Empowered by Innovation NEC

Understanding EMI Suppression Mechanism by Visualization of Electromagnetic Field

EMC/SI/PI Seminar in San Diego

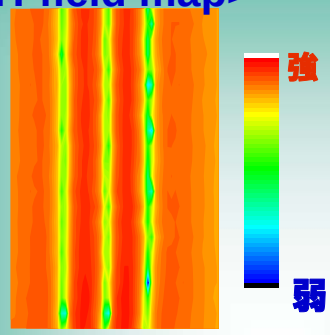
May 13 2011

HARADA Takashi

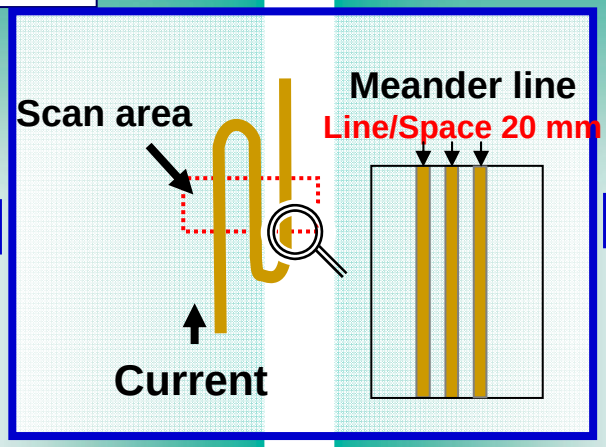
Visualization of EM Field

At low frequencies

<H-field map>

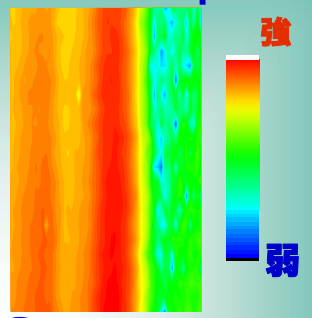


H_z@10 MHz



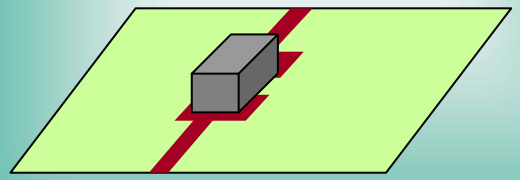
At high frequencies

<H field map>



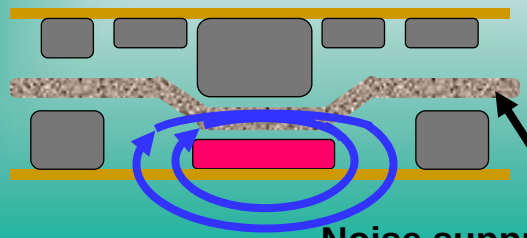
H_z@2.46 GHz

EM fields concentrate near traces



Controlled by lumped element components such as filters, capacitors

EM fields spread due to stray capacitance and intrinsic inductance



Understanding EM field behaviors by visualization

Contents

1. Electromagnetic field and theory

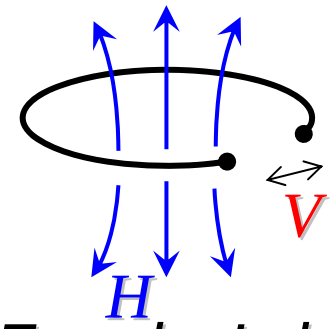
Maxwell's Equations

$$\nabla \times H = -\varepsilon_0 \varepsilon_r \frac{\partial E}{\partial t} - J$$

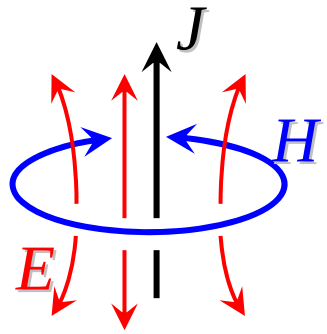
$$\nabla \times E = \mu_0 \mu_r \frac{\partial H}{\partial t}$$

$$\nabla \cdot E = -\frac{1}{\varepsilon} \rho$$

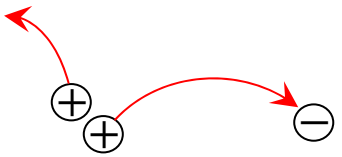
$$\nabla \cdot H = 0$$



Faraday's law



Ampere's law

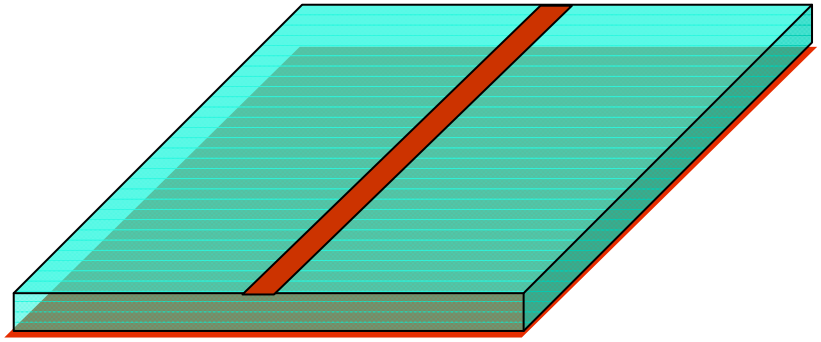


Gauss' law

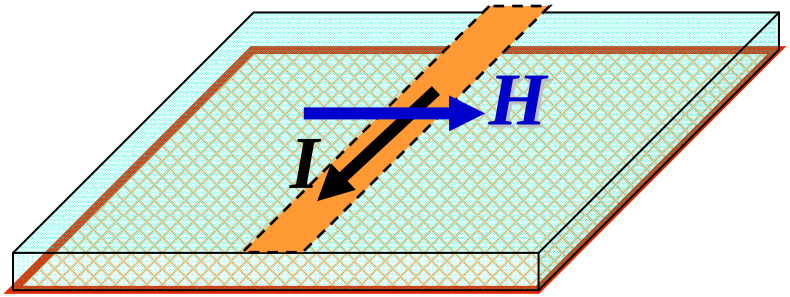
ε_0: **permittivity in free space**(8.85×10^{-12} [F/m])

μ_0: **Permeability in free space**($4\pi \times 10^{-7}$) [H/m])

Field Relations and Boundary Condition

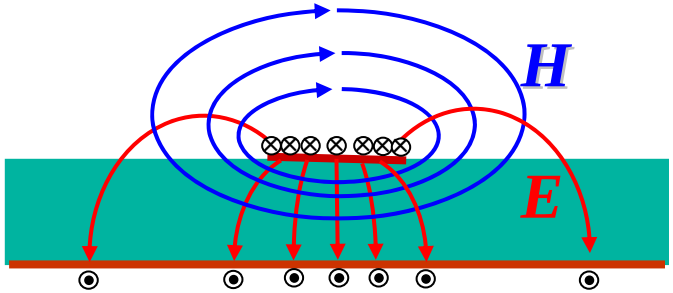


<Microstrip line>



H and I relations

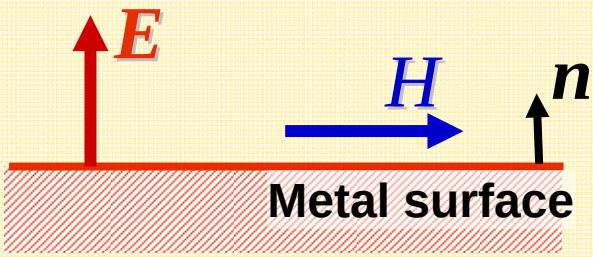
$H \perp I$



E and H relation

$E \perp H$

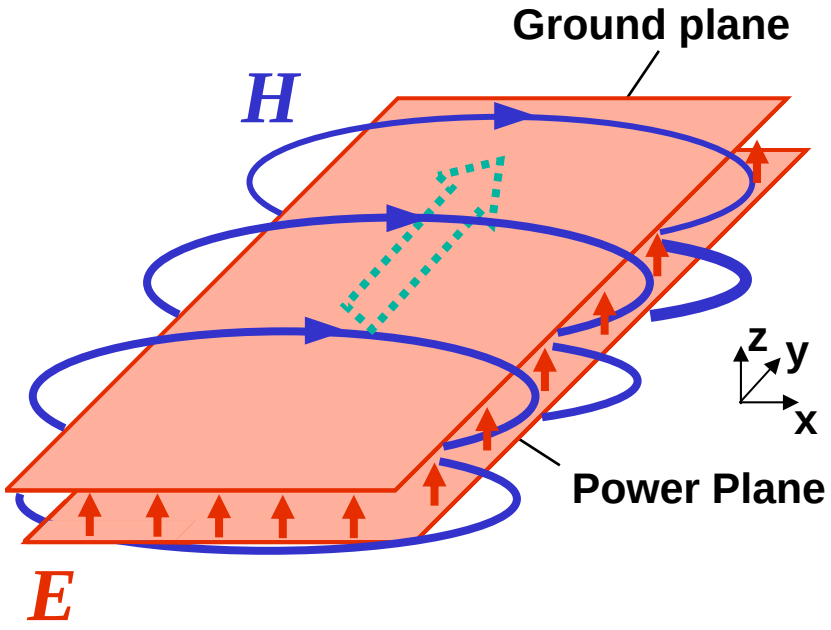
Boundary condition

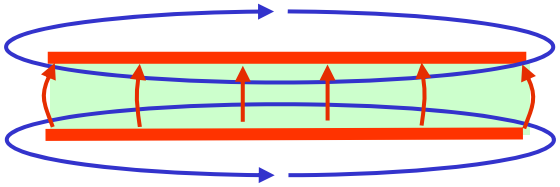


$E \parallel n$

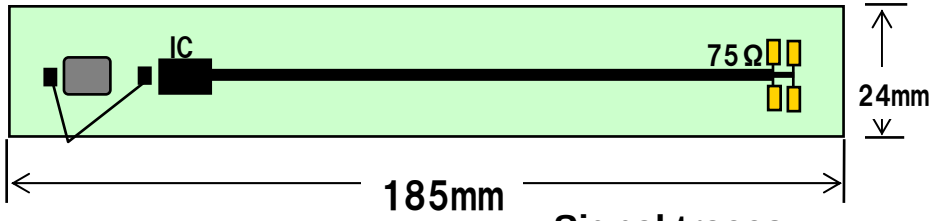
$H \perp n$

EM-field Distribution between Vcc and GND Planes

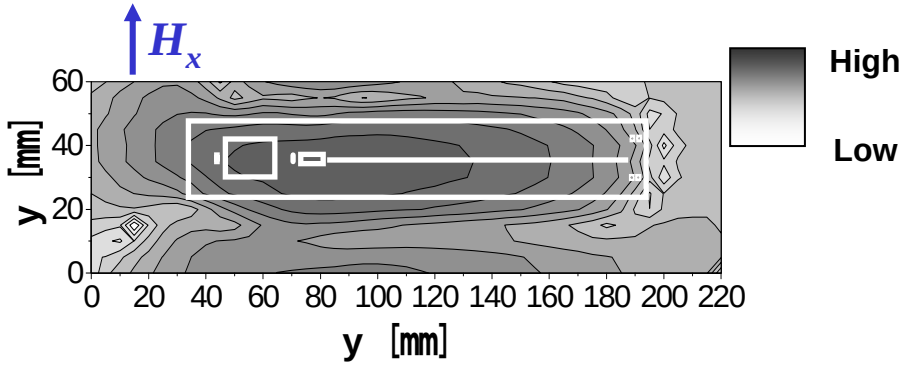




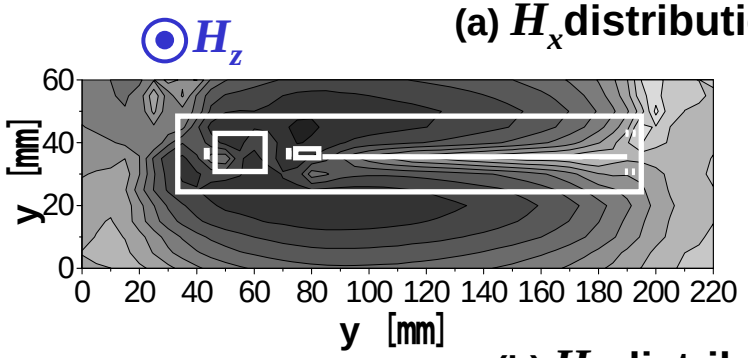
Cross sectional view



(Cross sectional view)



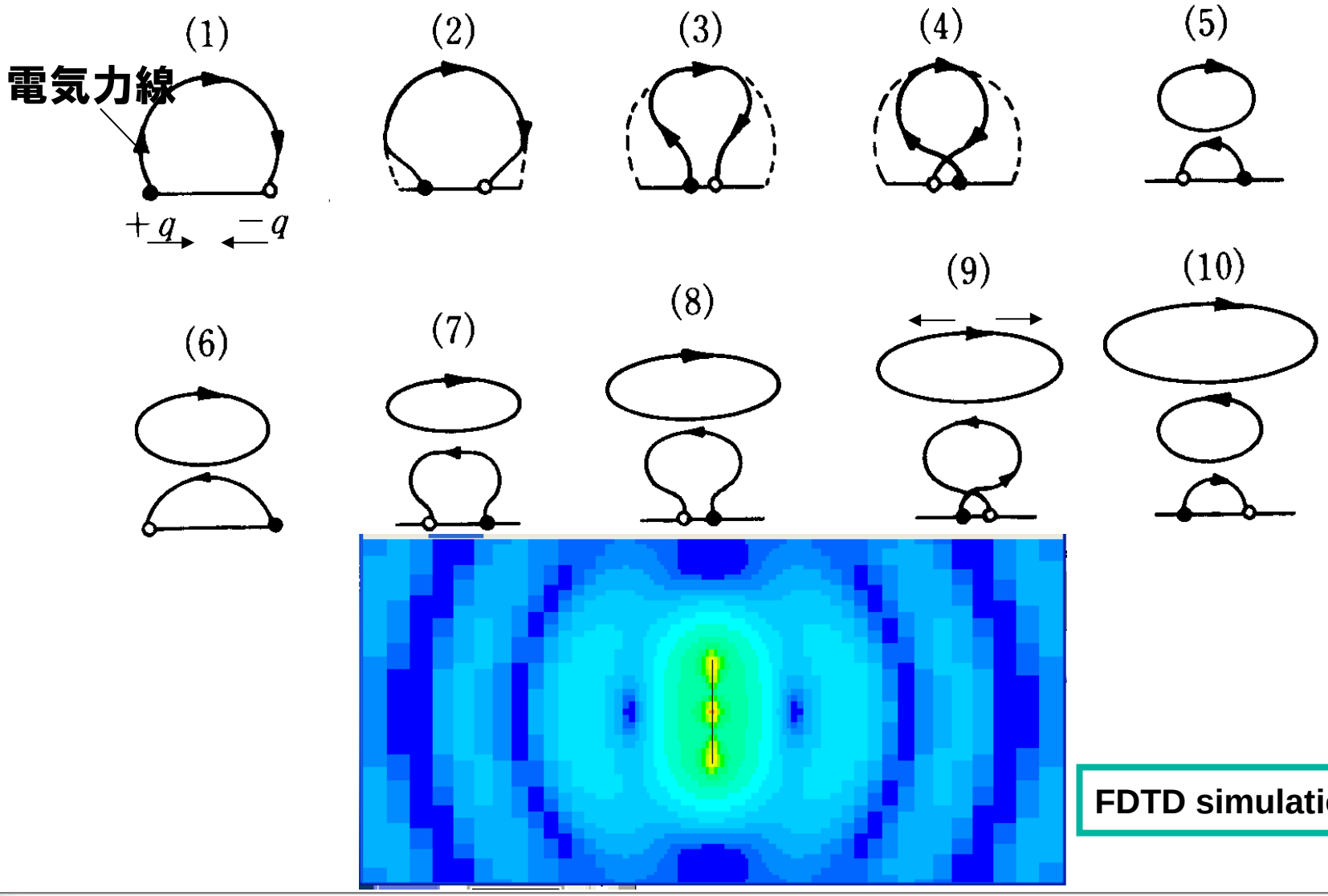
(a) H_x distribution



(b) H_z distribution

EM Radiation Mechanism of Dipole Antenna

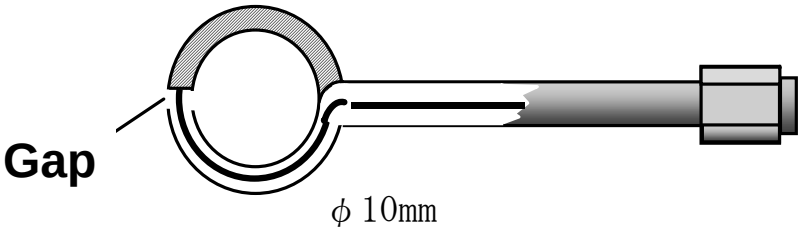
(Movement of charges)



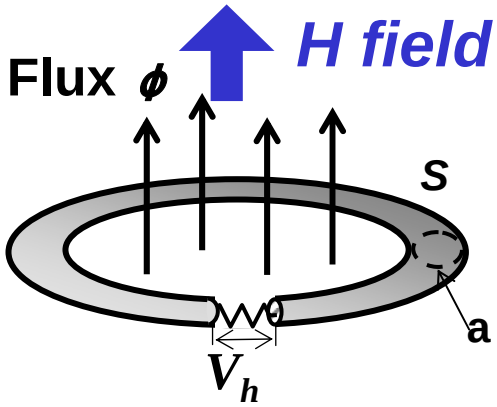
FDTD simulation

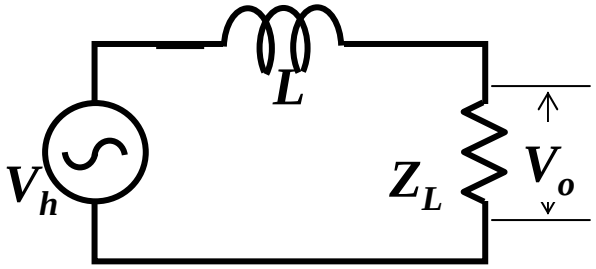
2. Visualization by Experiment
(Near field scanning)

H-filed Pick-up Loop Probe

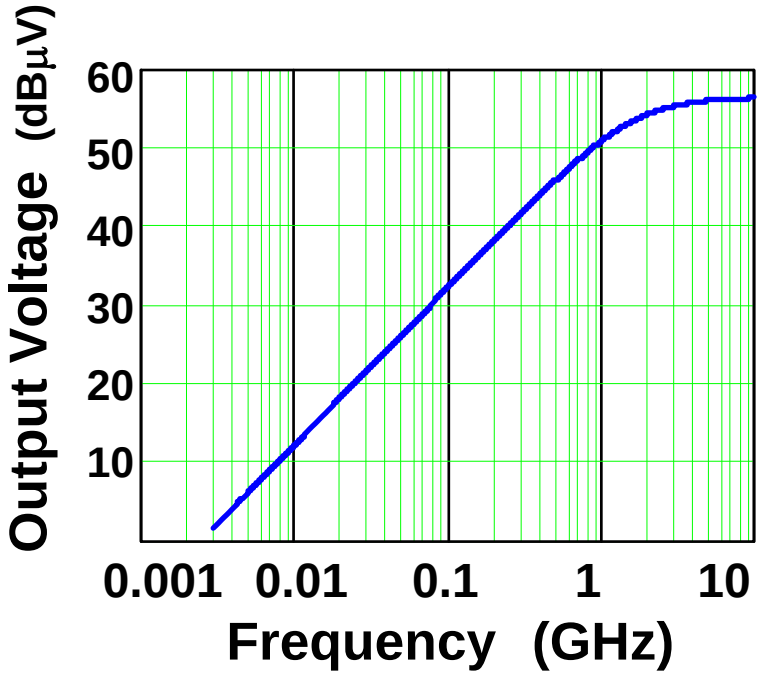


Shielded loop probe

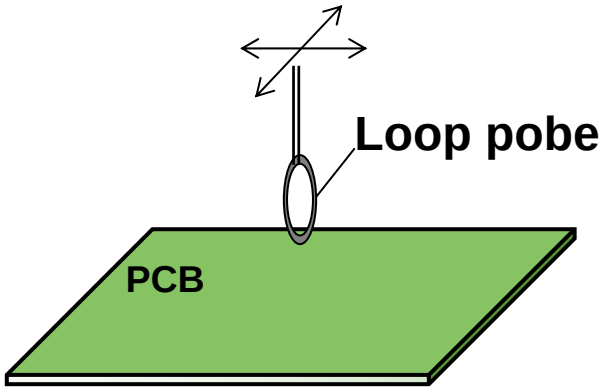




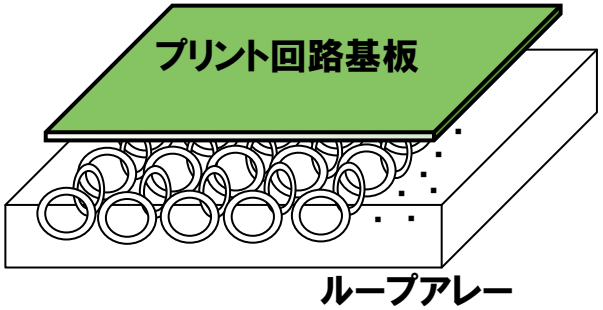
Equivalent circuit of the loop probe



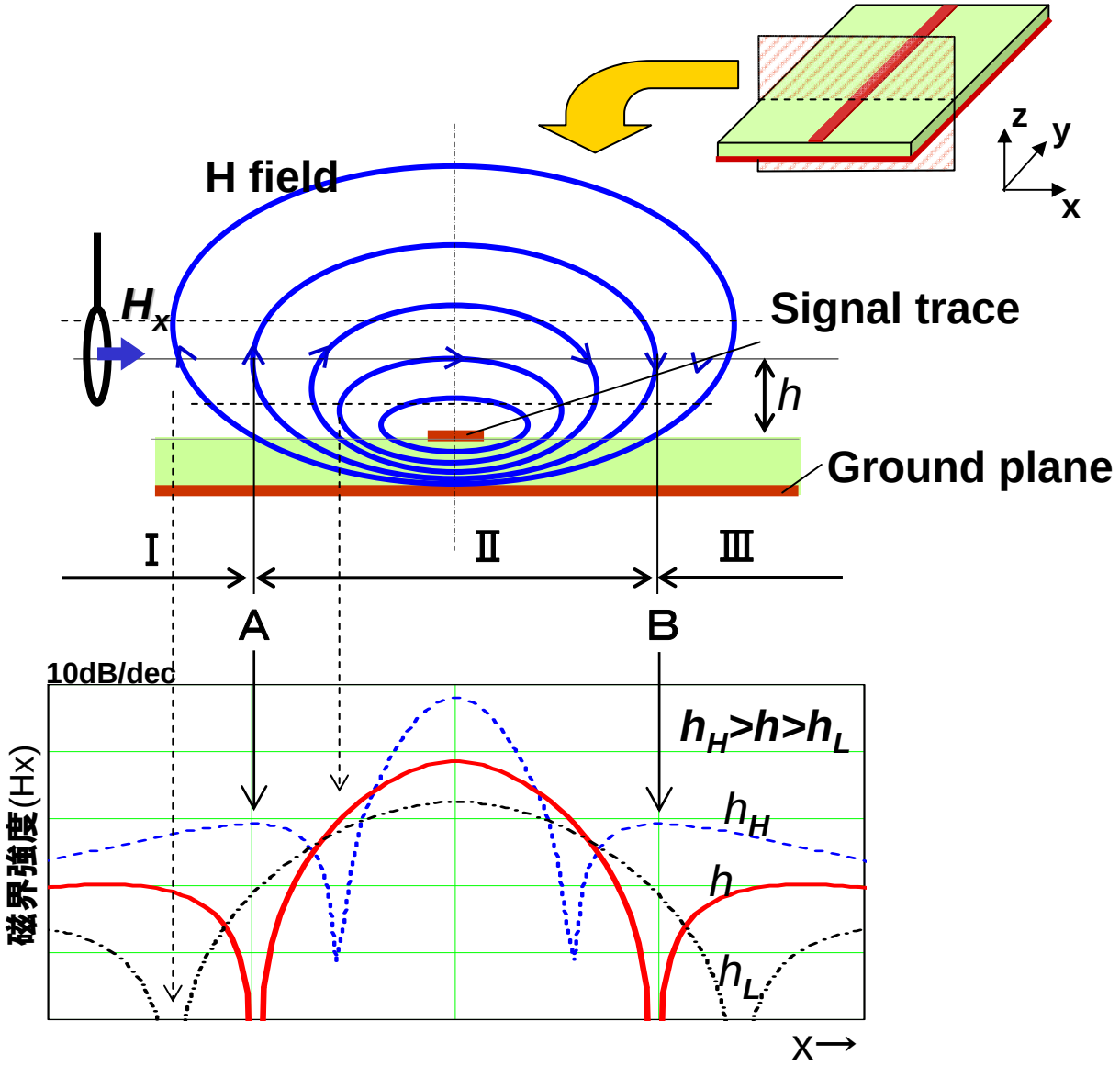
Magnetic-field Distribution Measurement



(a) Probe scanning



(b) Probe array



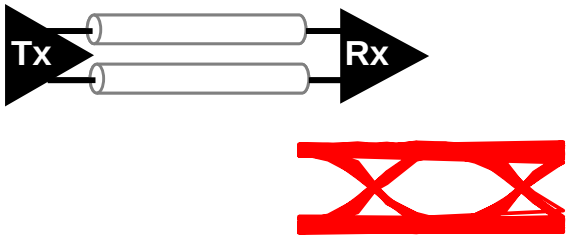
3. Visualization by Simulation

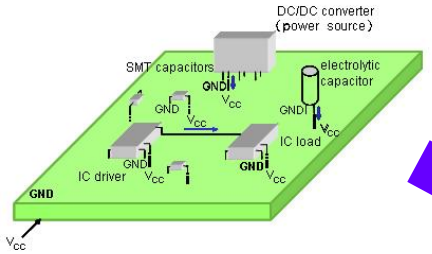
Circuit Simulator and Electromagnetic Simulator

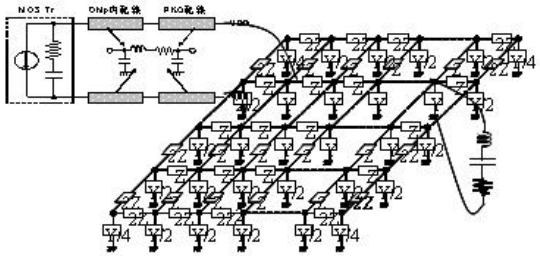
Circuit simulator

SPICE: Simulation Program with Integrated Circuit）

Signal Integrity

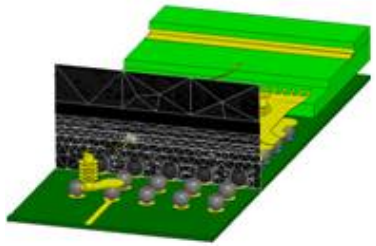


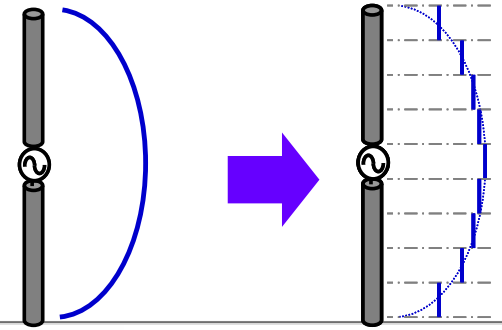




Full wave simulator

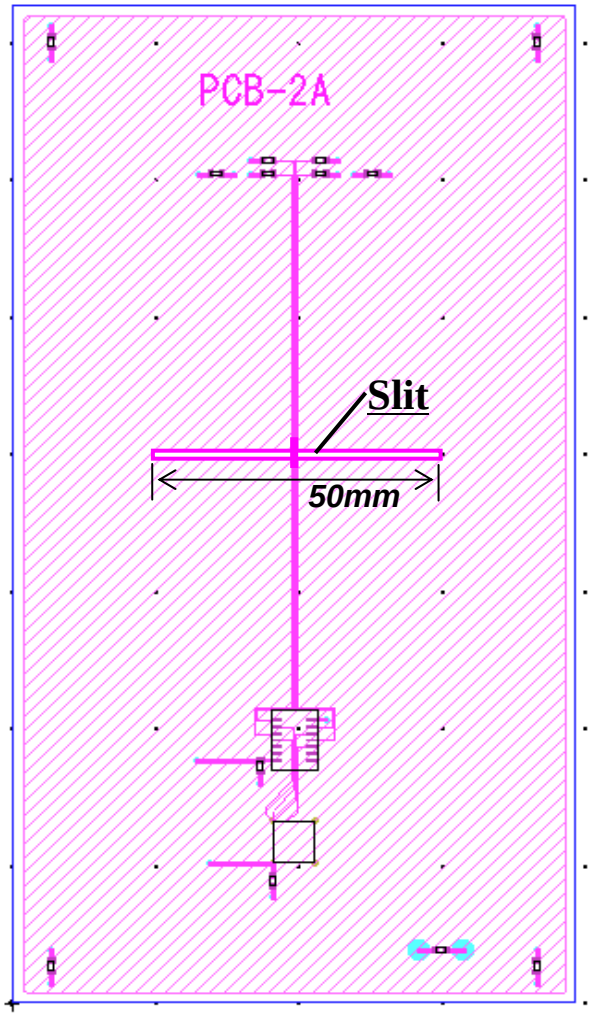
FEM: Finite Element Method
BEM: Boundary Element Method
FDTD: Finite Difference Time Domain

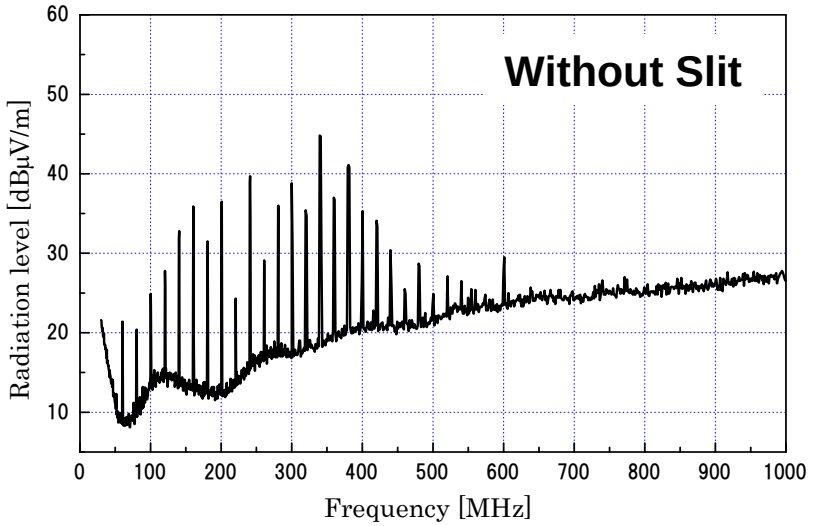


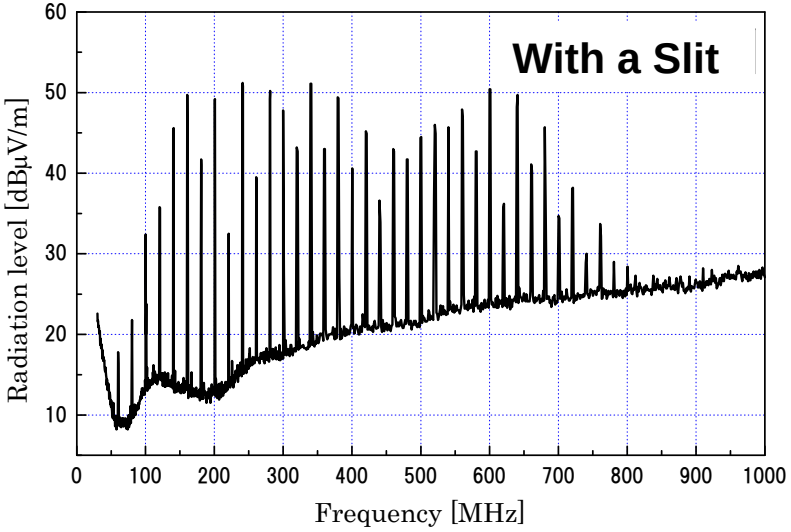


4. Understanding the EMI Mechanism

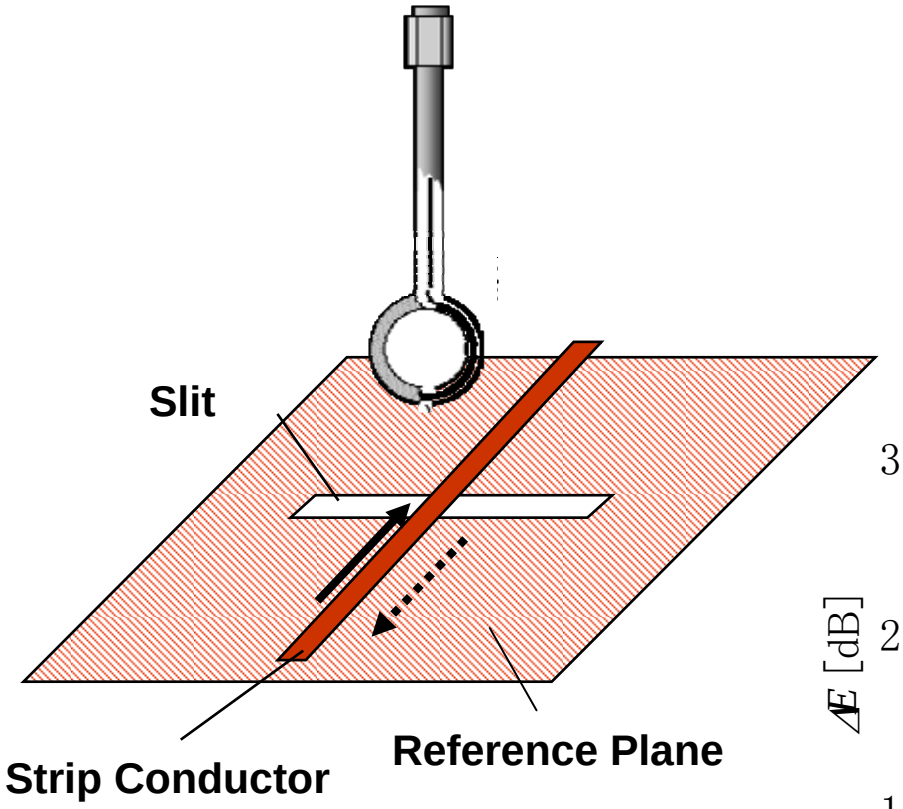
(1)Visualization of Current Flow on the Plane

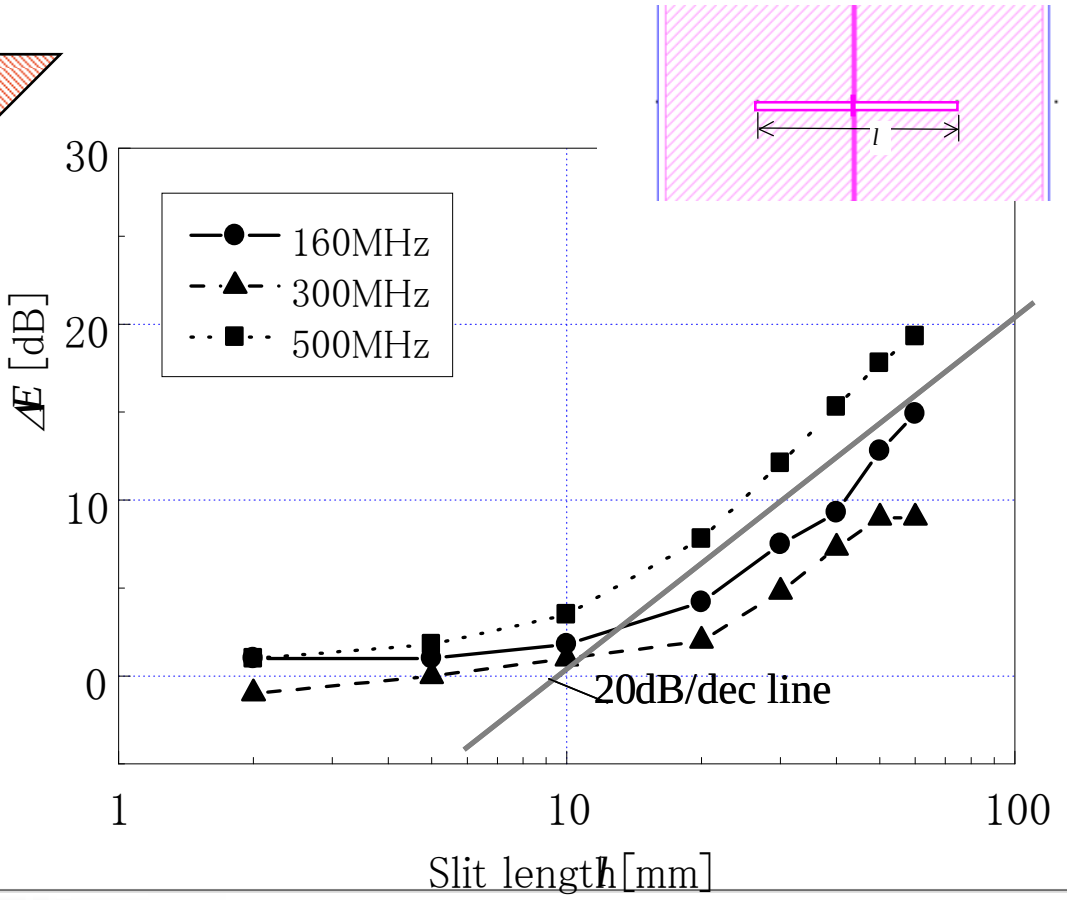




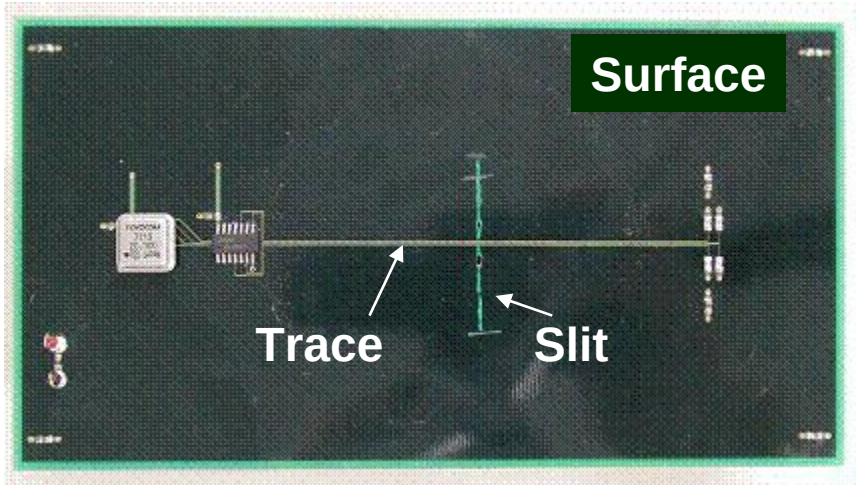


Visualization of the Current by Measuring H Field

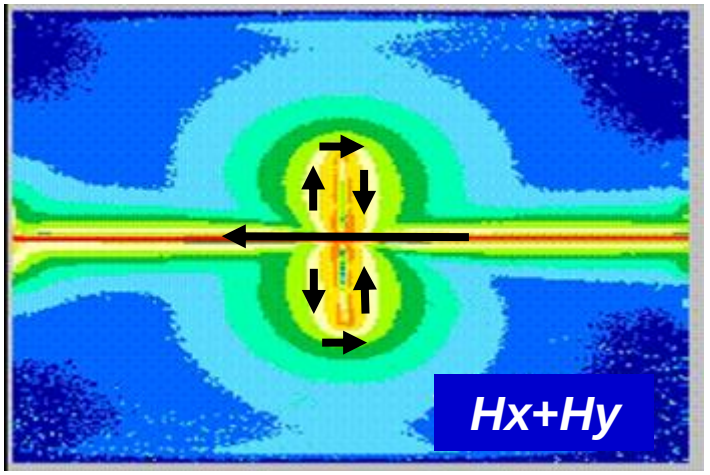


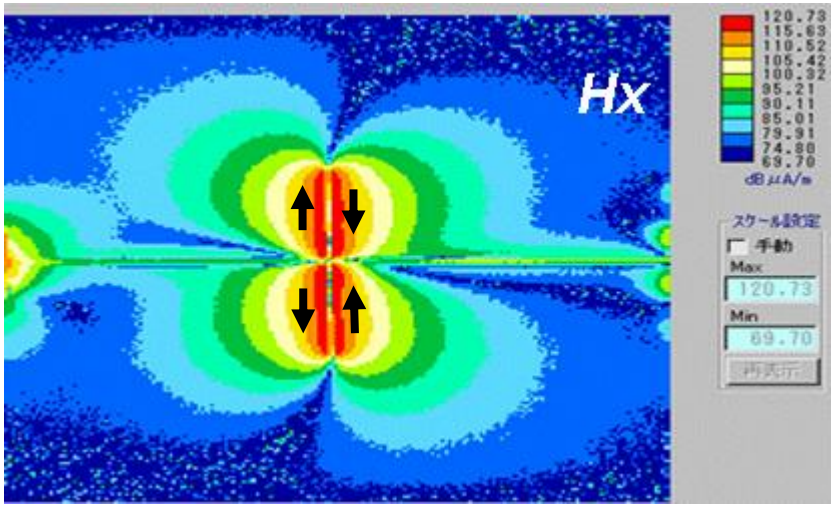


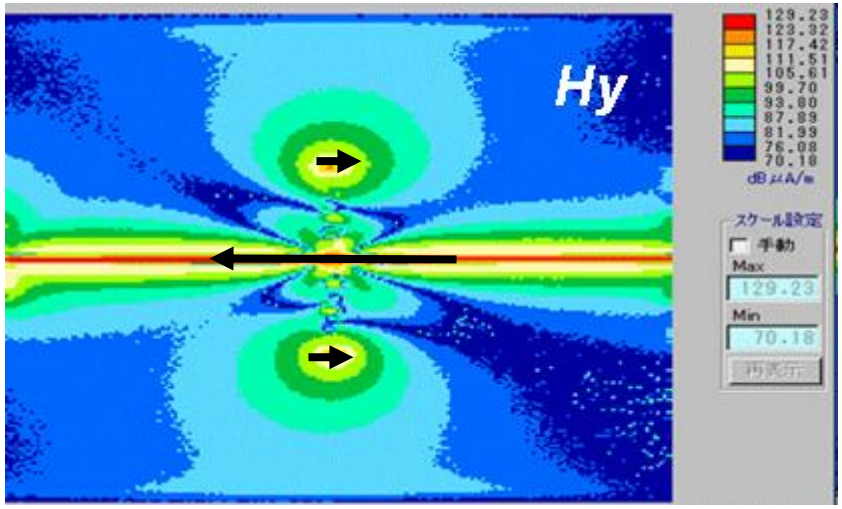
H field distribution near the board ①



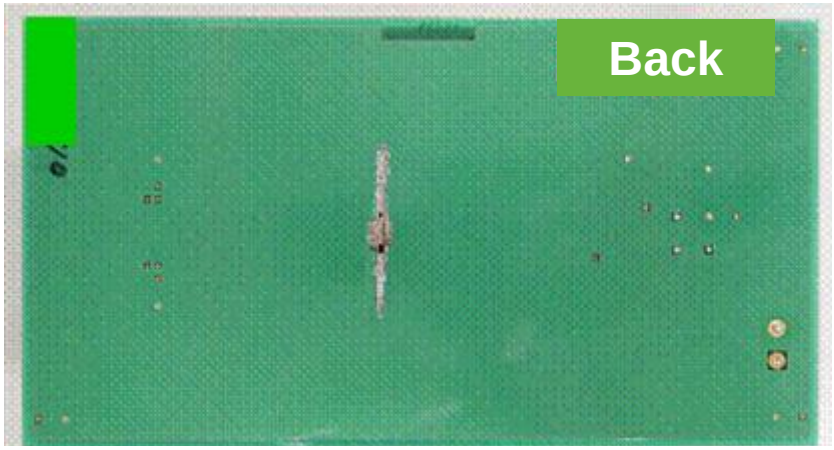
Hy
Hx

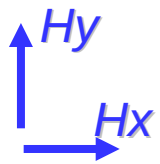


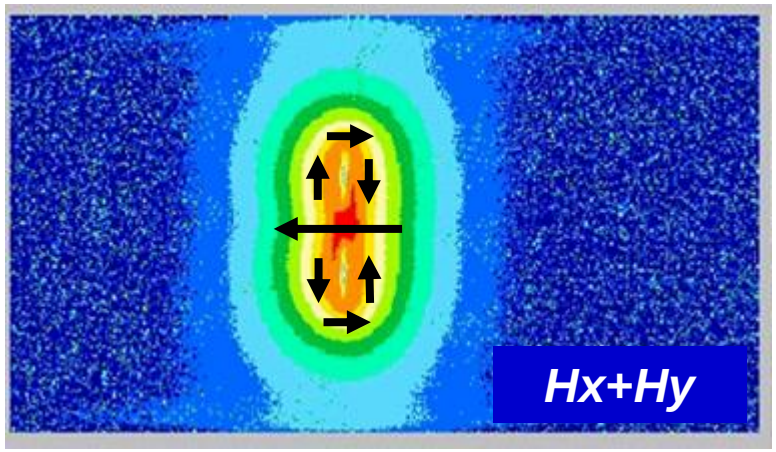


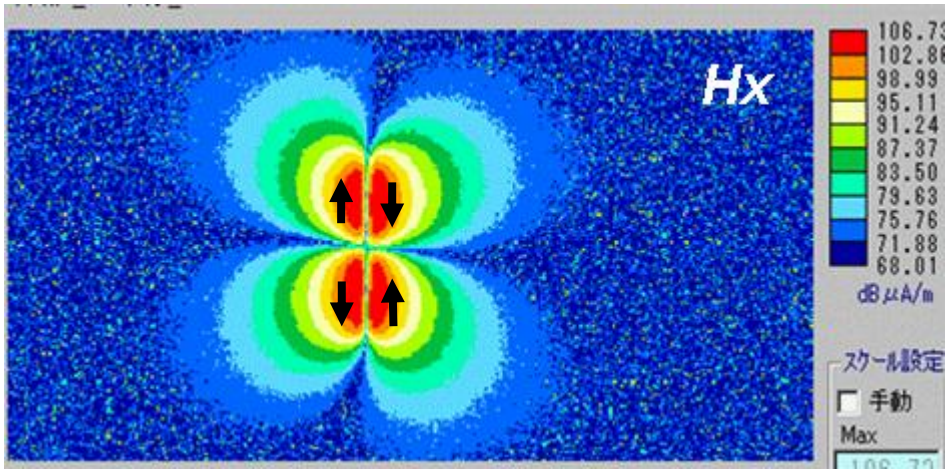


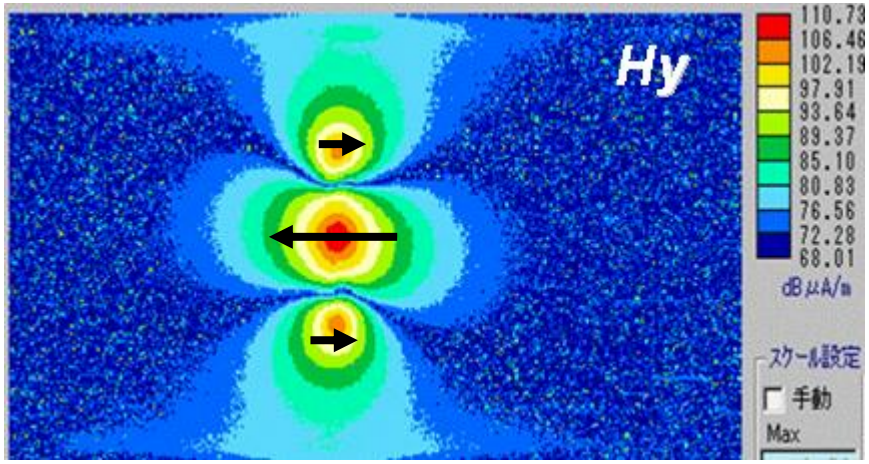
H field distribution near the board ②



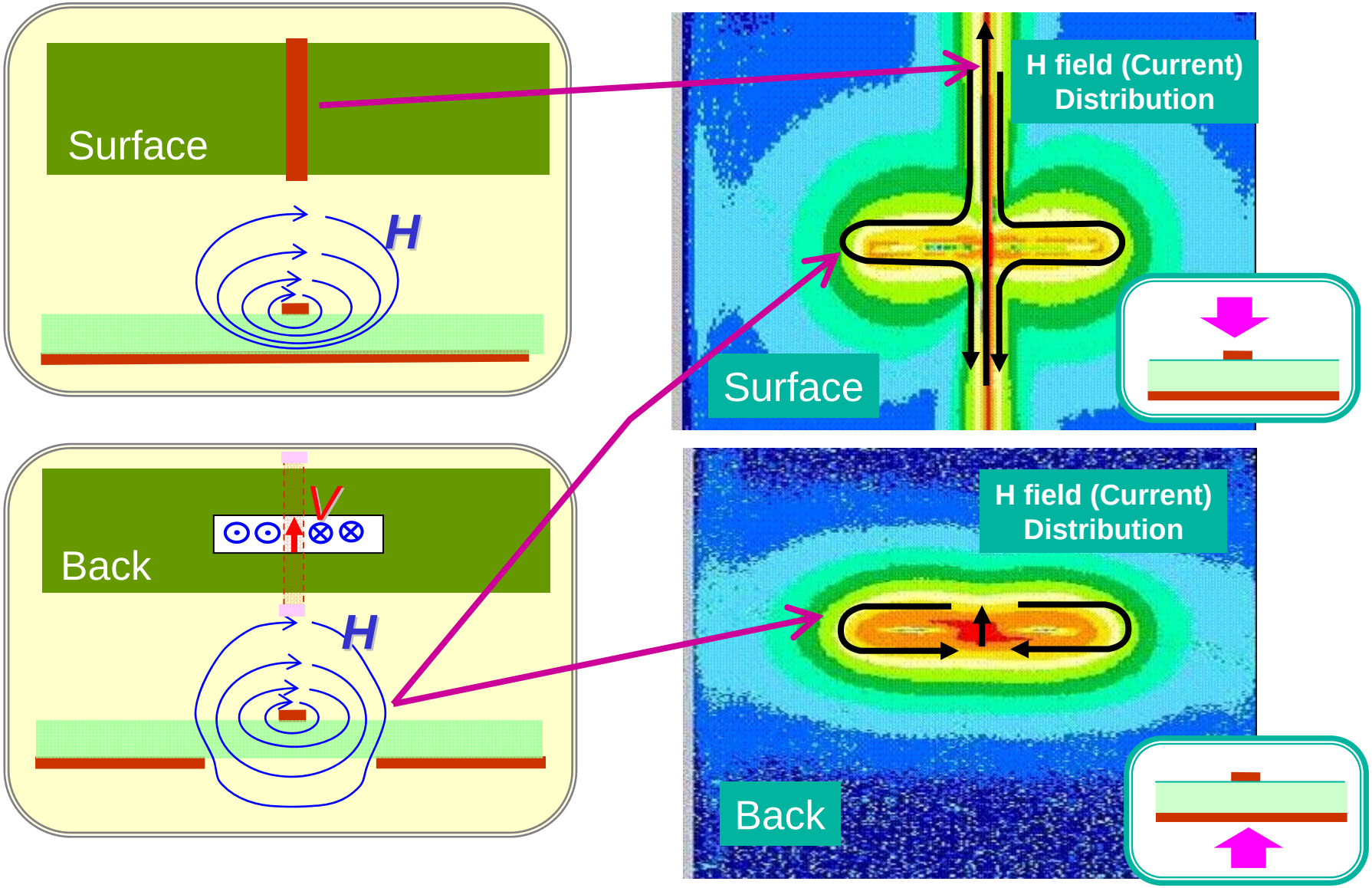






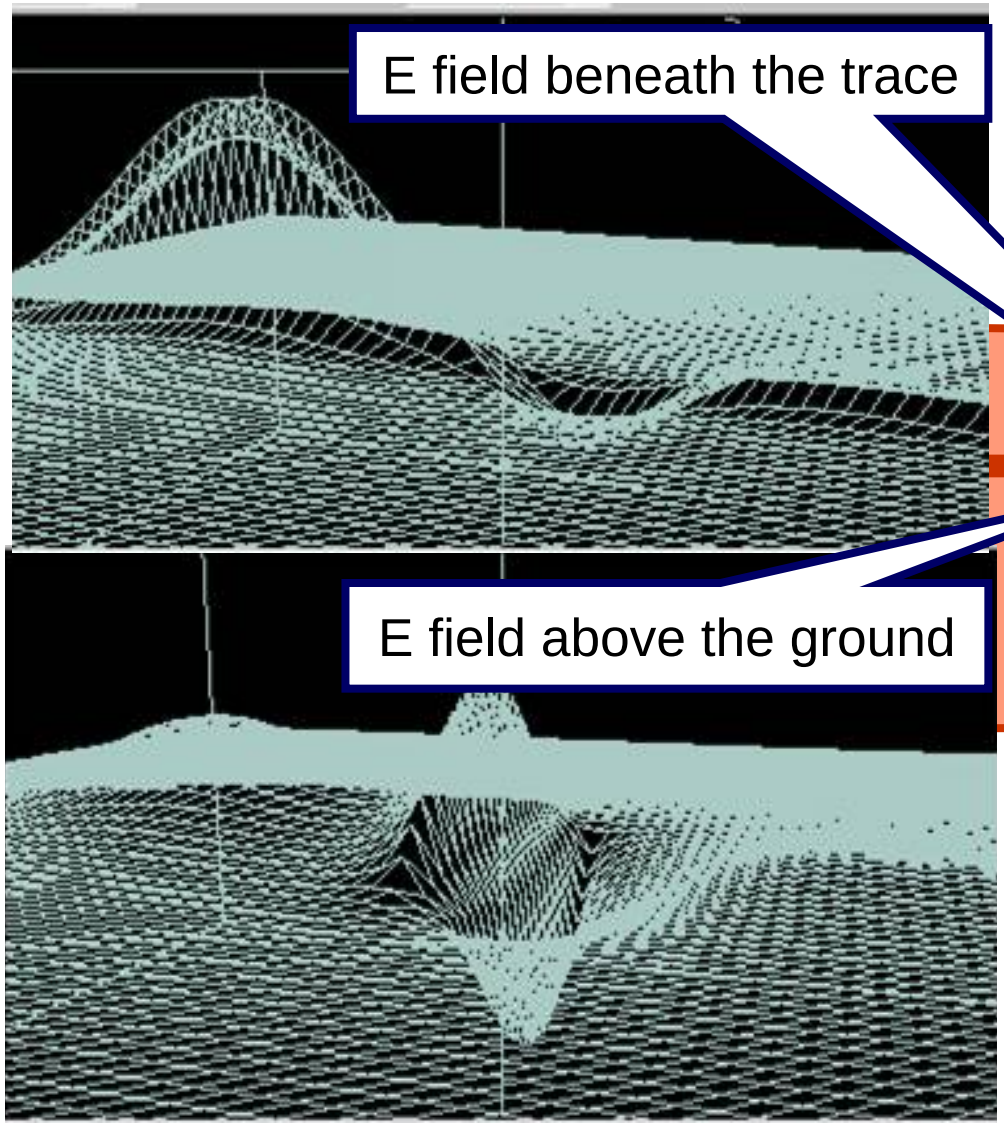


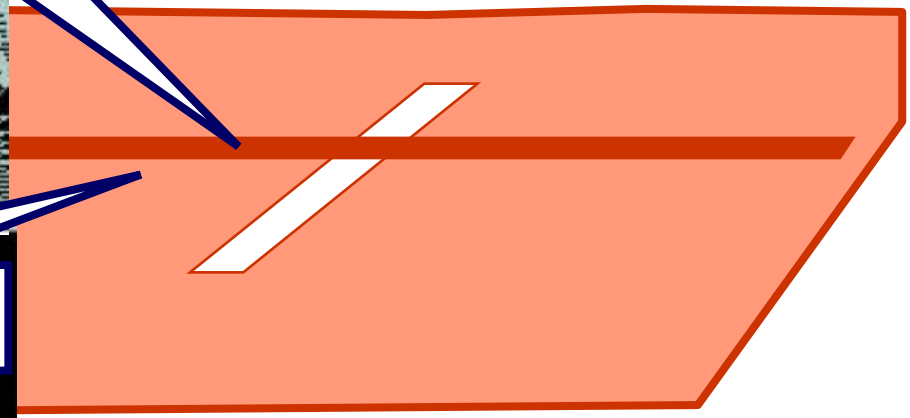
Visualization of the Current



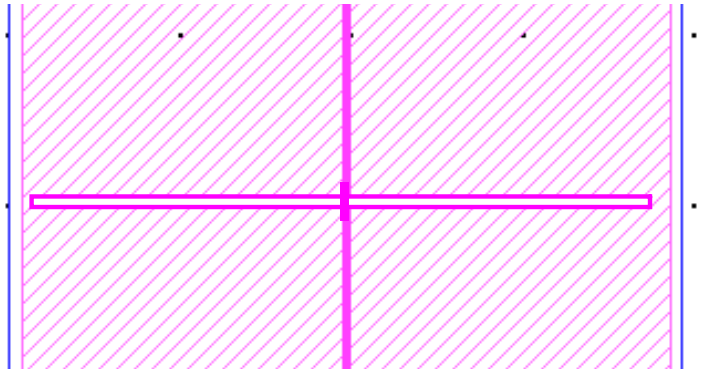
EM field behavior near the slit

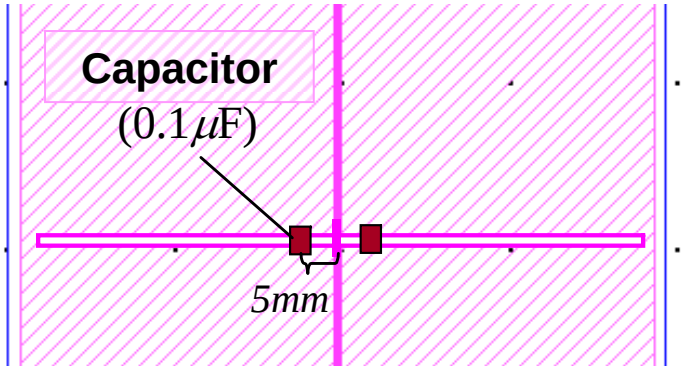
- Analysis by FDTD method -

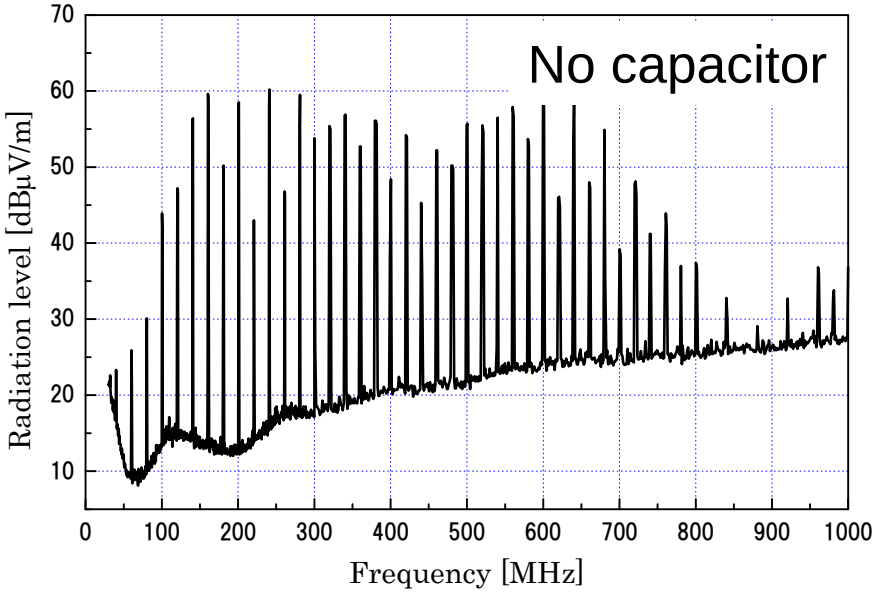


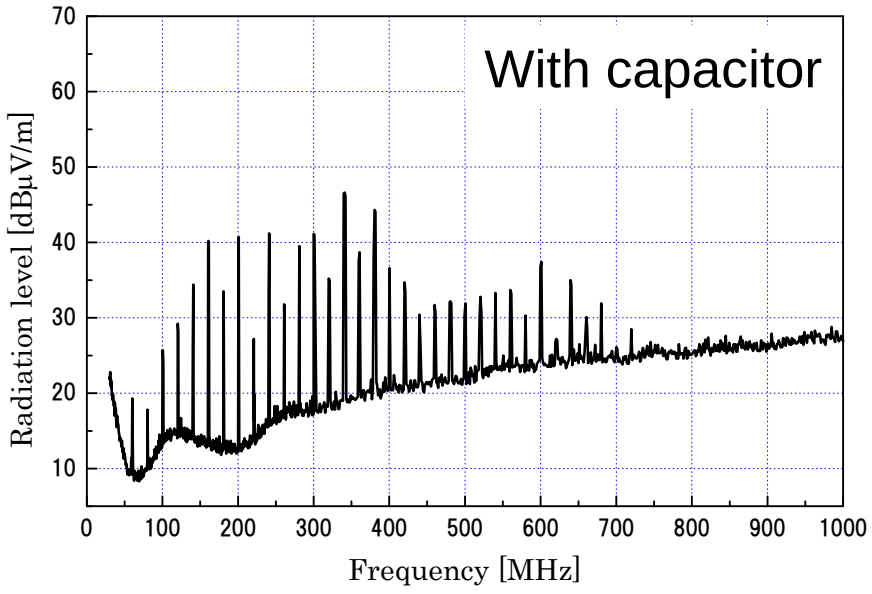


EMI Reduction by adding capacitor

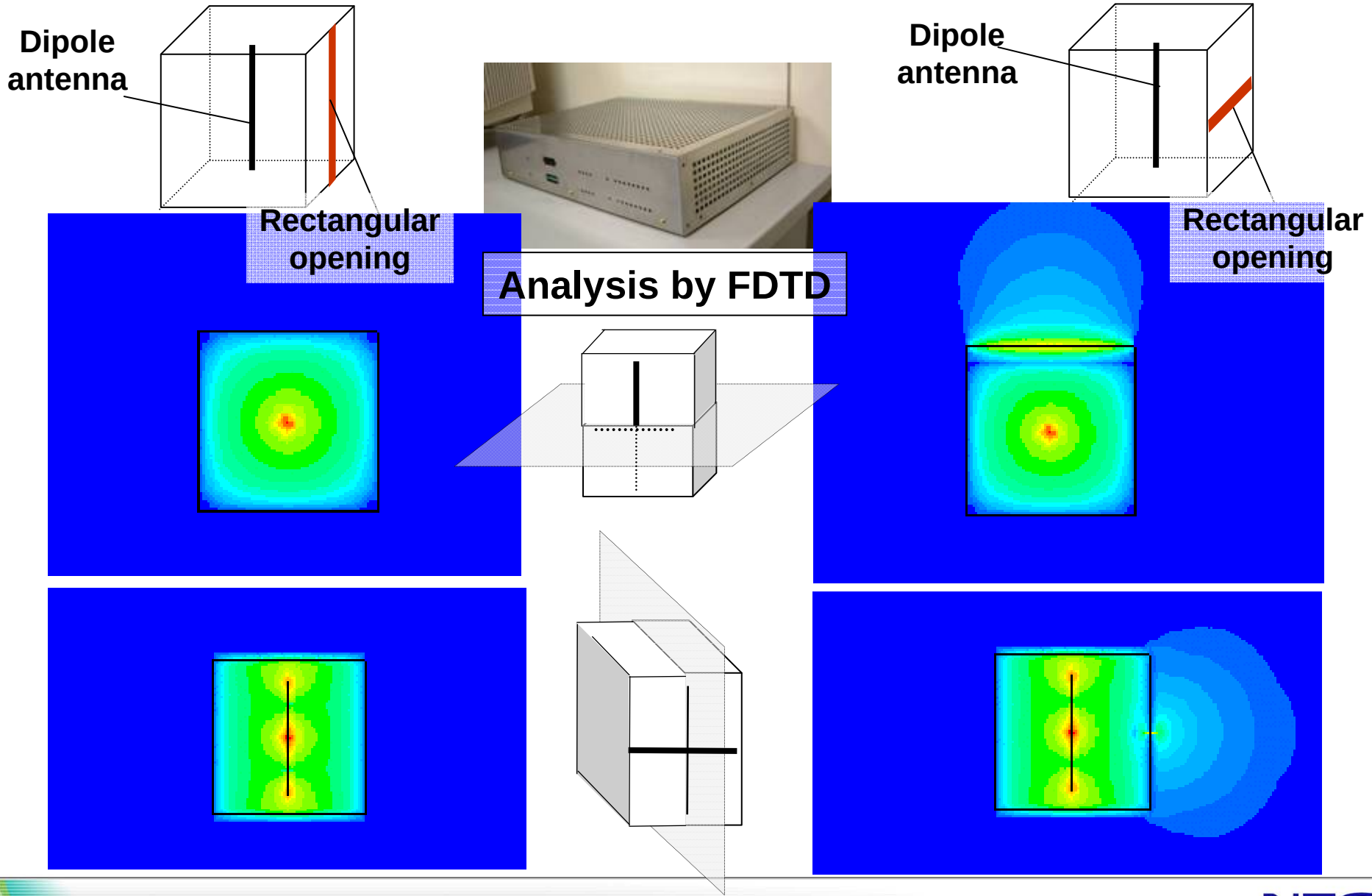




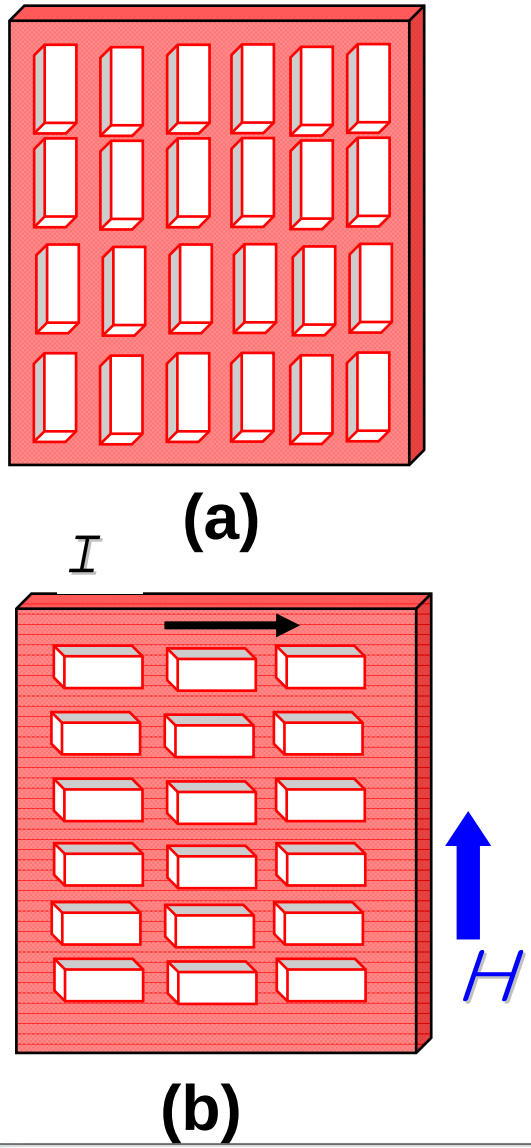


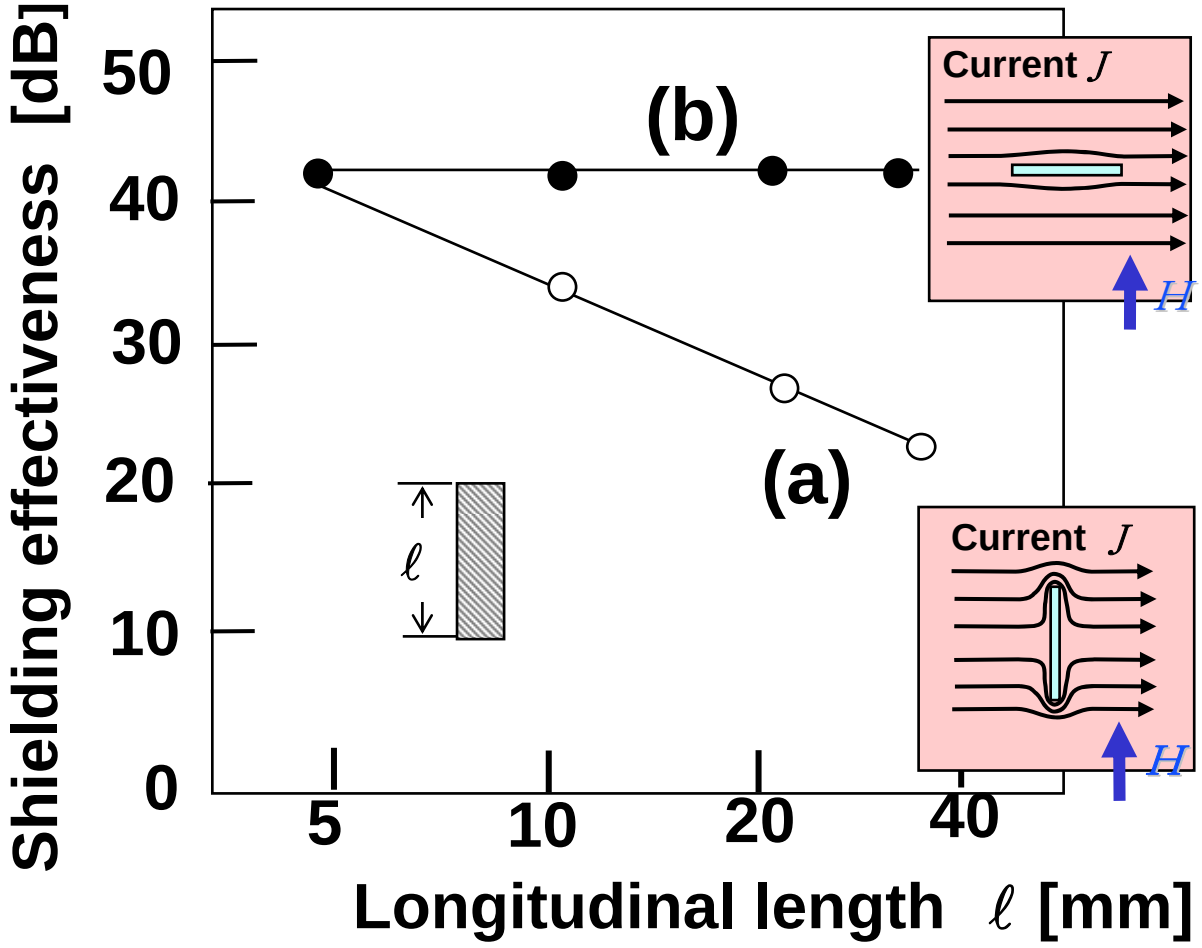


Shielding effectiveness of vent in chassis



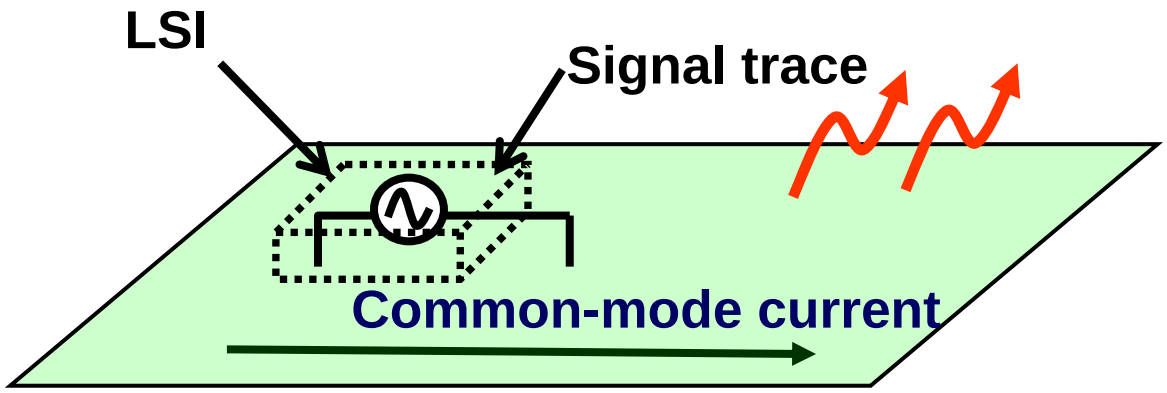
Shielding effectiveness of ventilation opening





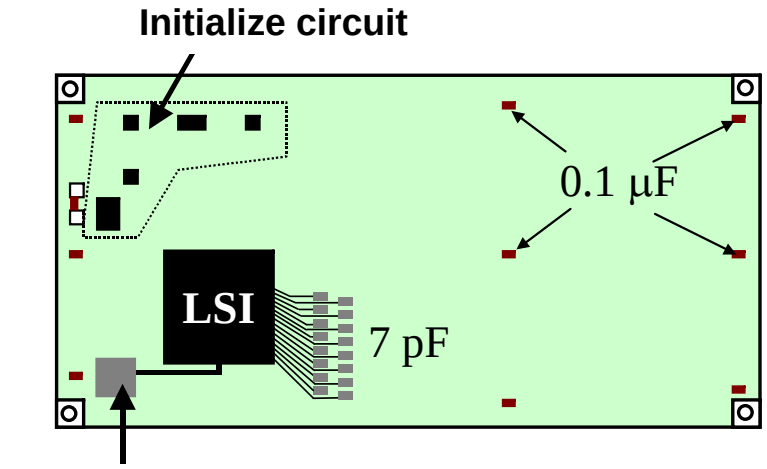
Common-mode radiation mechanism

Basically, the current which flows on dipole antenna is common mode.

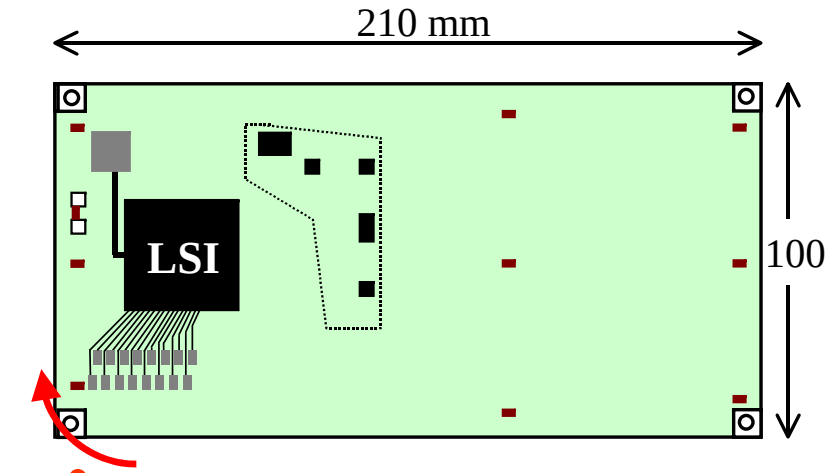


- **LSI and signal-trace current induce common-mode current on the board ground plane**
- **Ground plane acts as an dipole antenna, and radiate high level emission.**

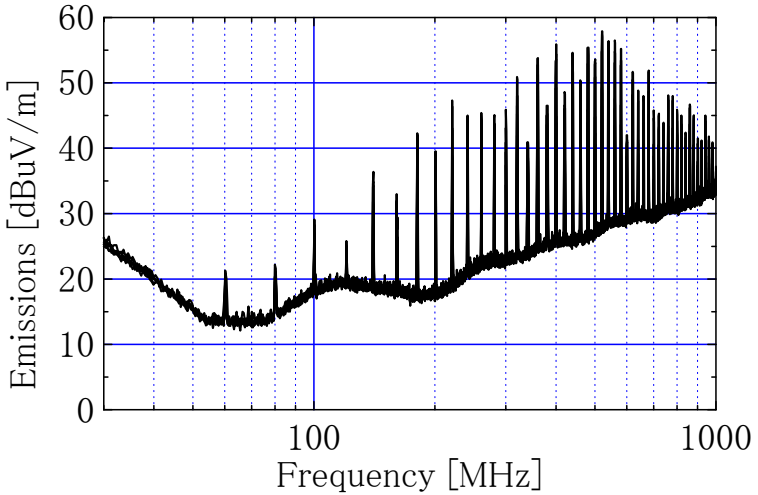
Common-mode Radiation from PCB

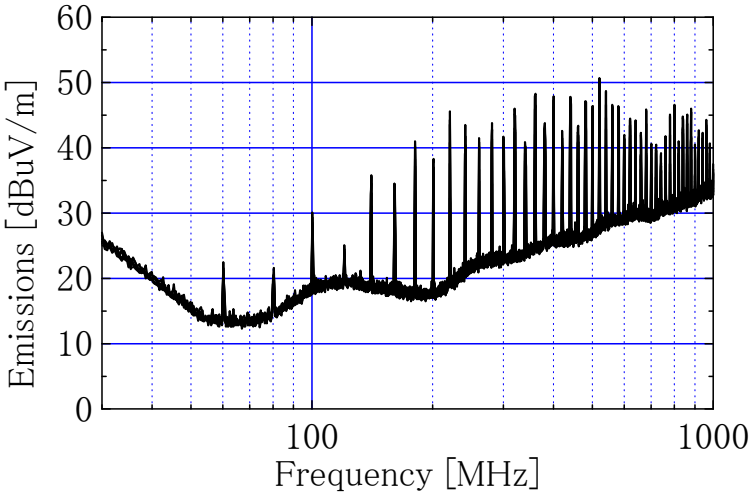


Board A

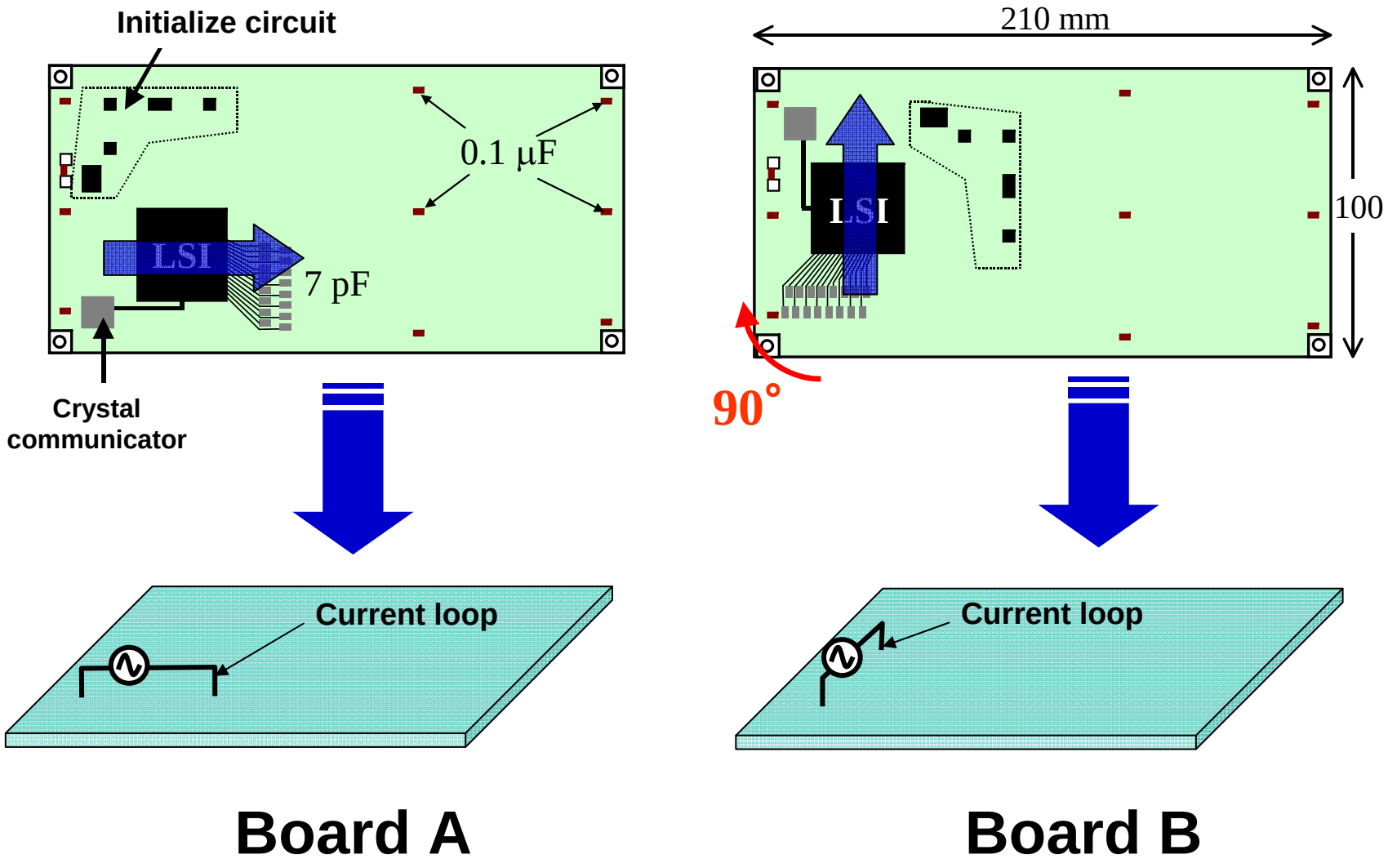


Board B

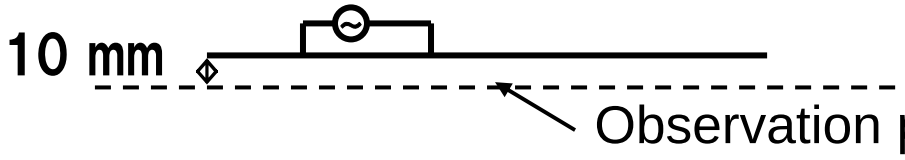


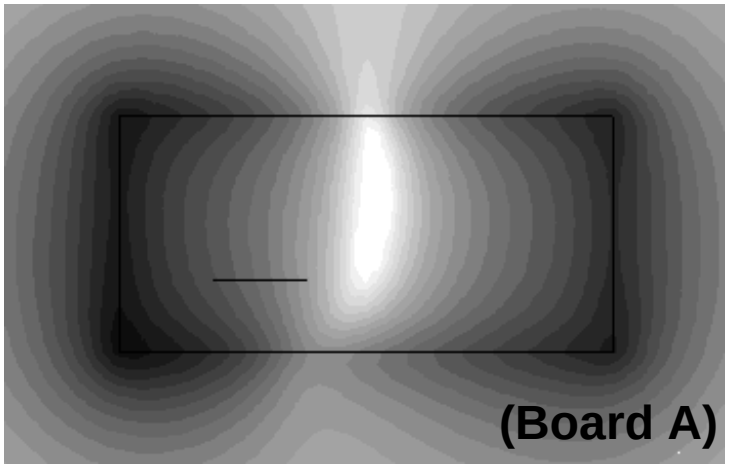


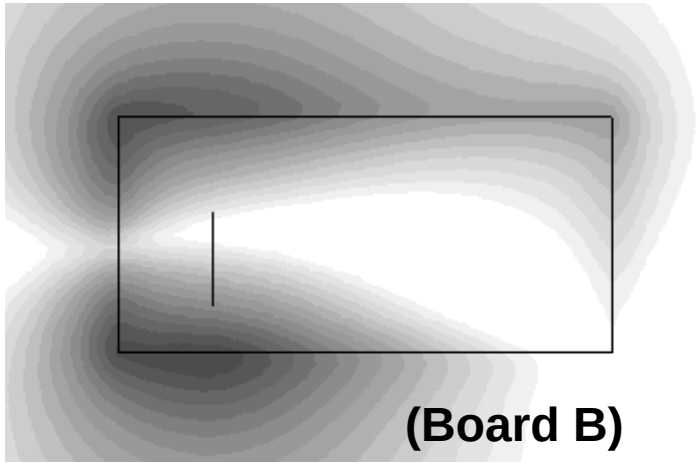
Model for analyzing common-mode radiation



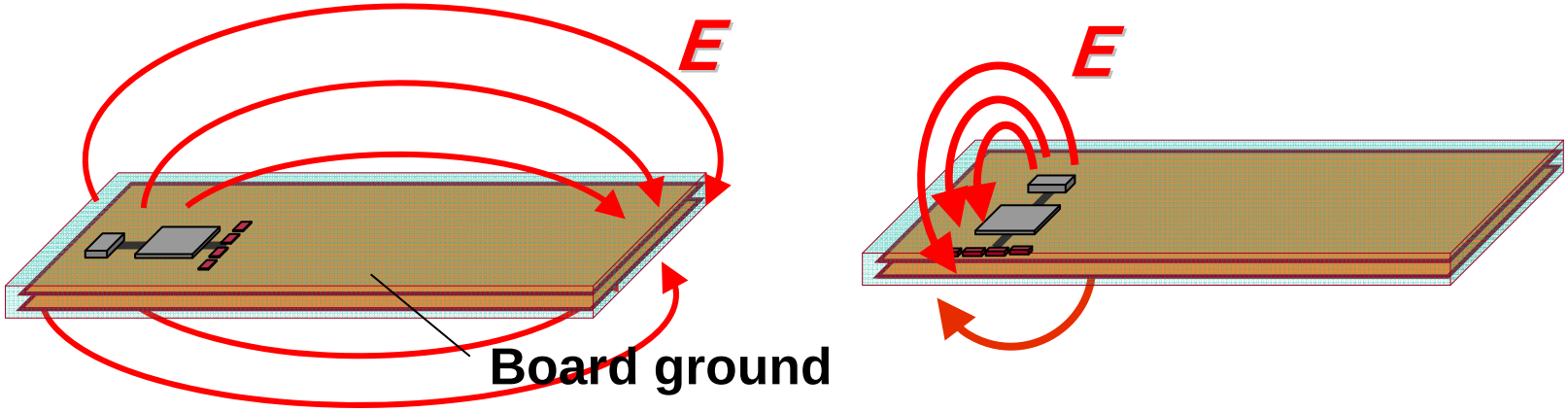
Common-mode current and E field characteristics



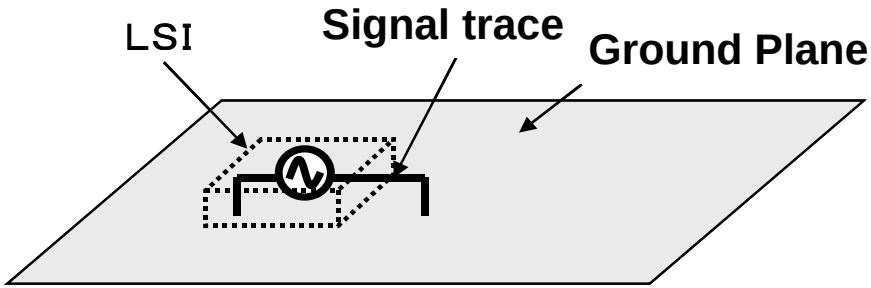


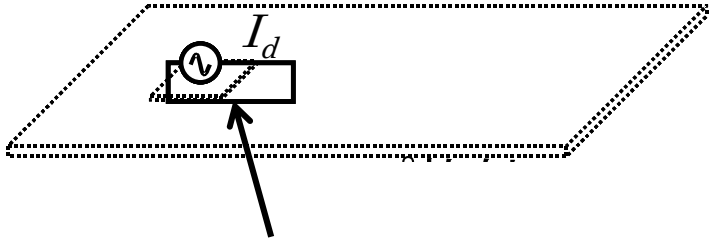


E field distribution beneath the board



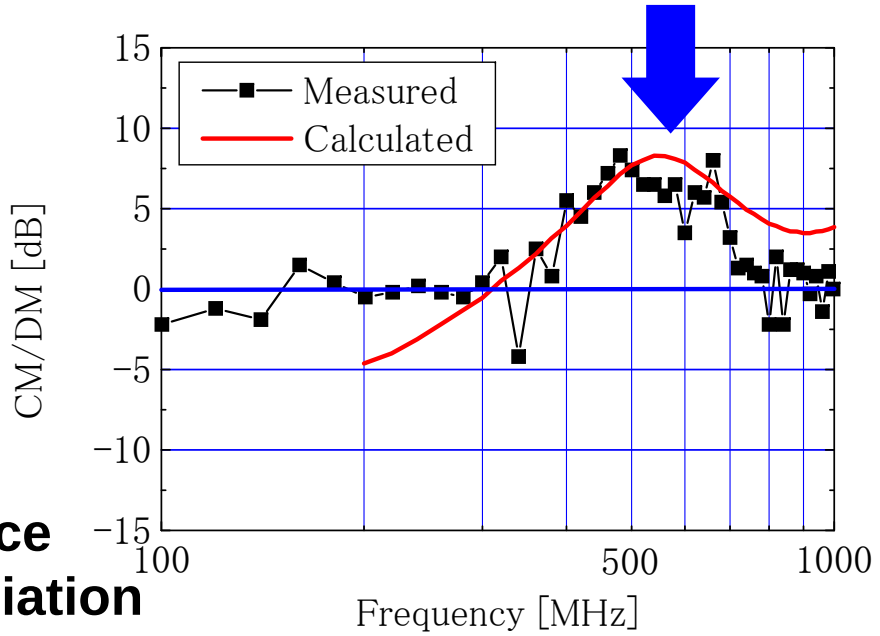
Mechanism of Common-mode Radiation





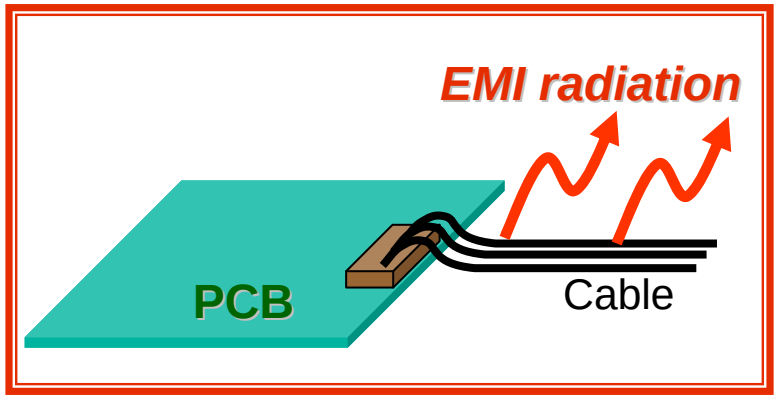
Differential mode (DM) wave source
→Common mode(CM) radiation

Peek of binding DM → CM at approximately half-wave length

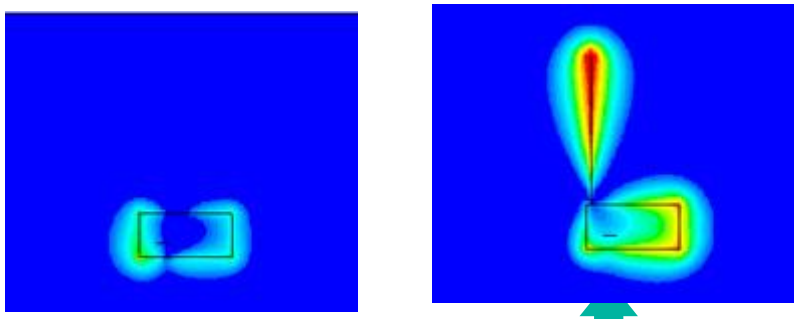


Common mode radiation is proportional to the current flowing on the signal trace.

Common-mode Radiation from a PCB with Cable

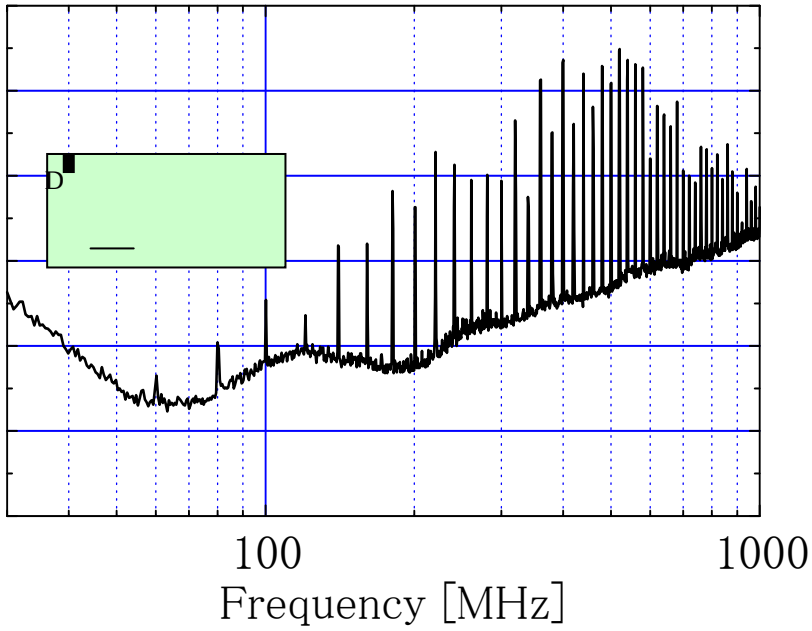


<Near E-field distribution>



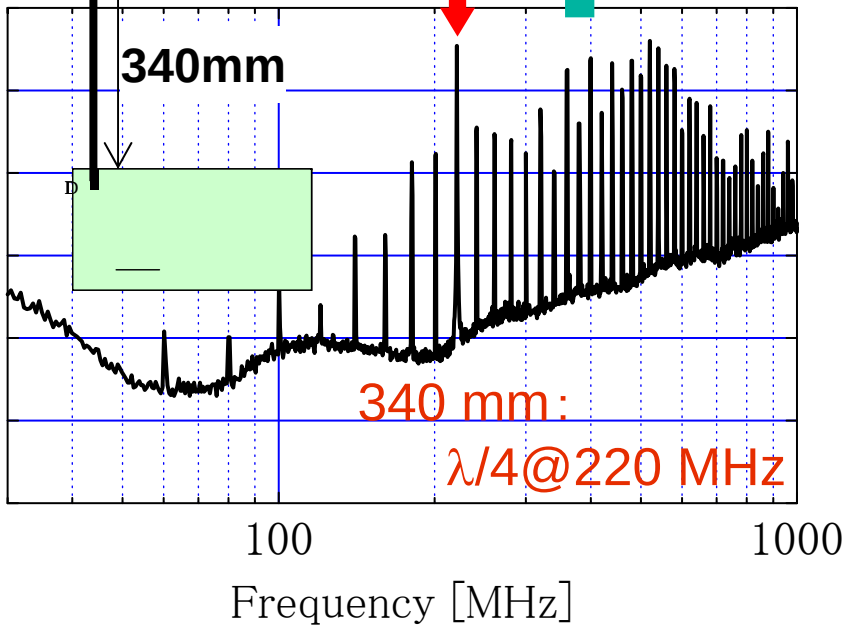
220 MHz

10dB/div

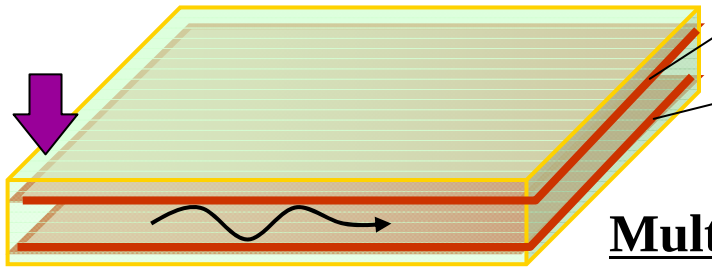


10dB/div

340mm

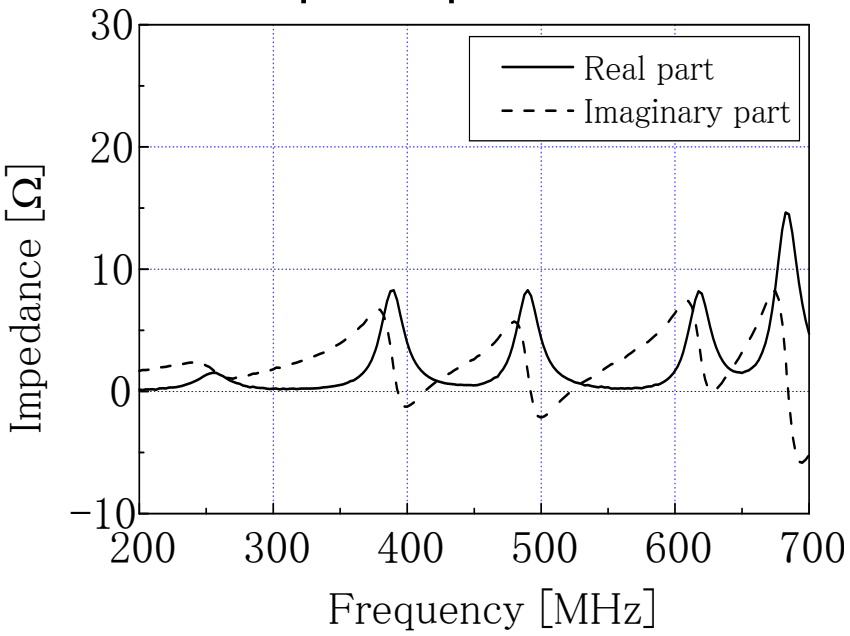


Radiation from Power/Ground Plane

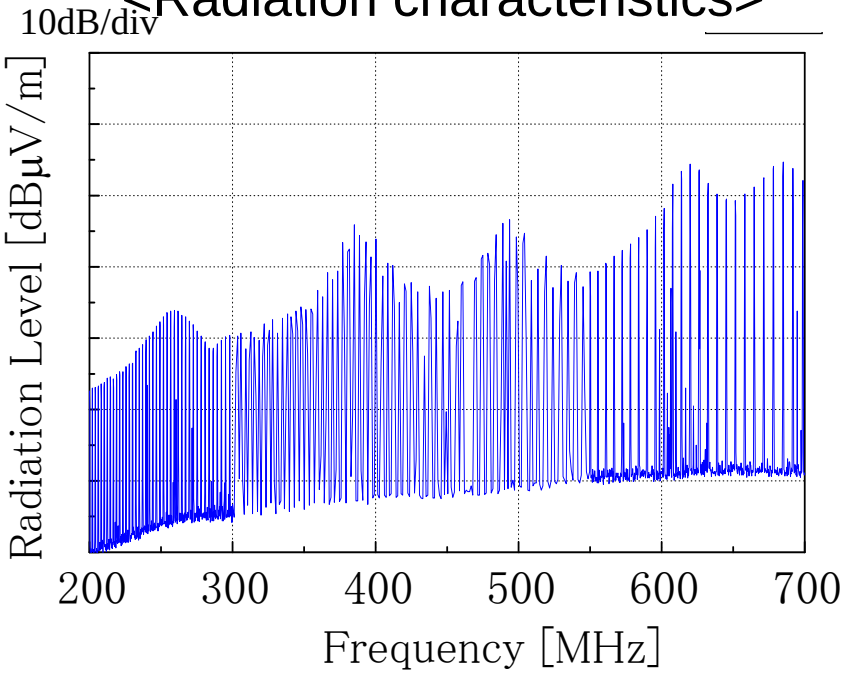


Multi Layer PCB

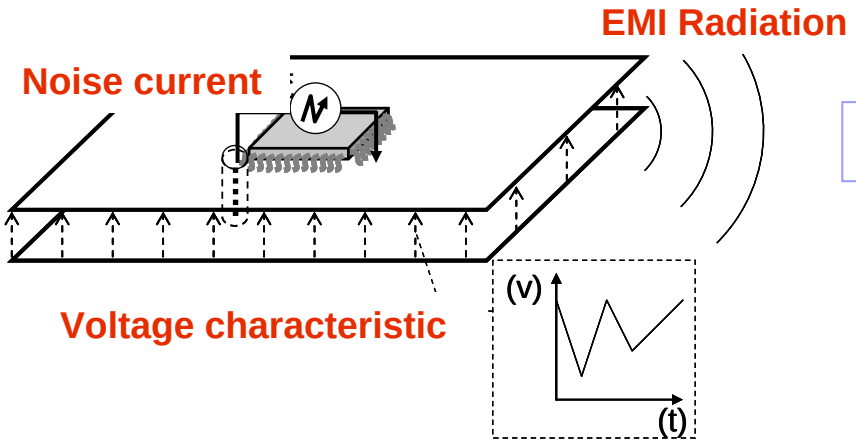
<Input Impedance>



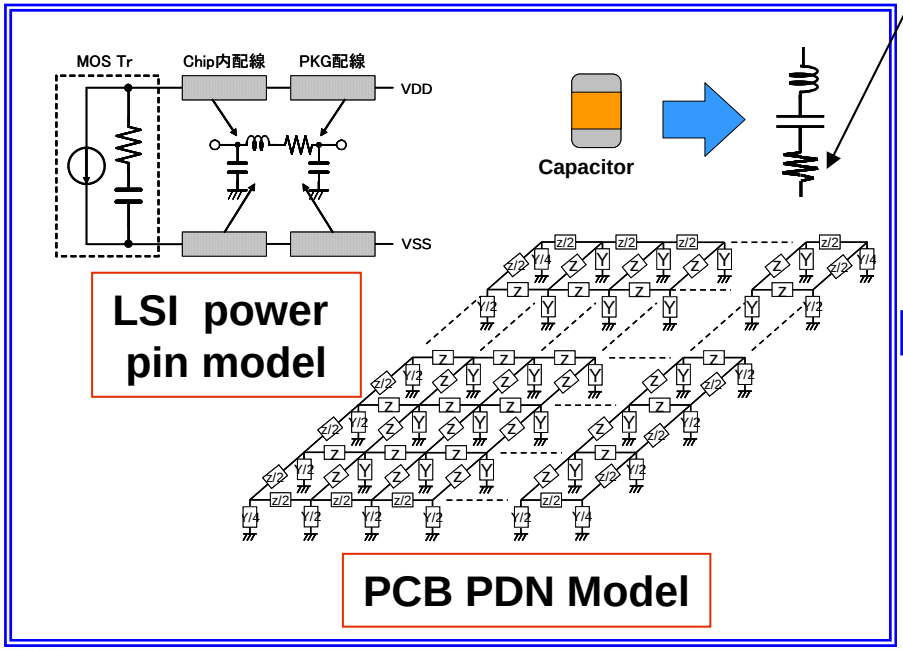
<Radiation characteristics>



Radiation from PDN

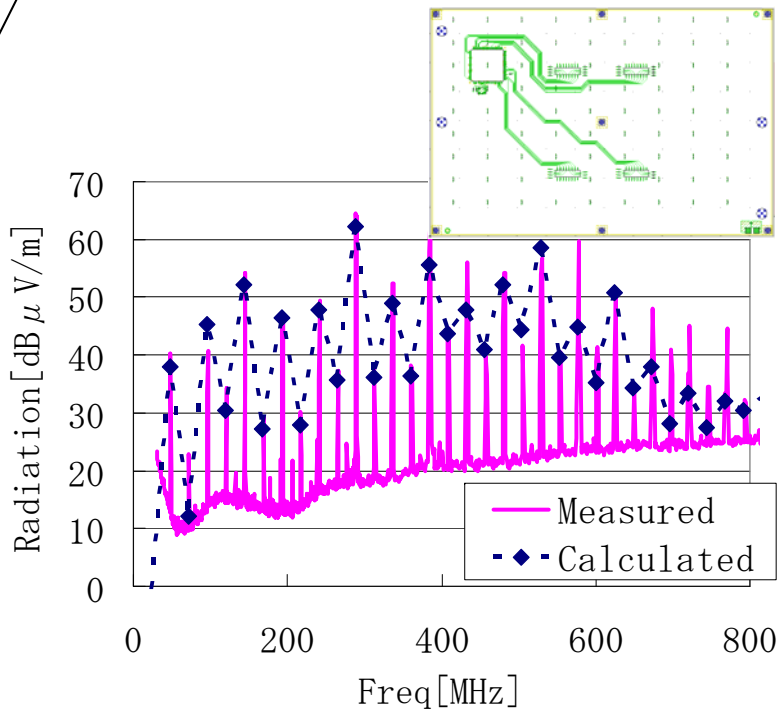


EMI radiation mechanism from PDN



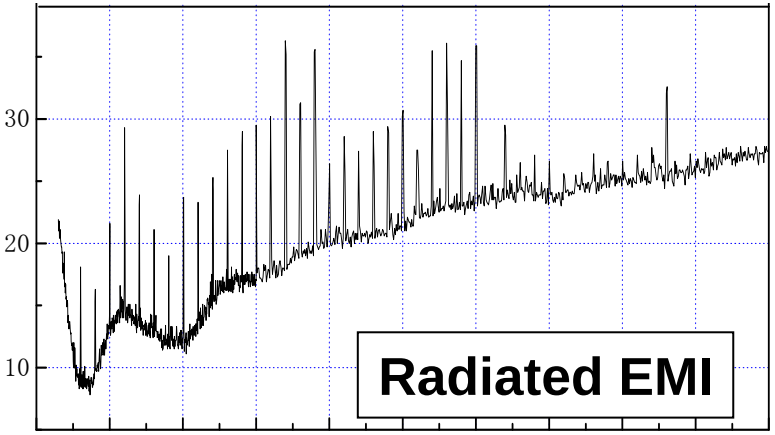
（Modeling & Analysis）

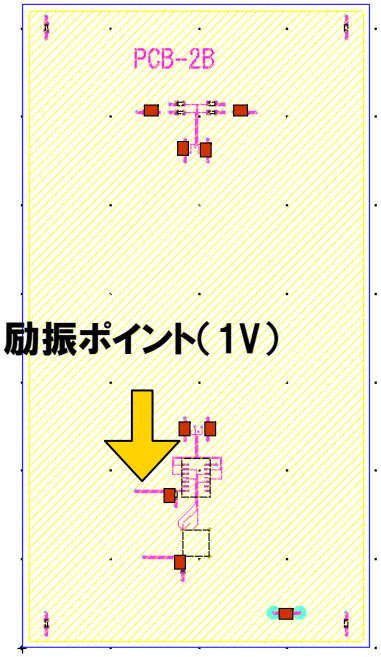
PEEC (Partial element equivalent circuit method)



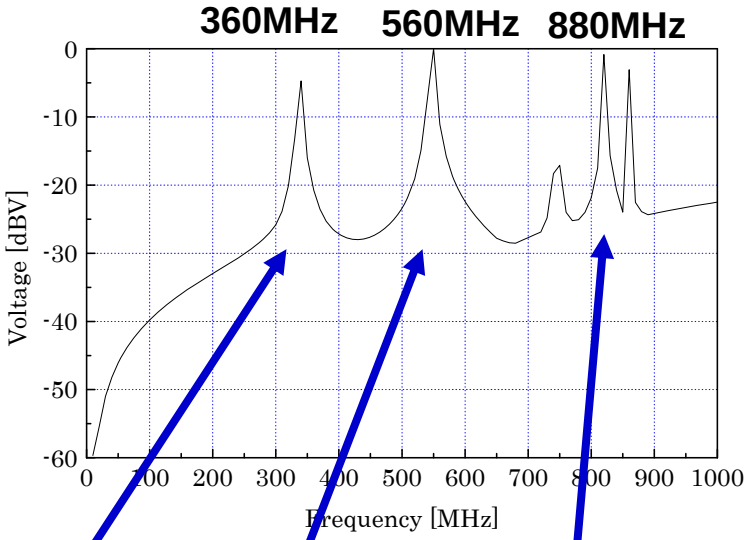
PDN: Power Distribution Network

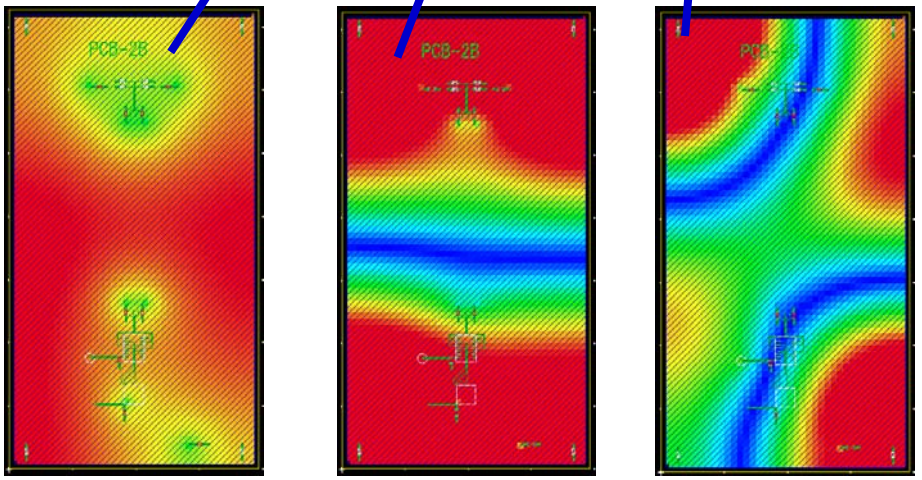
Analysis of PDN Resonance





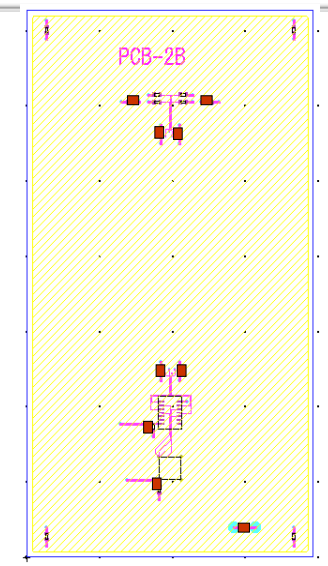
＜ボードレイアウト＞

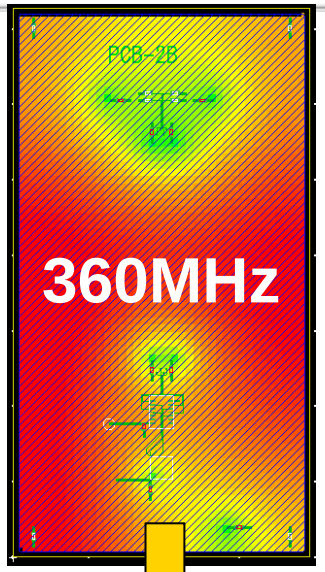


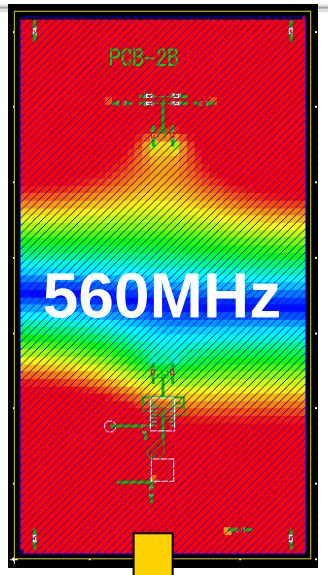


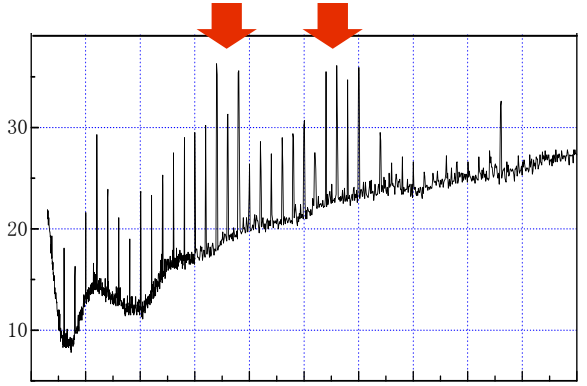
電源供給系(GND-Vcc間)の電圧分布

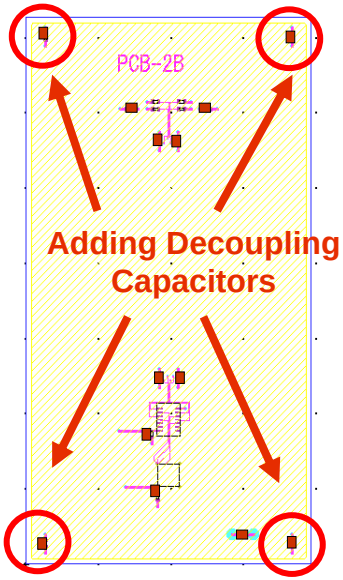
Controlling PDN Resonance Characteristics

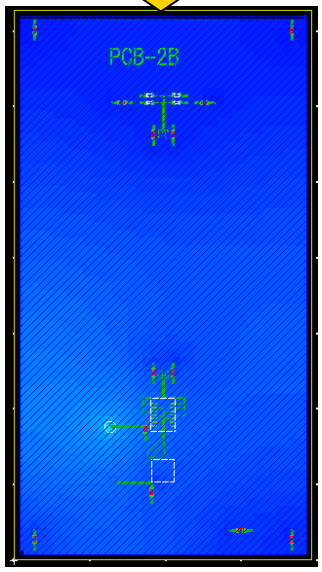


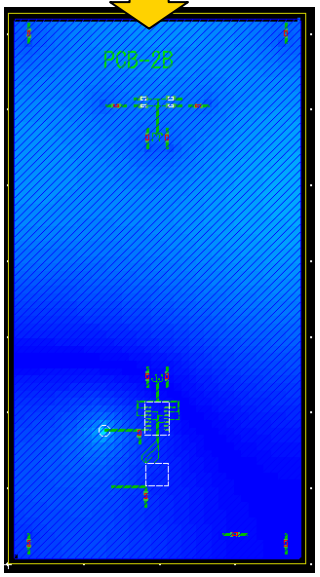


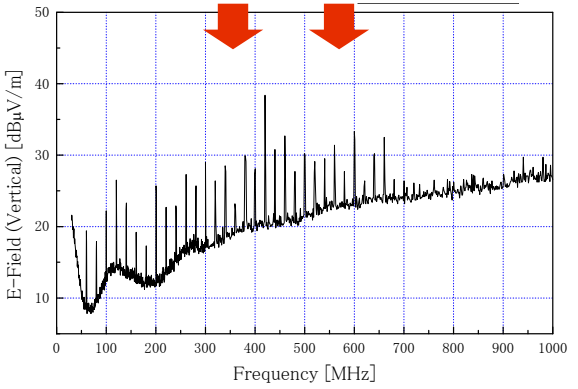












5. Conclusion

- SI, PI, EMC troubles are increasing due to high speed signal processing and high density packaging.
- Understanding electromagnetic field behaviors are important not only scientist but also electronic engineers and designers.
- Visualization of EM field is vest available way to understand them.

Empowered by Innovation