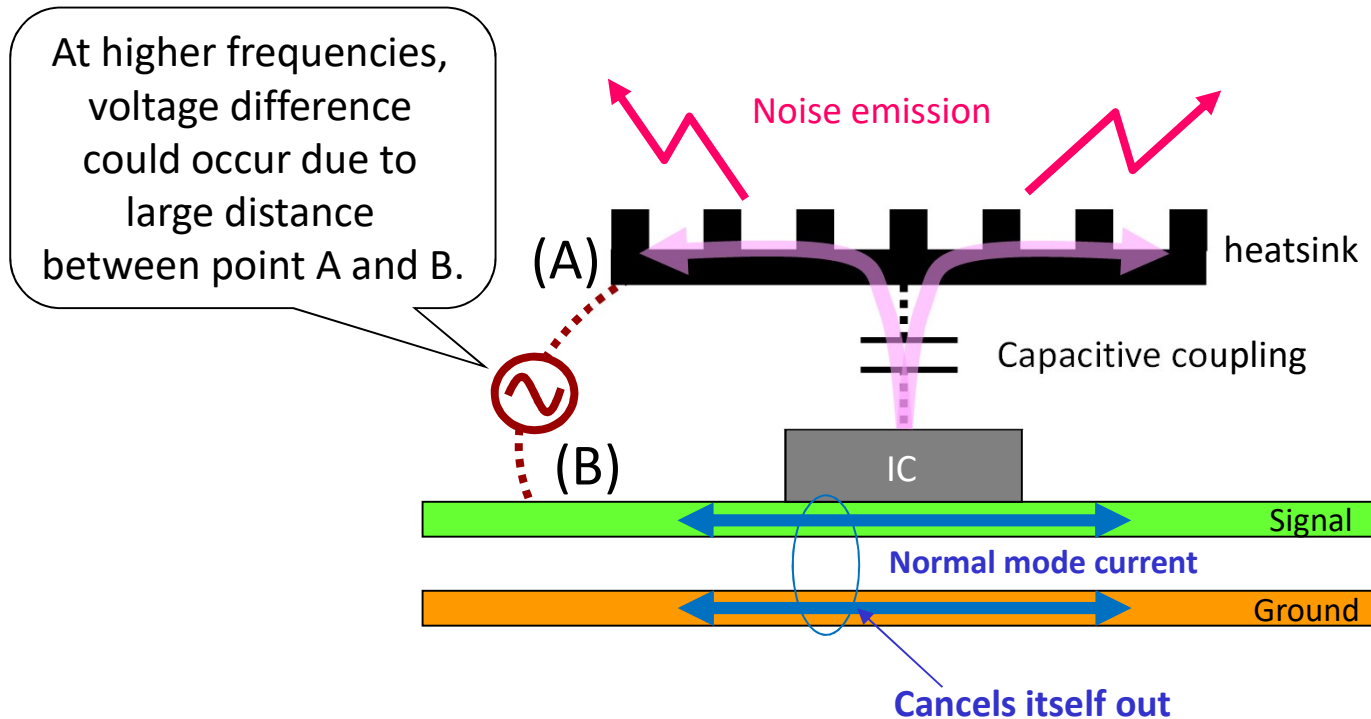


## Example of Mismatched Electrical Balance



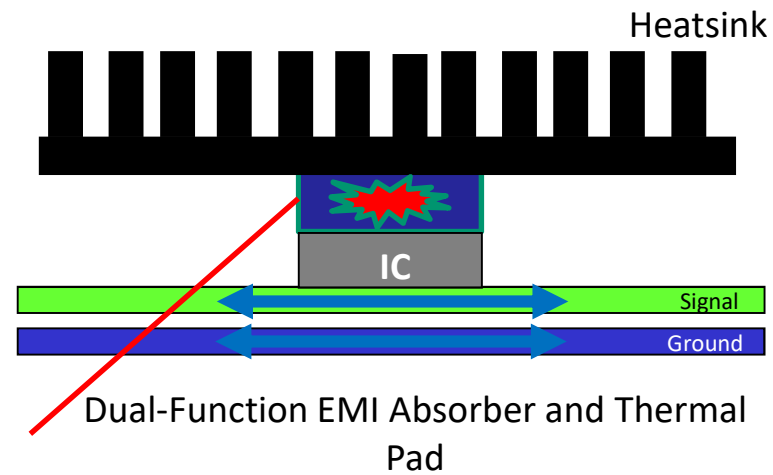
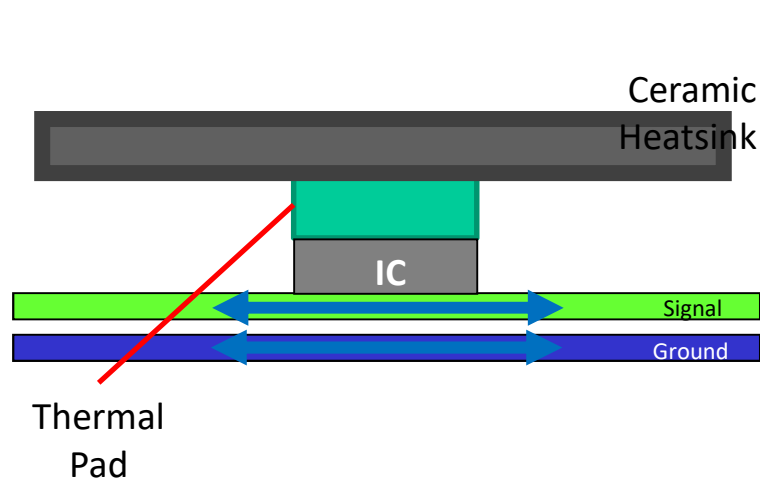
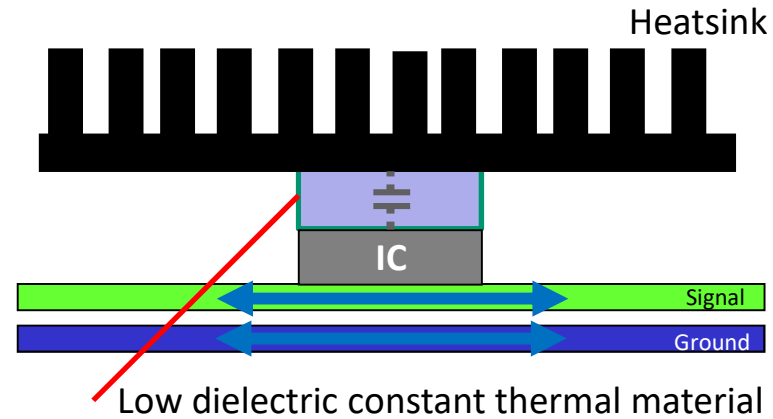
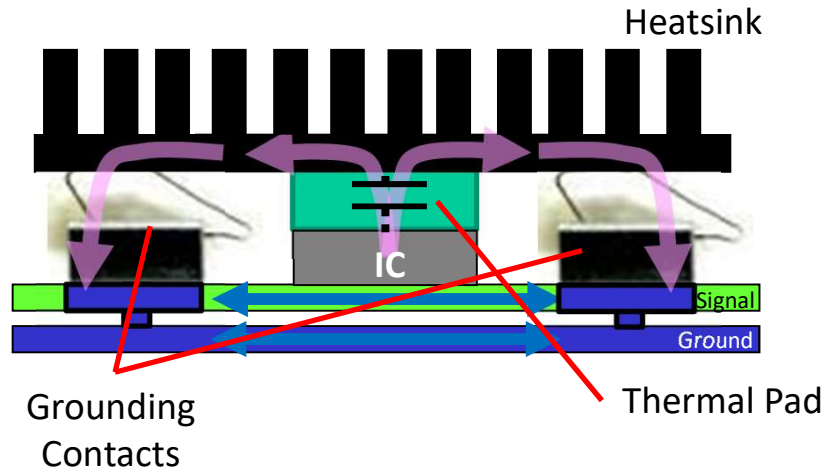
Even if micro-strip tracks are the same, if the ground width changes, so will the electrical balance.

# Voltage Driven Model

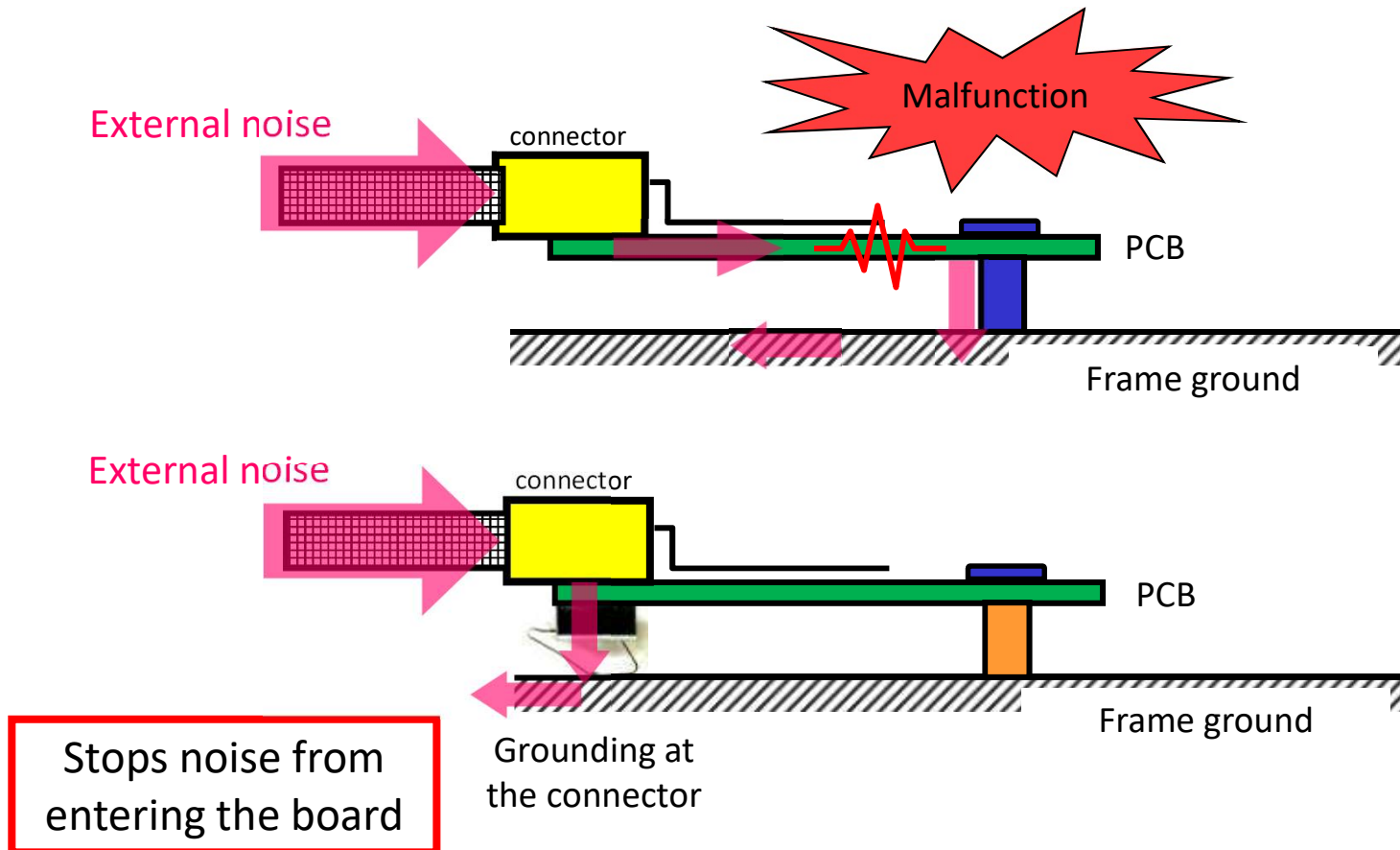


High frequency voltage difference and capacitive coupling generate common mode noise.

# Potential Solutions to Address Noise Antenna

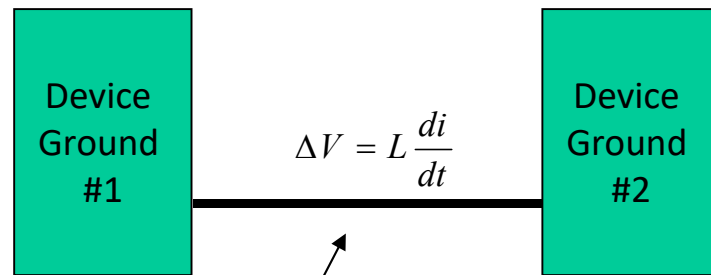


# Grounding Around Connectors



# Grounding High Frequency Noise

Noise caused by potential difference in ground



wire has inductance

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 ( $\Omega$ )	13.2	26.2	54.9	88.1	135.1	201.8
AWG16 ( $\Omega$ )	19.6	39.5	83.3	138.3	229.6	396.6

※ Low Impedance feature helps suppress the high-frequency noise



## 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

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