



Radiated Emission from Signal Traces Changing Reference Planes

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Outline

Radiated Emission from Signal Traces Changing Reference Planes

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Introduction

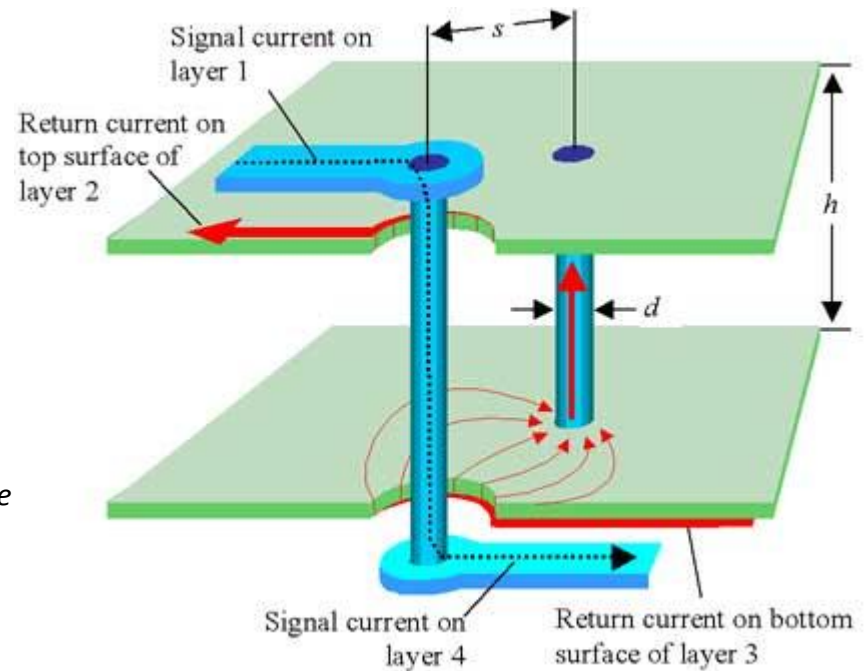
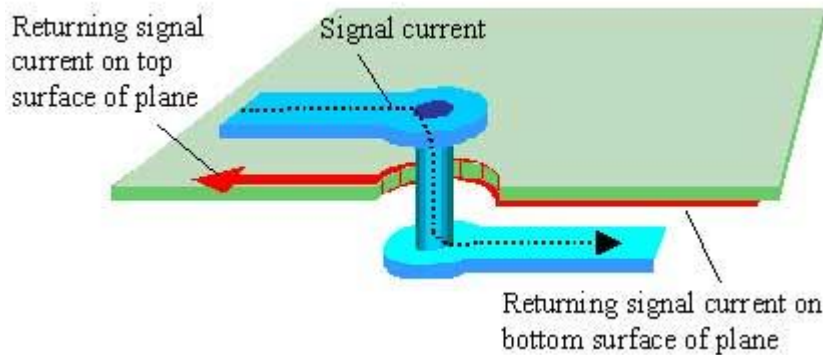
Trends and needs

- Trends
 - Faster components → bandwidth Increase
 - Shifting statutory emission requirements (CISPR 32) → from 1 to 6 GHz; to protect GHz communication bands
- Needs
 - Designers need new high-speed design insights and guidelines to make the right choices on PCB technology, cable & connector technology, and shielding design

This paper focuses on new quantitative design guidelines for printed circuit boards to control **radiated emission** of signal traces changing reference planes.

Introduction

Signal trace changing reference planes



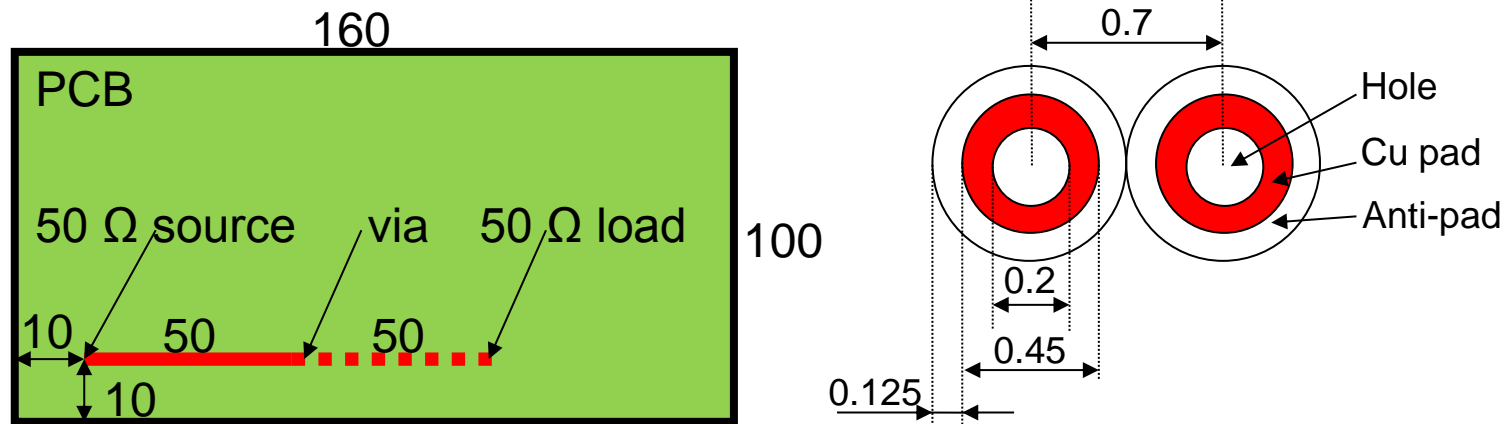
Source: Howard Johnson, *“High-Speed Signal Propagation: more black magic”* Chapter 5.5.5.1 Through-hole Via Induction

- Return current path when a signal trace changes reference planes

Modeling approach

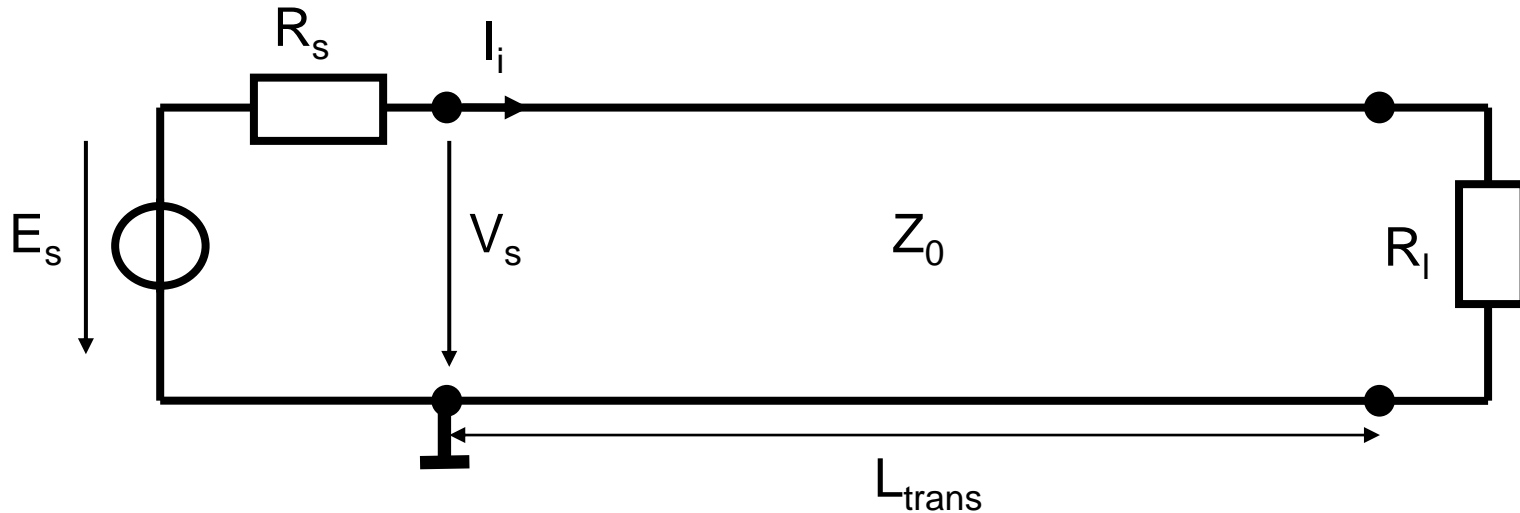
Board and via dimensions (in mm)

Board and via dimensions (in mm)



Modeling approach

Source model



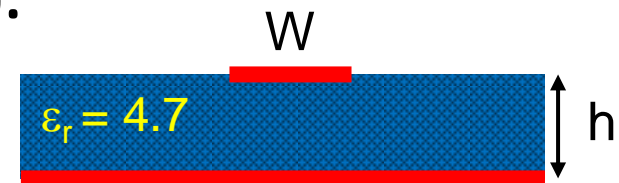
Transmission line on PCB (microstrip):

$E_s = 1 \text{ V}$ (100 MHz – 6 GHz)

$R_s = R_l = Z_0 = 50 \ \Omega$

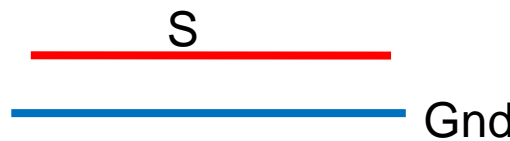
Trace height $h = 0.1 \text{ mm}$

Trace width $W = 0.16 \text{ mm}$

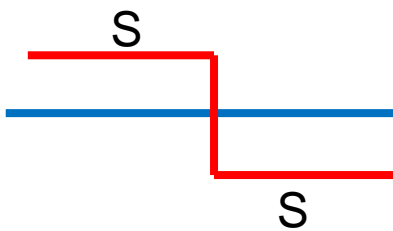


Modeling approach

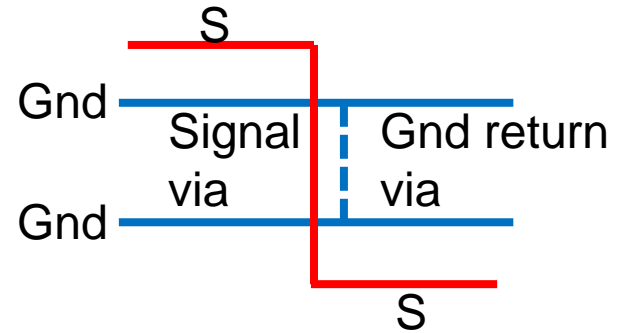
Simulation cases



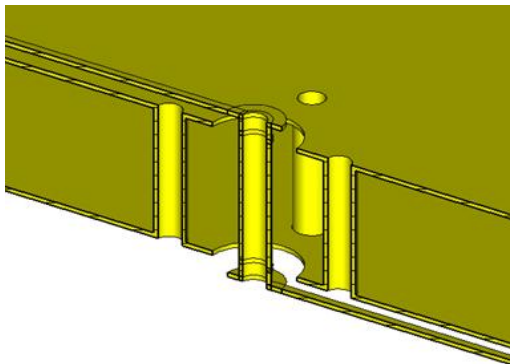
no plane crossing



1 plane crossing



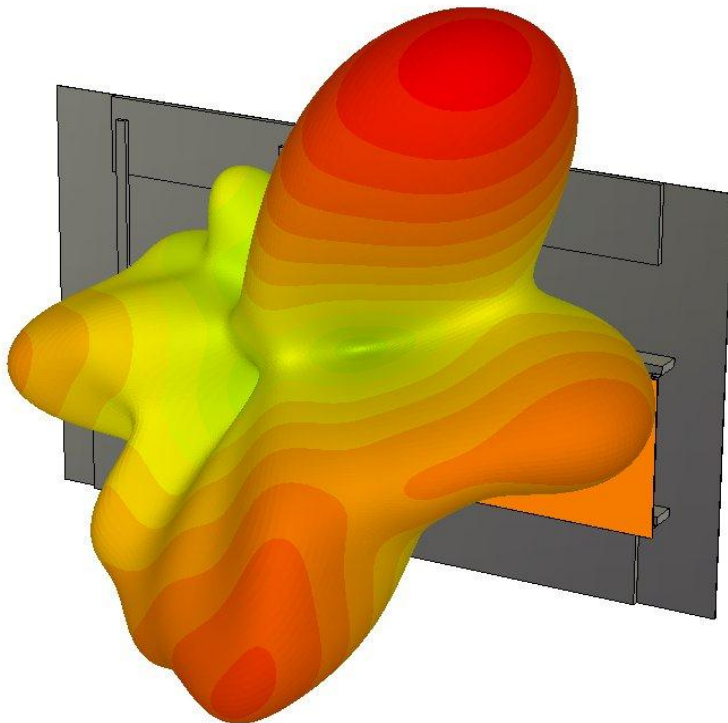
- 2 planes crossing
- number of vias
- via distance
- plane distance



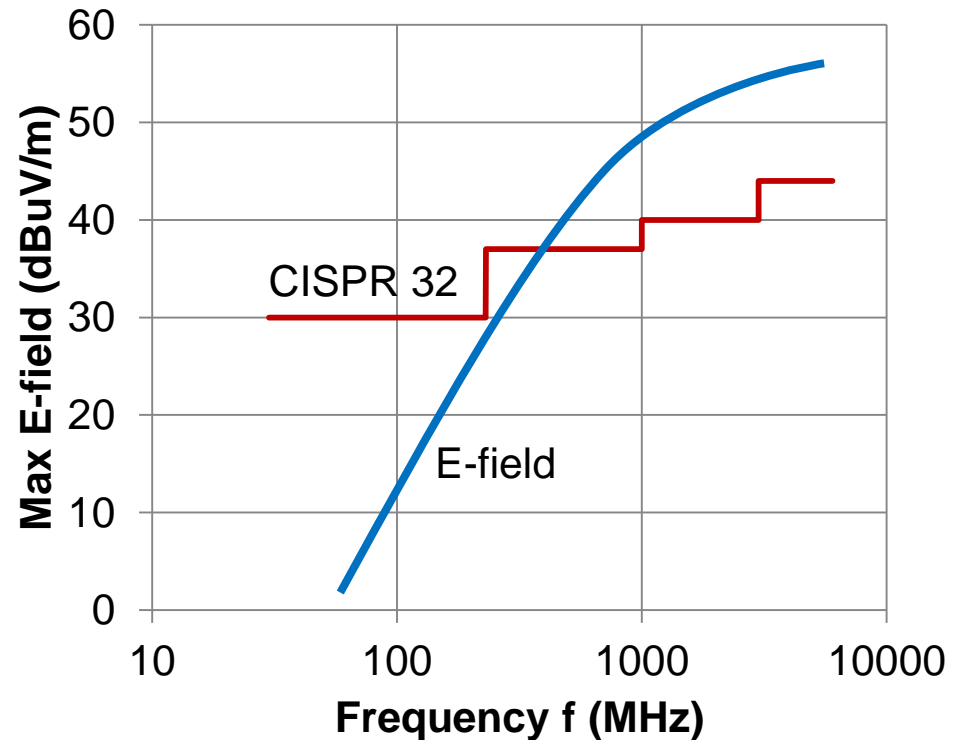
CST model of cross section with 1 signal via and 4 return vias (3 visible)

Modeling approach

Simulation output: maximum radiation



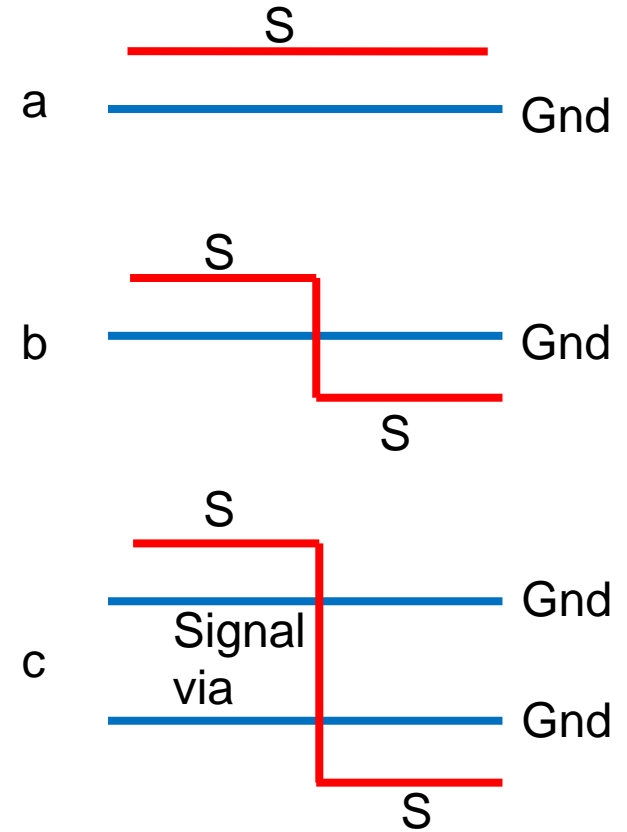
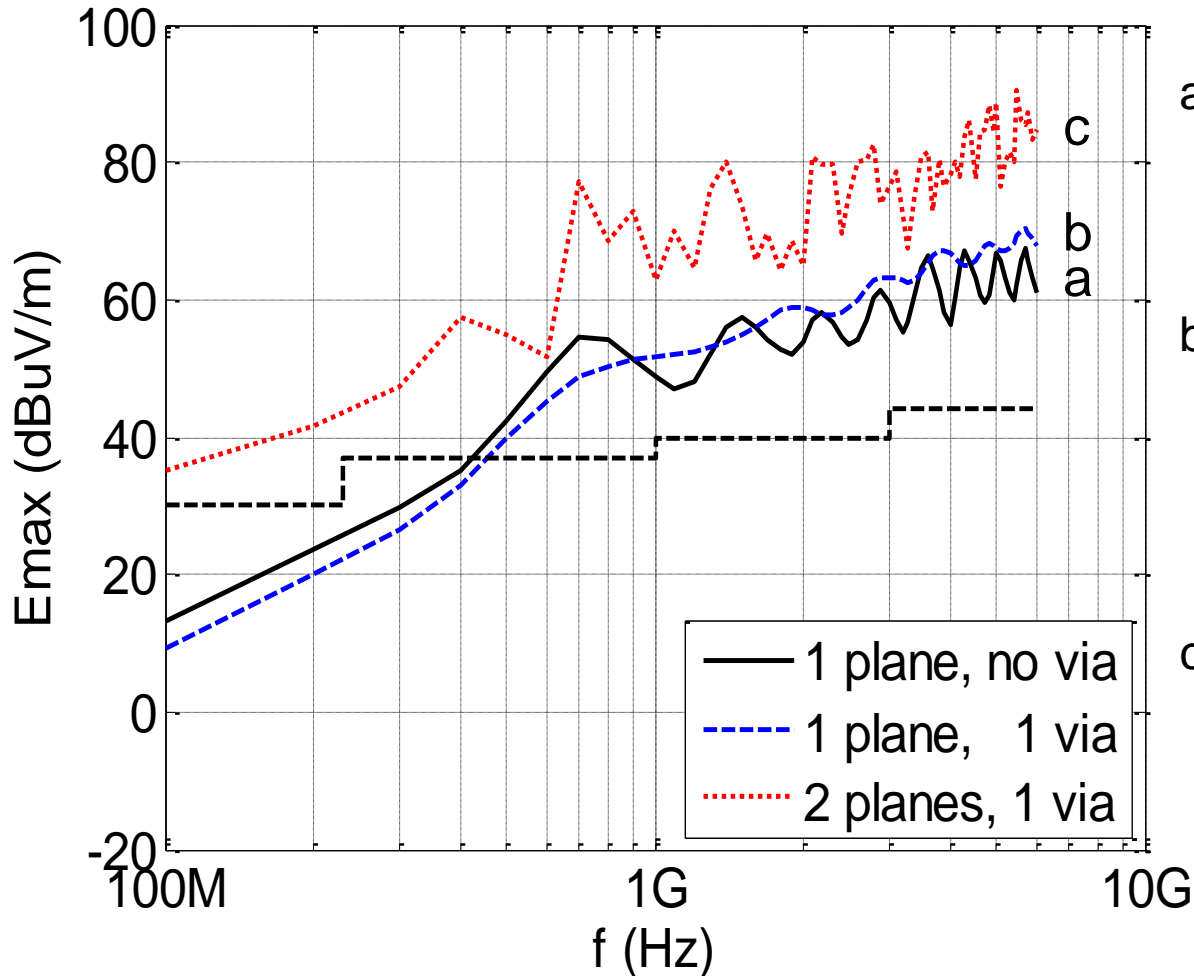
Radiation pattern at 1 GHz



Max E-field on sphere with radius 10 m as a function of frequency

Simulation results and design guidelines

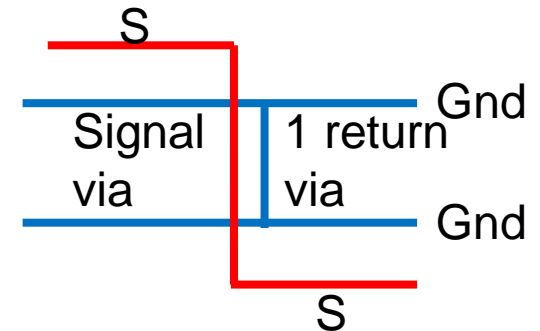
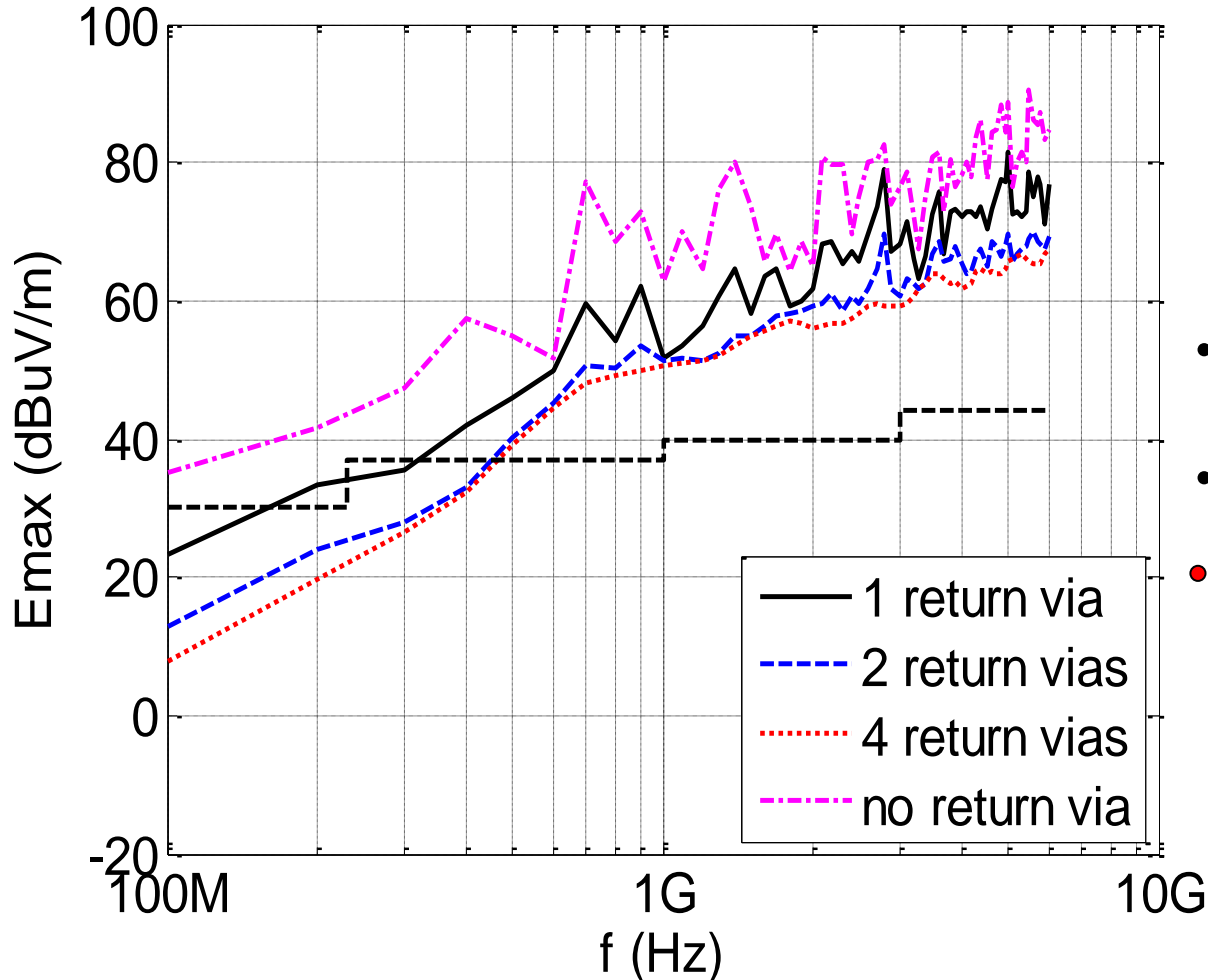
Crossing 0, 1, and 2 planes



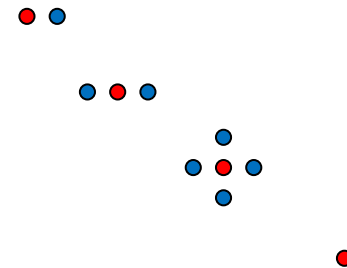
- Plane distance = 1 mm
- No return via

Simulation results and design guidelines

Number of vias

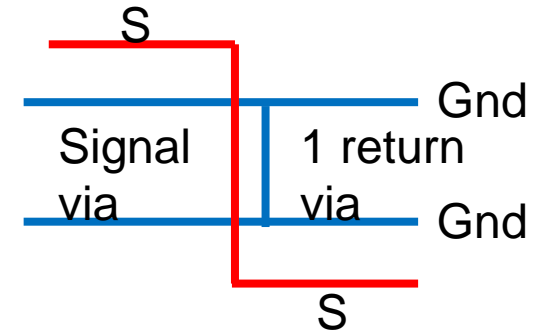
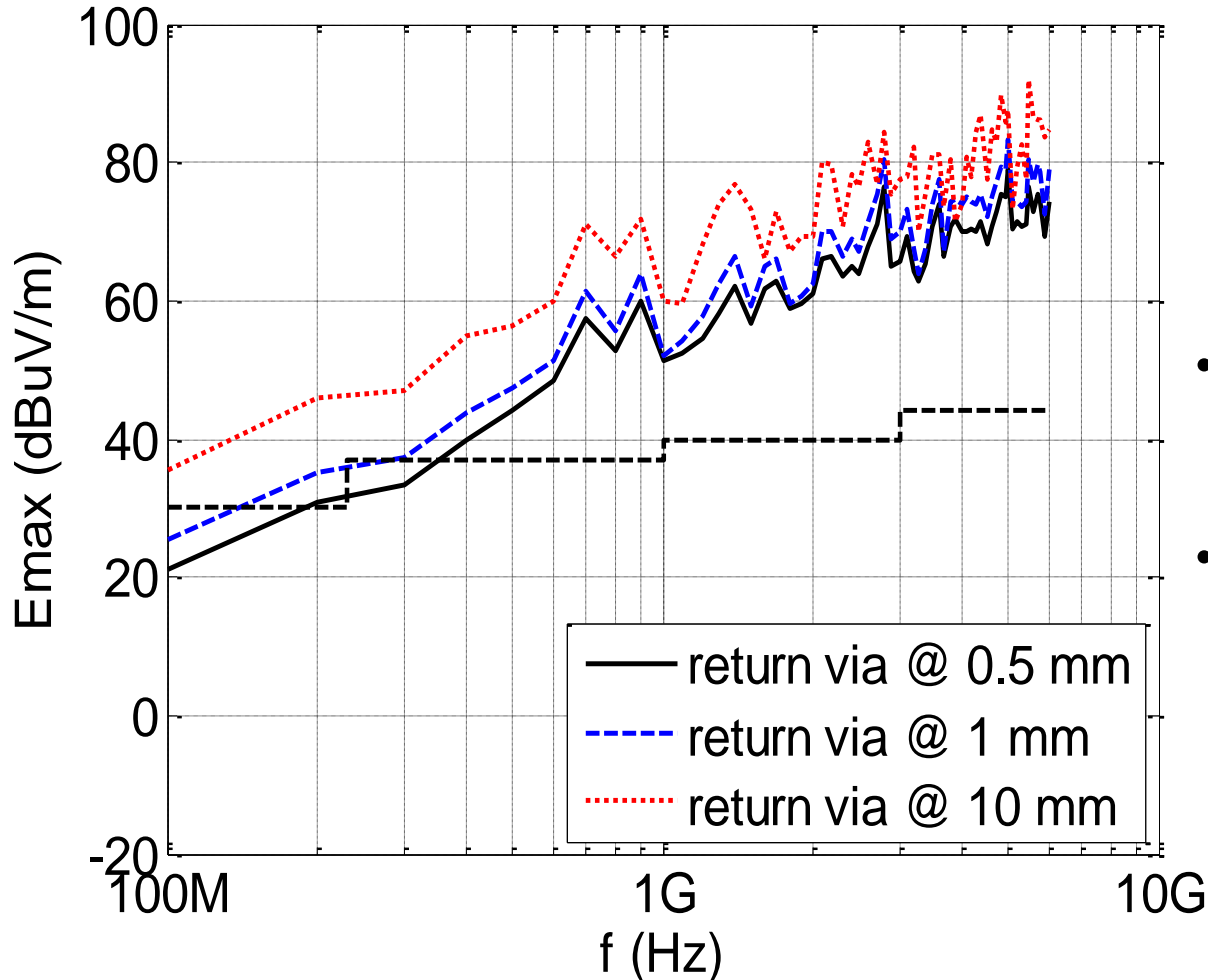


- Return via(s) at 0.7 mm distance from signal via
- Plane distance = 1mm



Simulation results and design guidelines

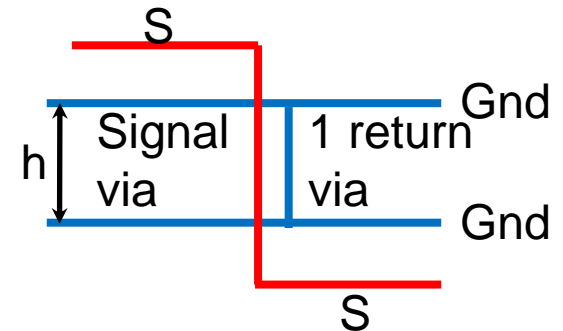
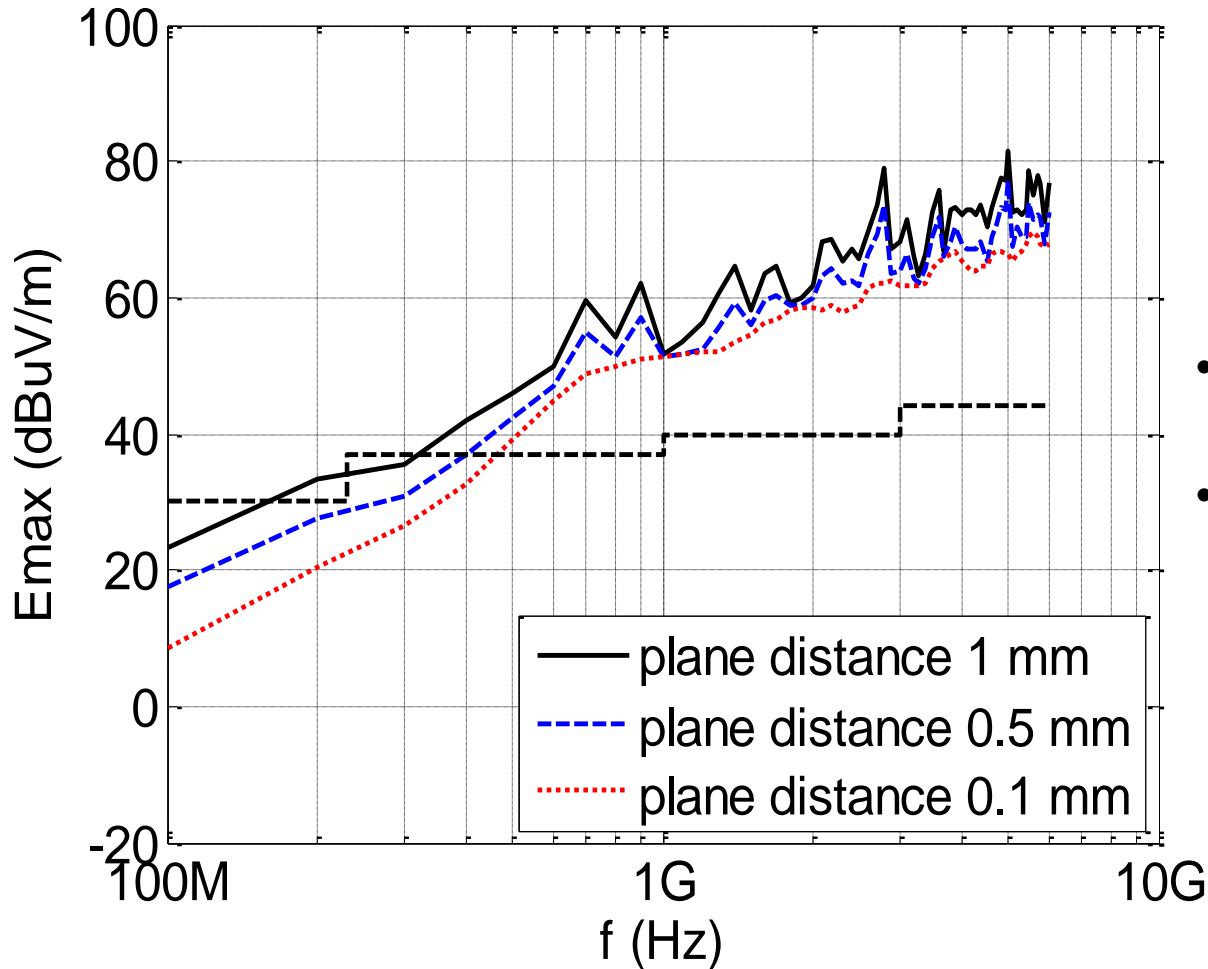
Via distance



- 1 return via at $d = 0.5, 1$ and 10 mm distance from signal via
- Plane distance = 1mm

Simulation results and design guidelines

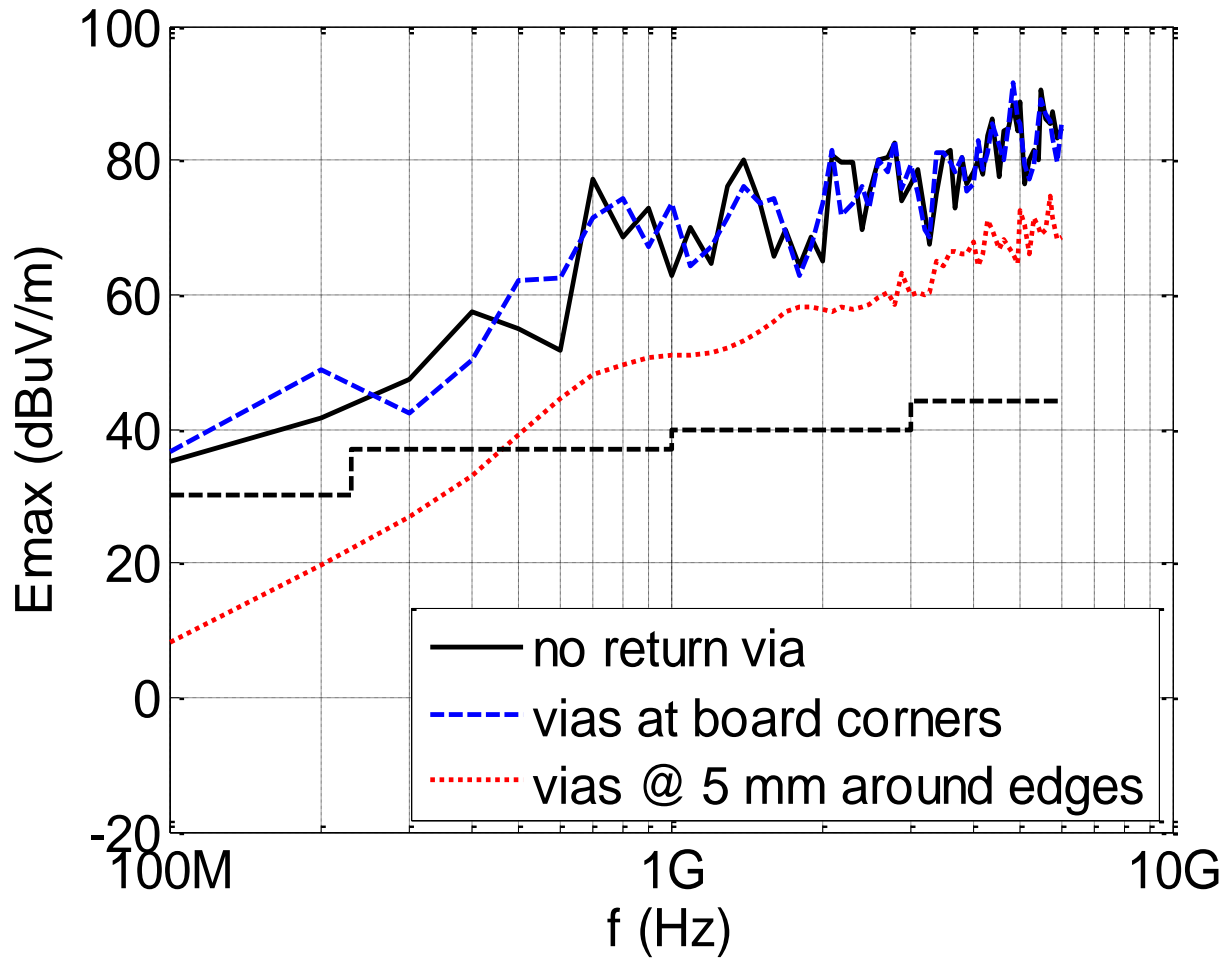
Plane distance



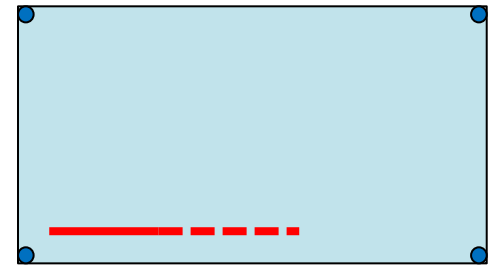
- 1 return via at 0.7 mm distance from signal via
- Plane distance $h = 1, 0.5$ and 0.1 mm

Simulation results and design guidelines

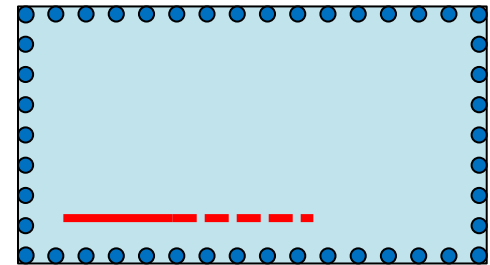
Stitching vias at board edges



- Plane distance = 1 mm



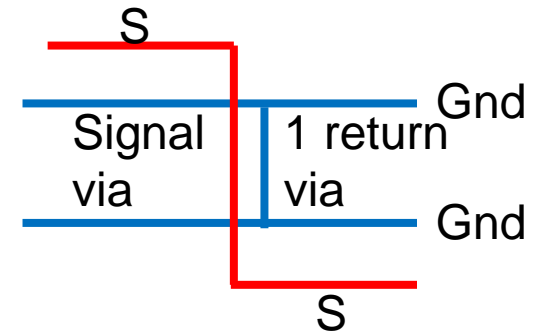
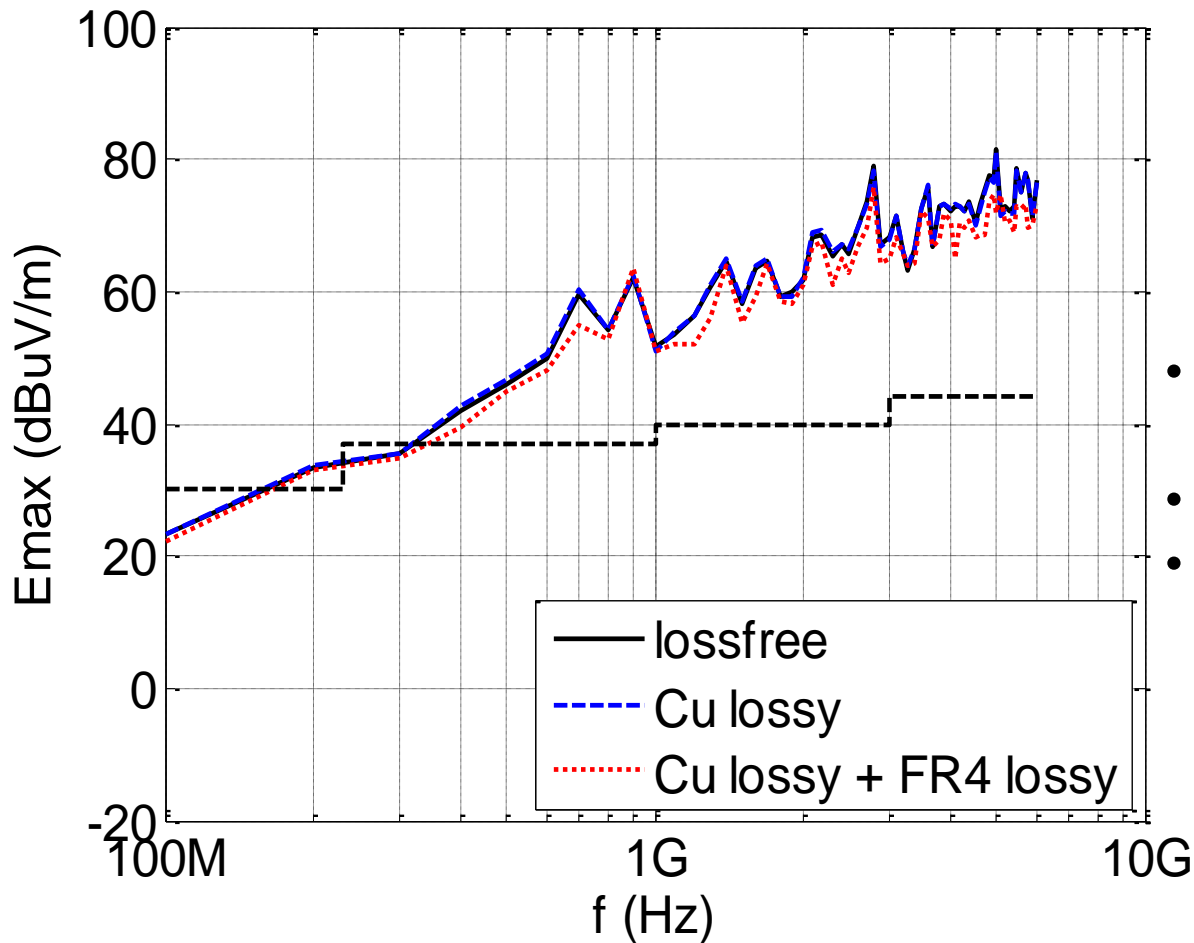
- 4 vias at board corners



- vias at 5 mm around board edges

Simulation results and design guidelines

Copper and dielectric losses



- Return via at 0.7 mm distance from signal via
- Plane distance = 1mm
- Dielectric loss: $\tan \delta = 0.02$

Concluding remarks

- Signal frequencies are increasing and statutory radiated emission requirements are shifting to higher frequencies.
- The design community needs new HF EMC design guidelines.
- In this paper design guidelines are presented to reduce the radiated emission of signals changing reference planes on PCBs up to 6 GHz.
- Earlier papers* contain more quantitative EMC design guidelines at board, cable and enclosure level (based on same modeling approach)

*
1. Van Doorn, “*EMC Expert System for Architecture Design*”, EMC Korea Jeju Island 2011
2. Van Doorn, “*EMC Design Guidelines for Electrical Architectures*”, EMC Europe Brugge 2013

Acknowledgement

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