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Near Field Radiation of Storage Inductors in Power Electronics – Causes, Prevention & Suppression

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- DC-DC converters
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- Radiating components
  - Storage inductor
  - Discrete components (MOSFET’s, diodes,..)
  - Power sources (input DC power supply)

Near Field

- Magnetic & electric fields are considered separately
  - H-field is dominant when
    - $\frac{E}{H} < 377$ Ohms
    - Reduces at the rate of $\frac{1}{r^3}$
    - where r is the distance
  - E-field is dominant when
    - $\frac{E}{H} > 377$ Ohms
    - Reduces at the rate of $\frac{1}{r^2}$

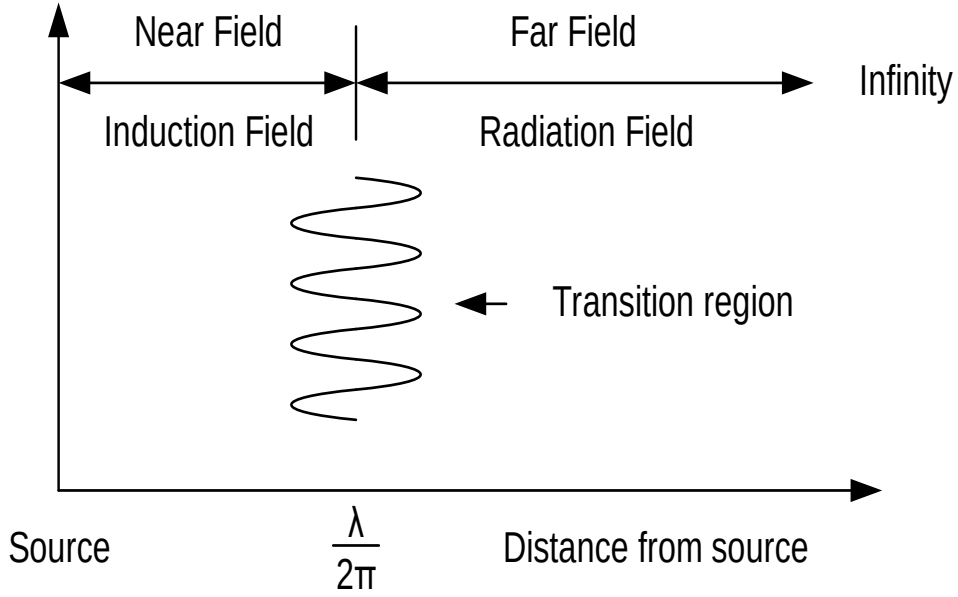


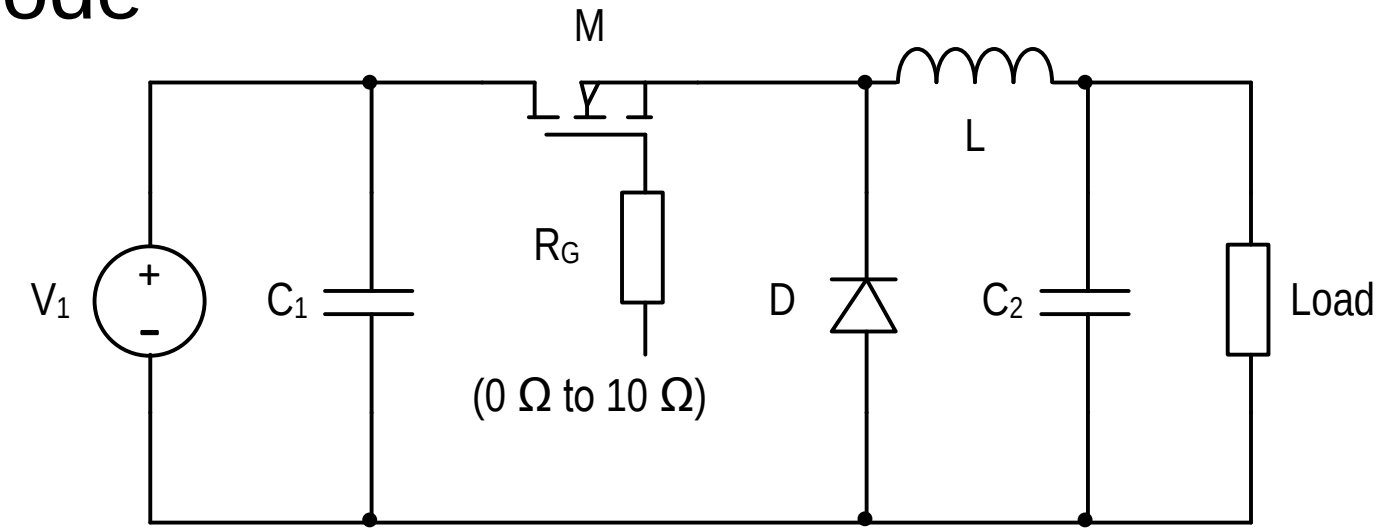
Fig 1: Near and far-field region(s) spread spectrum

Far Field

- Magnetic & electric field are considered as one
  - $\frac{E}{H} = 377$ Ohms
  - Combined fields
  - Both electric & magnetic fields reduce at the rate of $\frac{1}{r}$

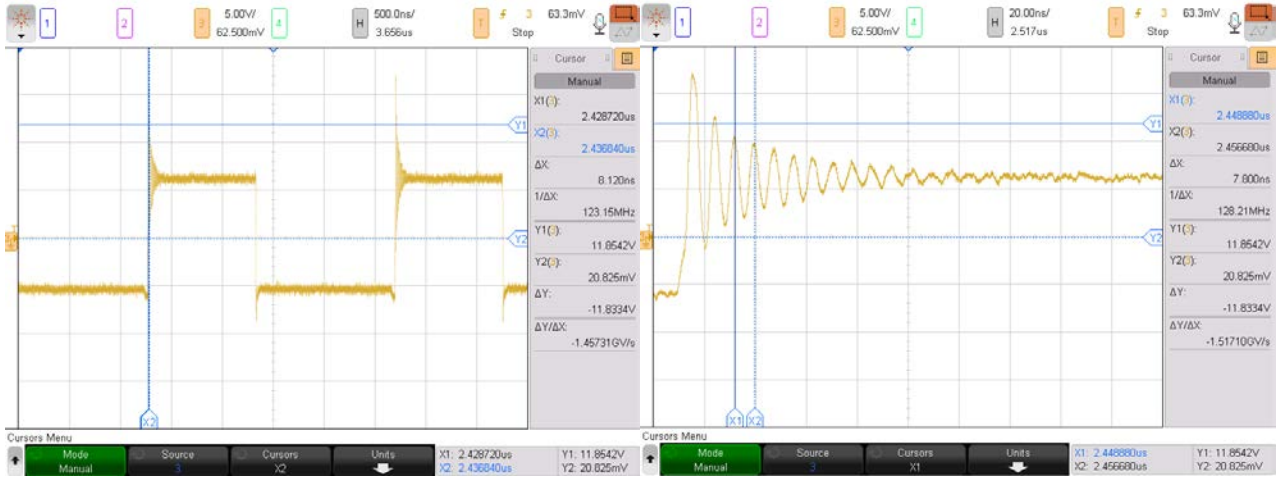
Causes & Prevention of excess near field radiation

- Radiation from the storage inductor is due to fast switching transitions that cause ringing frequencies at switch node



Causes & Prevention of excess near field radiation

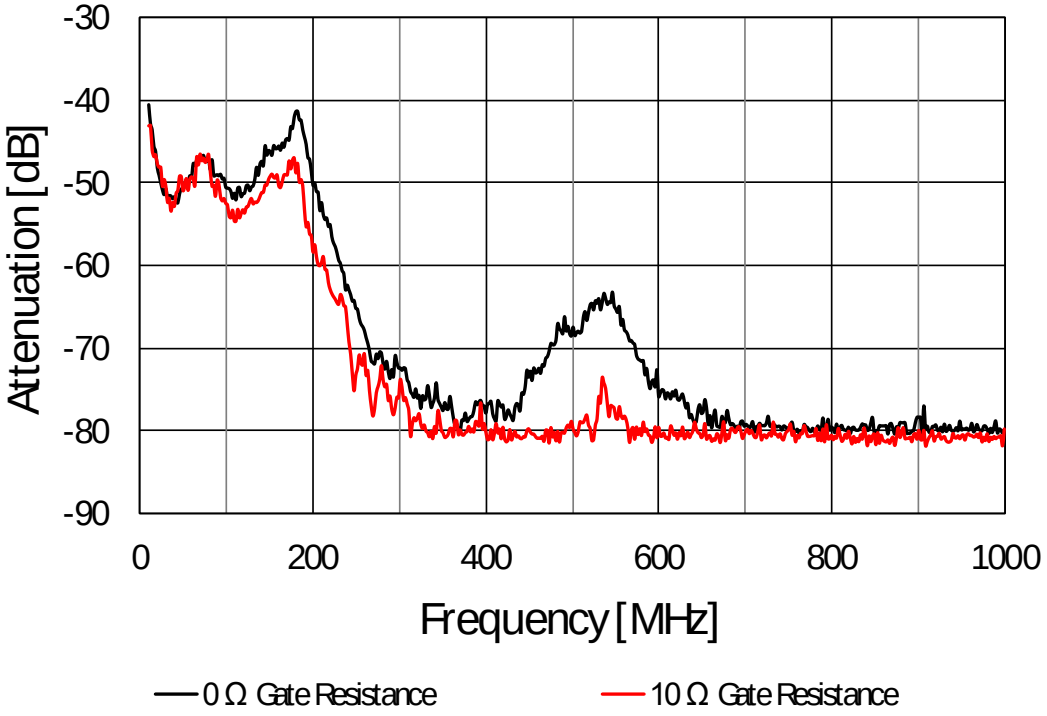
V_DS of Buck converter on the left and switch node ringing during turn on of S1 on the right



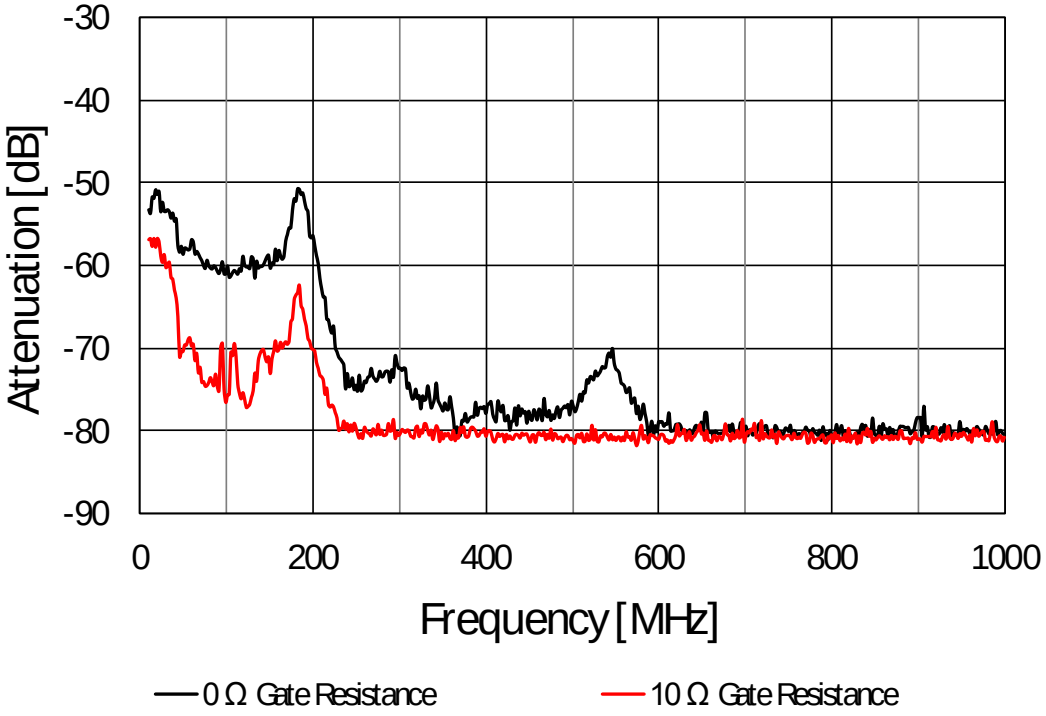
Voltage waveform over the storage Inductor of buck converter on the left and resulting ringing on the inductor during turn on of S1 on the right Note: Input: 12V, Output: 5V, 5A, Switching Frequency: 400 kHz
Ringing Frequency: 100 to 200 MHz depending on the loop resonance

Causes & Prevention of excess near field radiation

- Near field radiation with less ringing. The ringing is controlled by reducing the rise time



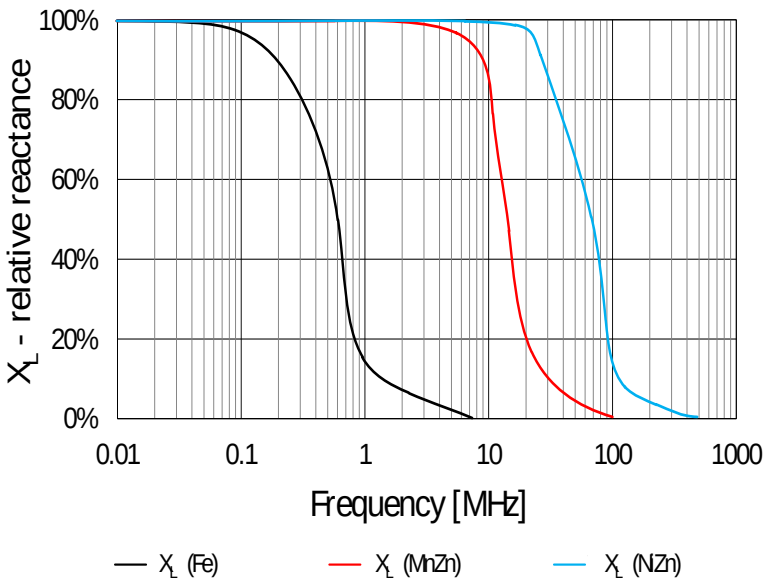
H-field of the inductor at different rise times

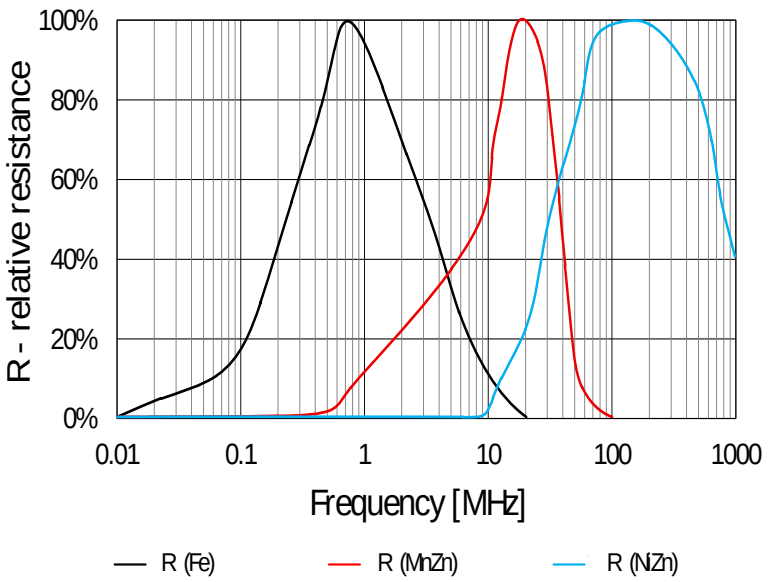


E-field of the inductor at different rise times

Causes, Prevention Suppression of excess near field radiation

- Inductor core materials characterisitics
  - MnZn
  - NiZn
  - Iron Powder
  - Metal Alloy
  - Nano Crystalline

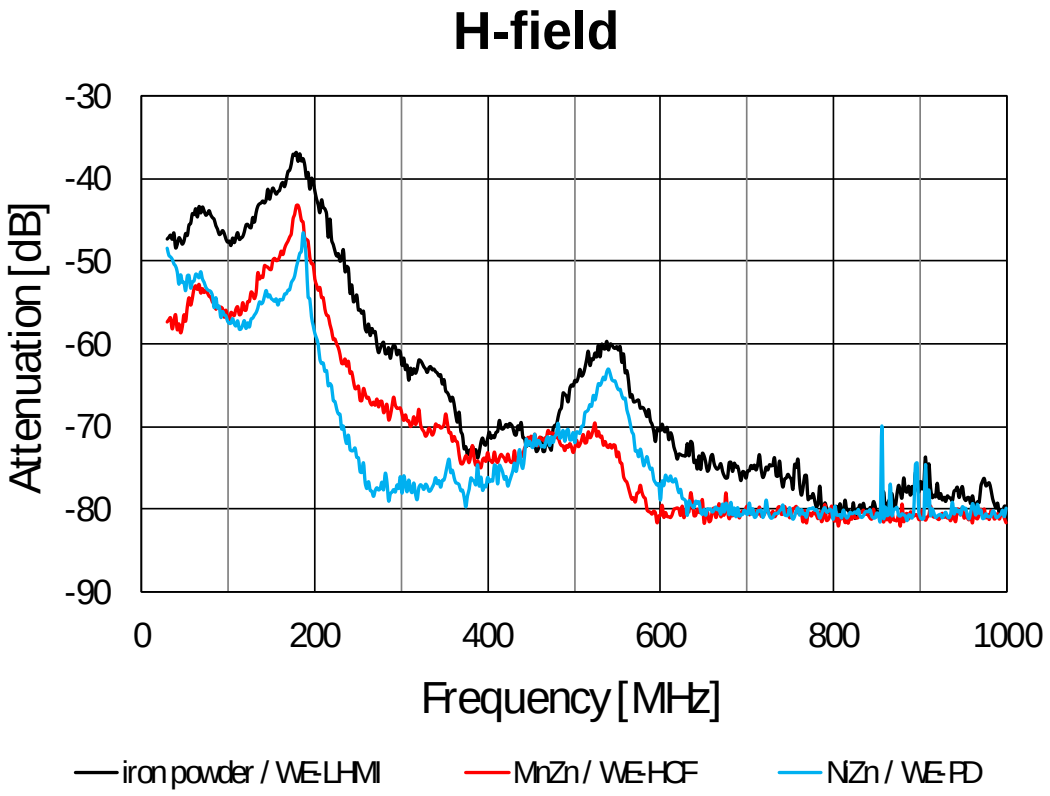


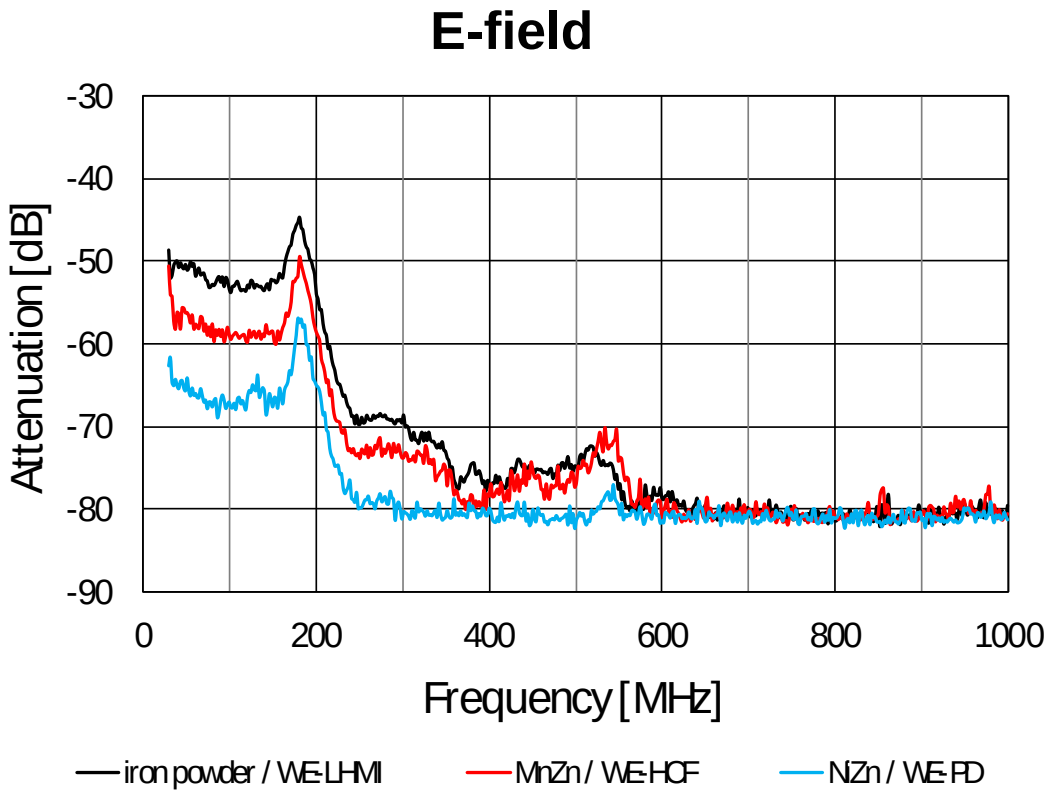


Resistive and inductive characteristics of widely used core materials- Iron powder, MnZn and NiZn.

Causes & Prevention of excess near field radiation

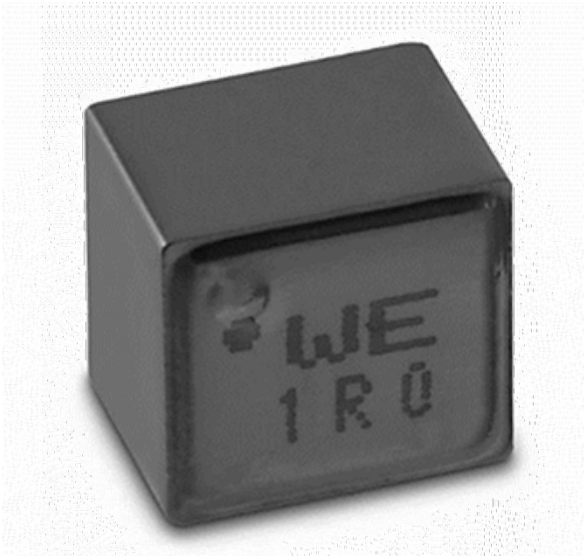
Comparison of **iron powder** (WE-LHMI), **MnZn** (WE-HCF) and **NiZn** (WE-PD) core material

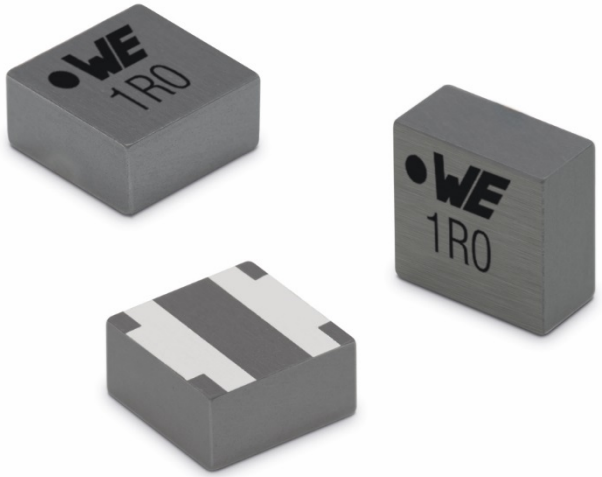




Causes & Prevention of excess near field radiation

- EM Radiation due to the Influence of Start of the Winding in an Inductor

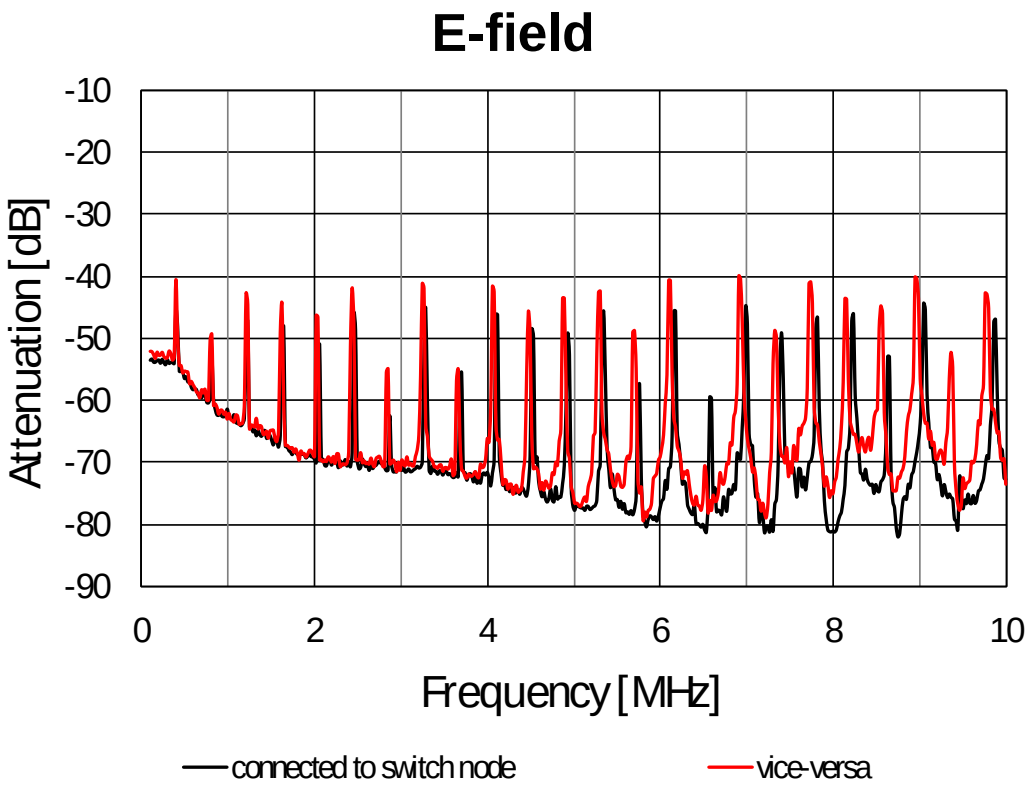


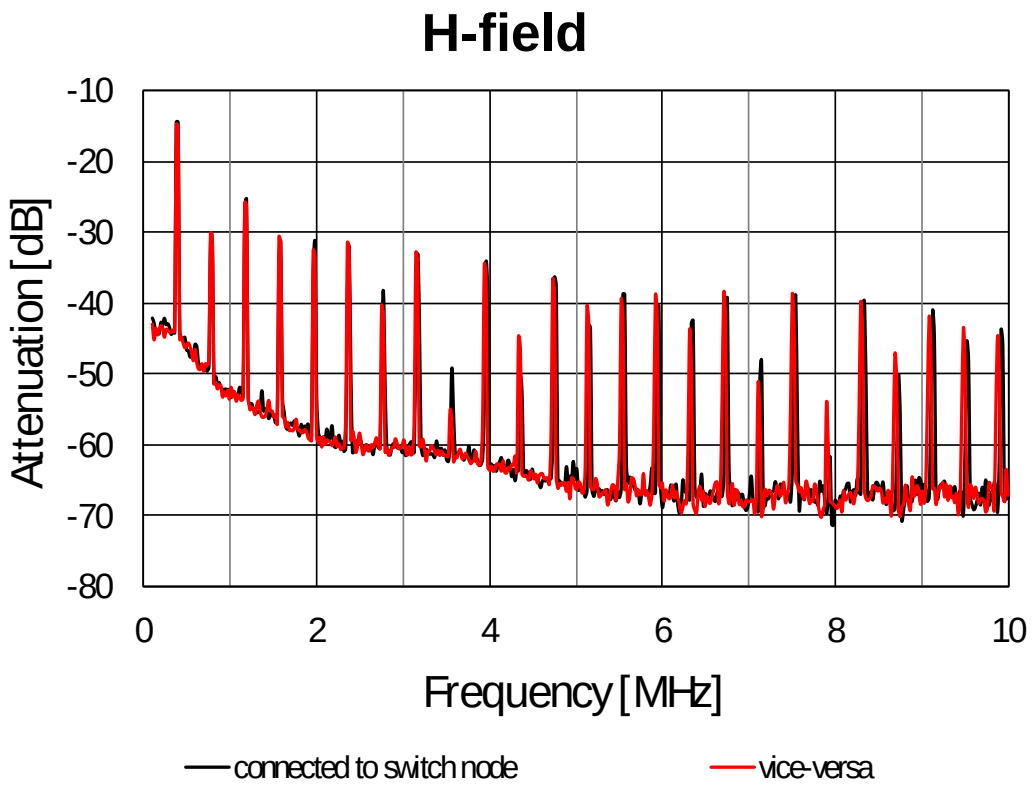


WE-XHMI, WE-MAPI and WE-PD2 with the 'dot' identifying the location of the start of the winding

Causes & Prevention of excess near field radiation

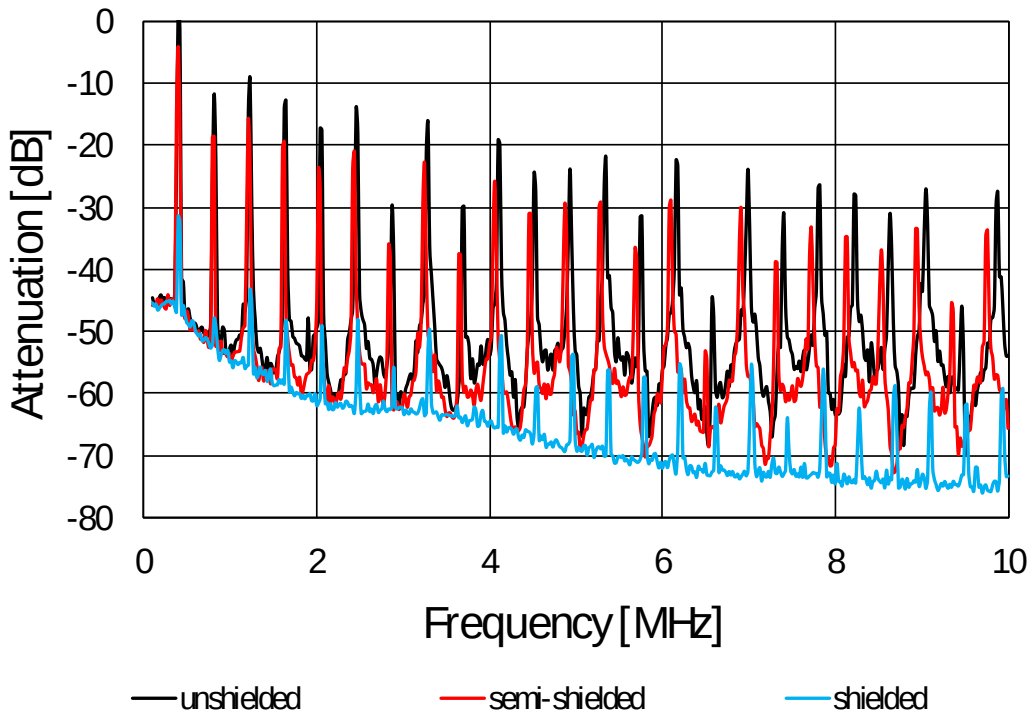
Inductor's start of winding connected **to the switch node** and **vice-versa**





Causes & Prevention of excess near field radiation

- **EM radiation behavior of Unshielded, Semi-Shielded and Shielded Inductors**



Magnetic radiation of unshielded, semi-shielded and shielded inductors

Causes & Prevention of excess near field radiation

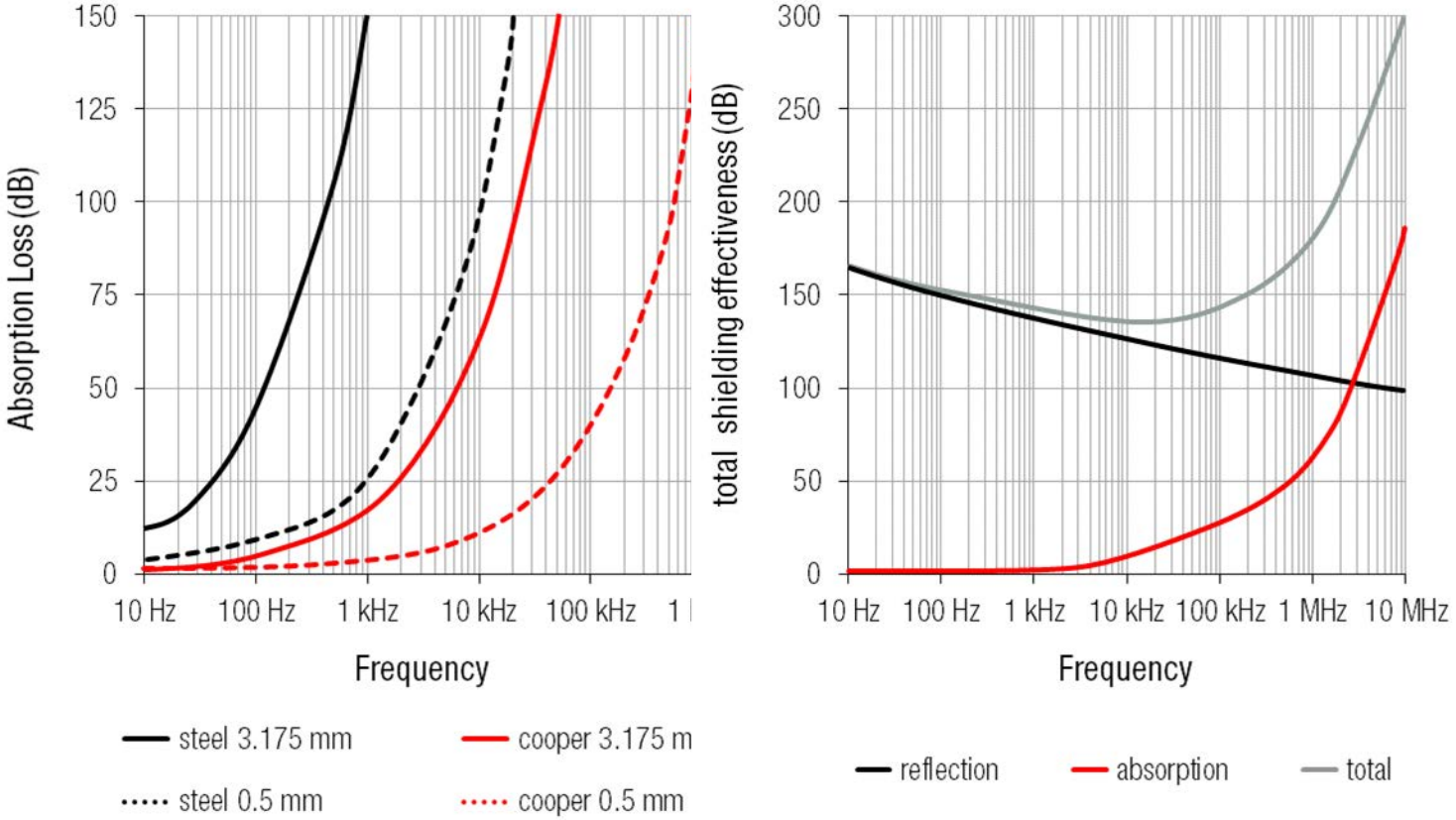
- Other factors include..
  - Permeability of the core material at desired frequency
  - Large AC currents at relatively higher frequencies
  - PCB layout
  - Source properties like shape of the waveform, switching frequencies
  - Orientation of the inductor relative to other components

Prevention

- Shielding
  - Absorption
  - Reflection
  - $S = (Absorption + Reflection)\ dB$
- Shielding Effectiveness
  - $S = 20 \log \left(\frac{H_0}{H_1}\right)\ dB$
  - $S = 20 \log \left(\frac{E_0}{E_1}\right)\ dB$

Prevention

- Shielding metals
  - Copper
  - Aluminum
  - Metal Alloys
  - Composite Mixtures

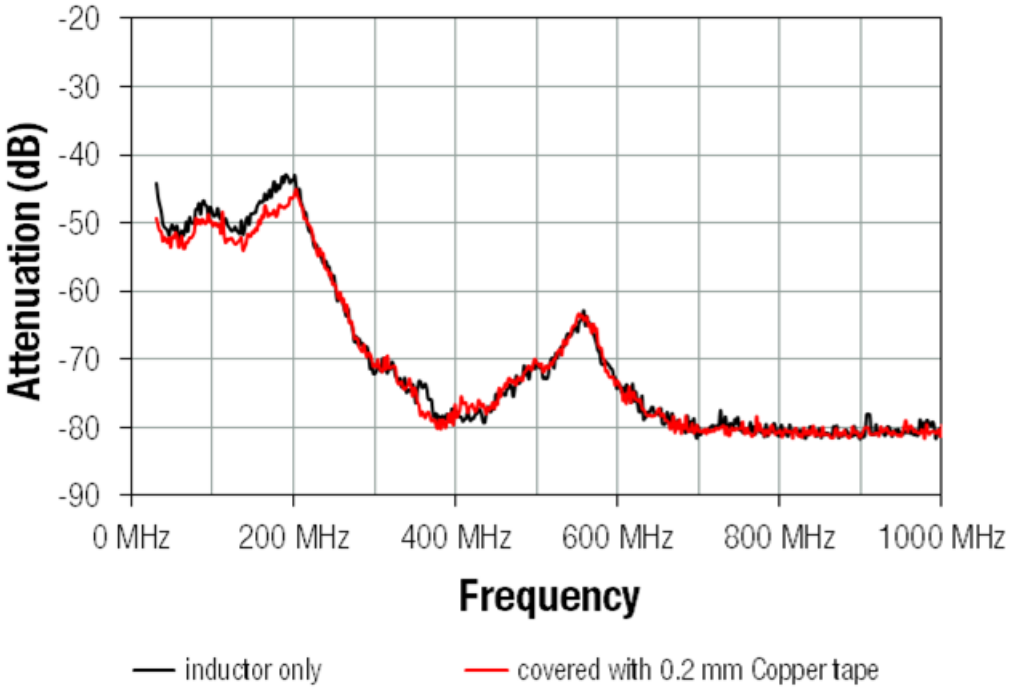


Absorption and reflection characteristics of metal shielding

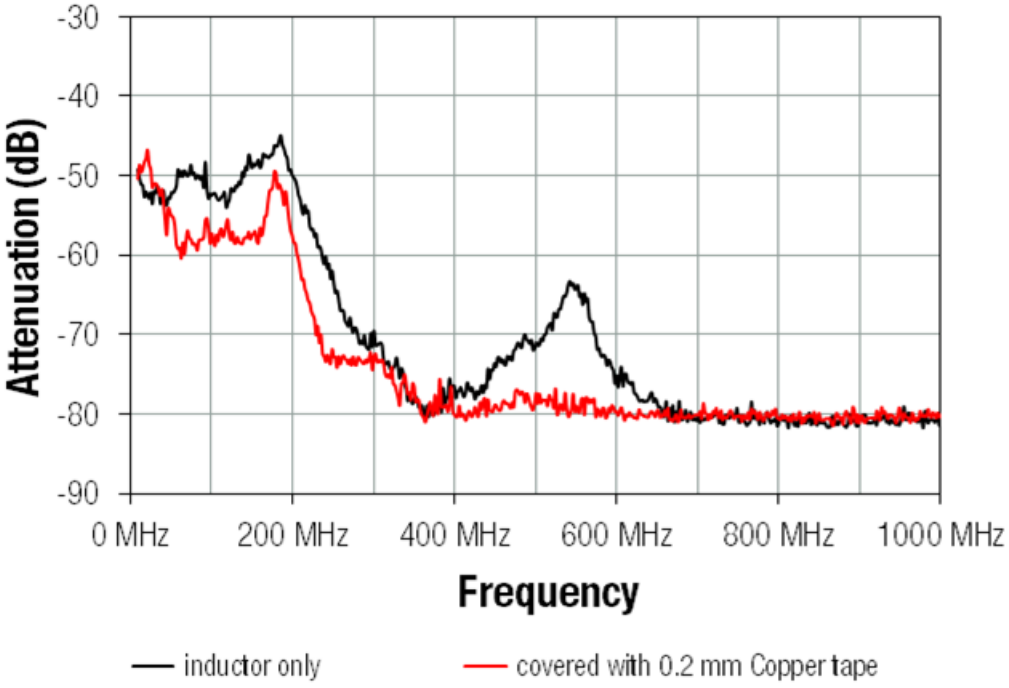
Prevention

comparison of iron powder (WE-LHMI) **without additional shielding**,
and **with 0.2mm copper tape**

H-field



E-field



Conclusion

- Shielding solutions for fast switching devices including GaN, SiC devices
- Reduction of far field radiation as well
- Metal & Magnetic shielding solutions can be done optimally based on the application
- A few techniques can also be considered during switching, like reducing the rise & fall times

Questions

References

- R. Bramanpalli, *The Behavior of Electro-Magnetic Radiation of Power Inductors in Power Management*
- H. Ott, *Electromagnetic Compatibility Engineering,* John Wiley & Sons, Hoboken, NJ, 2009