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ELECTROMAGNETIC COMPATIBILITY, SIGNAL & POWER INTEGRITY

TU-PM-4: Automotive EMC

Sponsored by IEEE EMCS TC-2

Investigation of the Effectiveness of RF Absorbers for Mitigation of Automotive Radiated Emission by Measurement and Simulation

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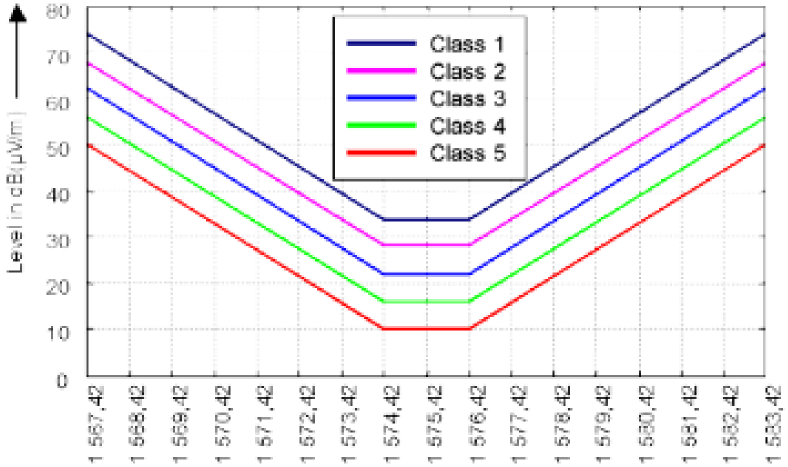
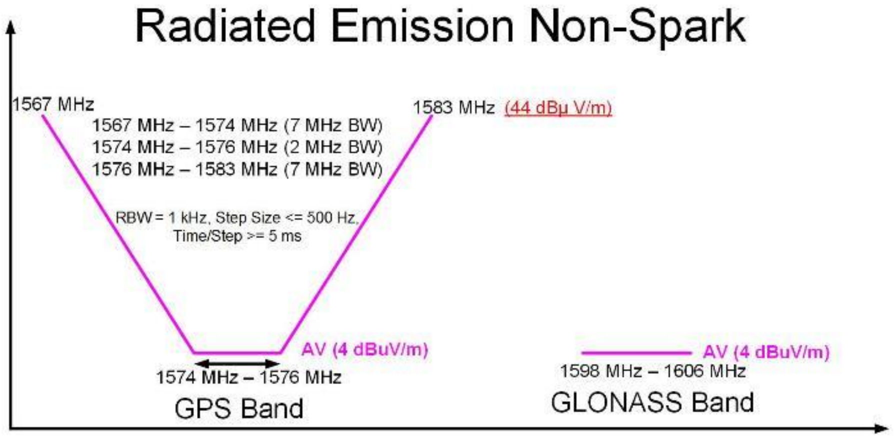
Motivation

- *Progressive connectivity leads to increase of data rates in and between components while EMC requirements at automotive sector remain strict or even increase like GPS/GLONASS band RE (4 dBµV/m @ 1.575 GHz)*

Motivation in more Detail

- Harsh GPS + GLONASS emission requirements on component level lead to a need to look out for additional components to suppress radiation





- RF Absorber materials can improve EMC behavior and be purposeful on the last steps to EMC compliant development of ICs and ECUs
- This collaboration investigates near field and far field behavior of a commercial RF absorbers on real automotive component development by simulation and field measurements.

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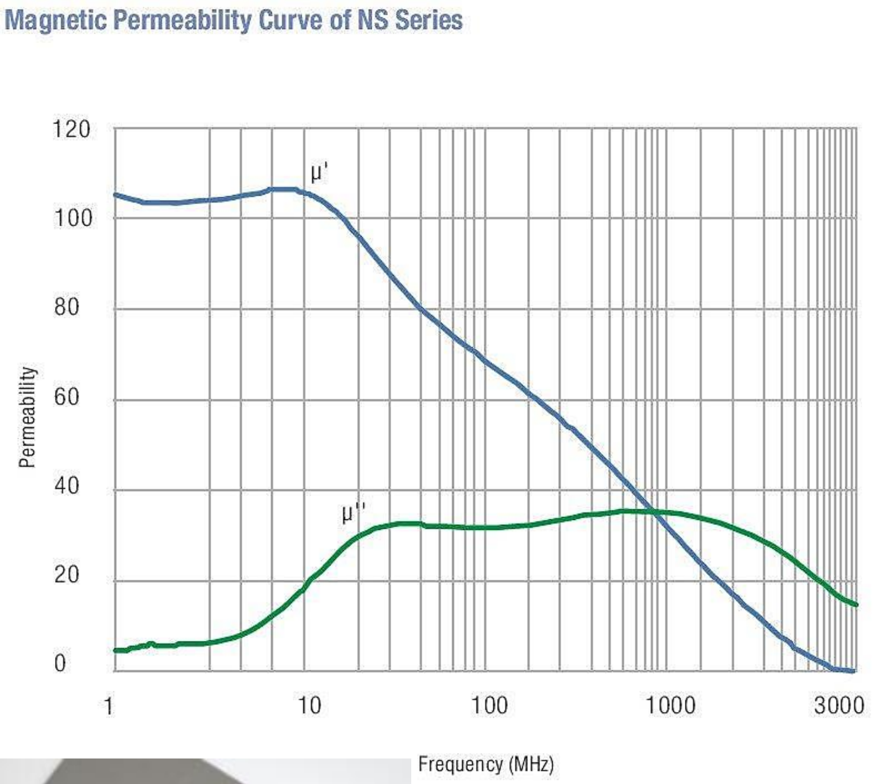
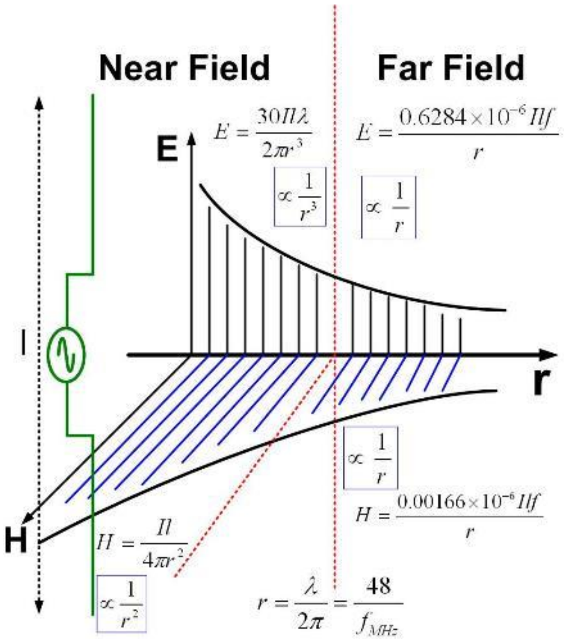
What exactly is an RF absorber?

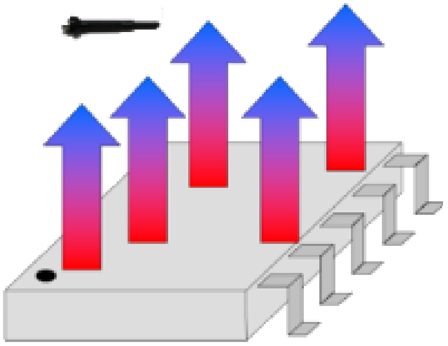
- Electrically non-conductive silicone rubber sheet
- Elastomer based, “magnetically loaded” material
- Frequency dependent complex permeability (and permittivity)
- Intended to absorb energy in the ***near-field***

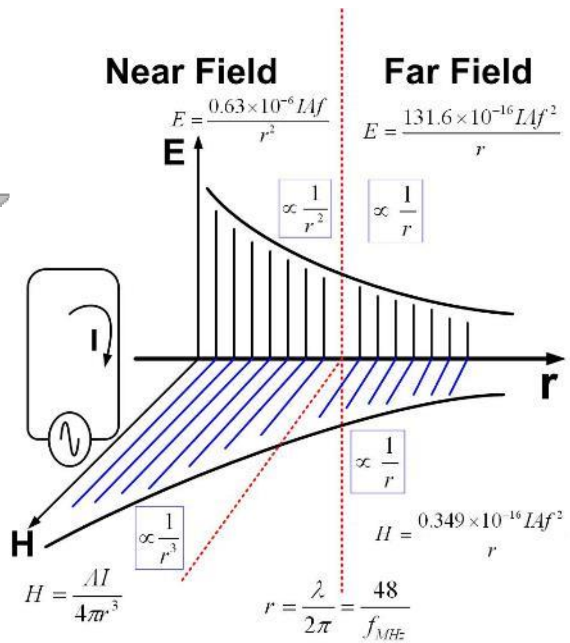


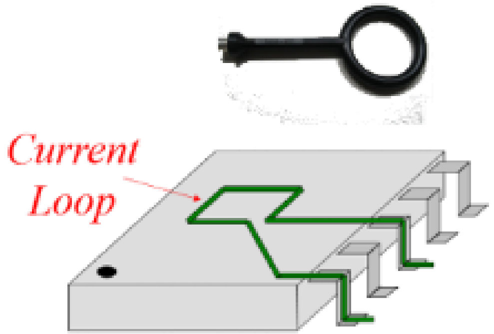
Field Theory – Electric and Magnetic Fields

- How will the material act on these fields?



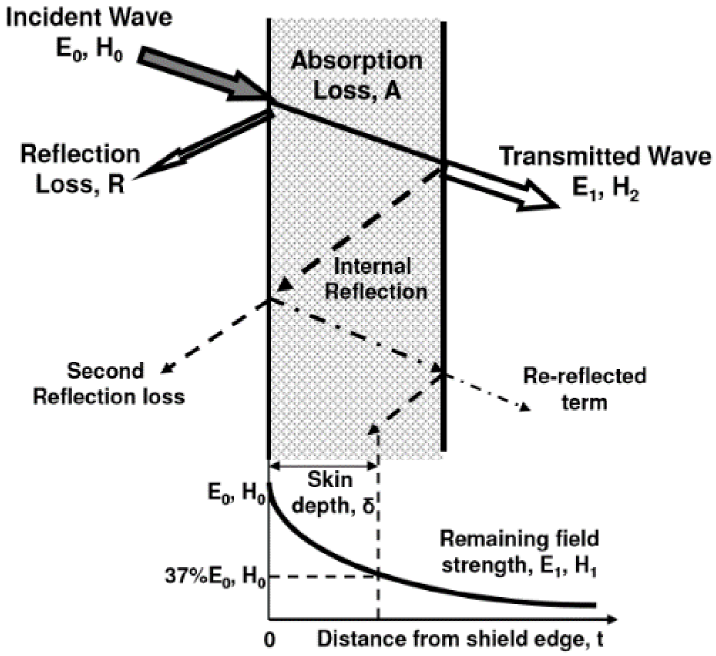






Shielding Effectiveness

- Absorption loss and reflection loss



$$R_E = 321.8 + 10\log\frac{\sigma}{f^3 r^2 \mu}$$

$$R_H = 14.6 + 10\log\frac{f r^2 \sigma}{\mu}$$

$$R_P = 168 - 10\log\frac{f\mu}{\sigma}$$

Where R_E, R_H, and R_P are the reflection losses for the electric, magnetic, and plane wave fields expressed in dB; σ is the relative conductivity referred to copper; f is the frequency in Hz; μ is the relative permeability referred to free space; r is the distance from the source to the shielding in m.

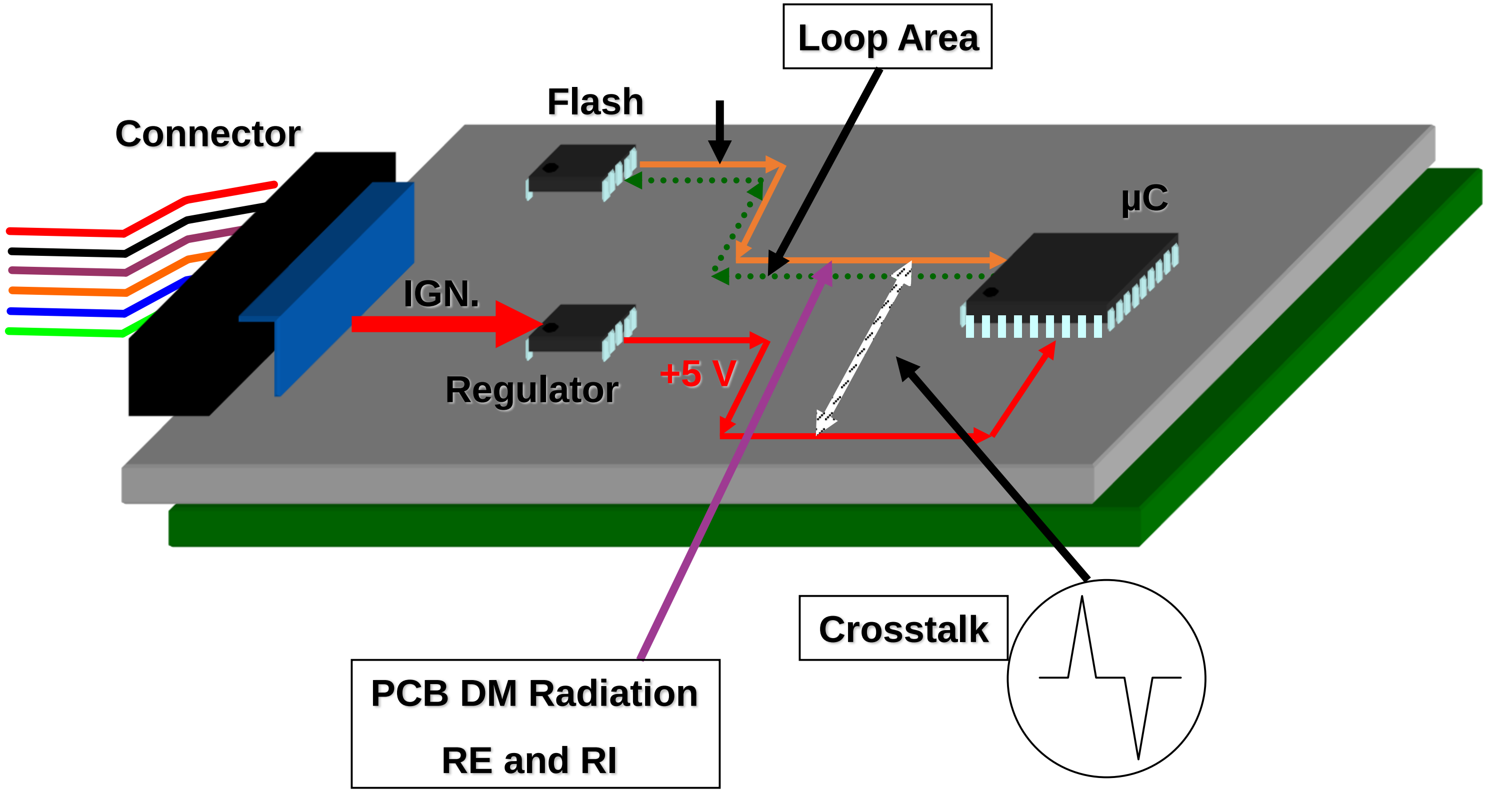
Absorption loss depends on material thickness, permeability, electrical conductivity, and the frequency of the incident wave. It is the same for all electromagnetic waves.

Reflection loss depends on the distance of the EMI source to the material (different for electric, magnetic, and plane waves), material electrical conductivity, and the frequency of the incident wave.

Source: http://www.flexautomotive.net/EMCFLEXBLOG/post/2016/04/27/shielding-effectivenes

Field Theory – Multi Layer Printed Circuit Board

- Effects, which can be suppressed by absorber pads



Field Theory – Multi Layer Printed Circuit Board

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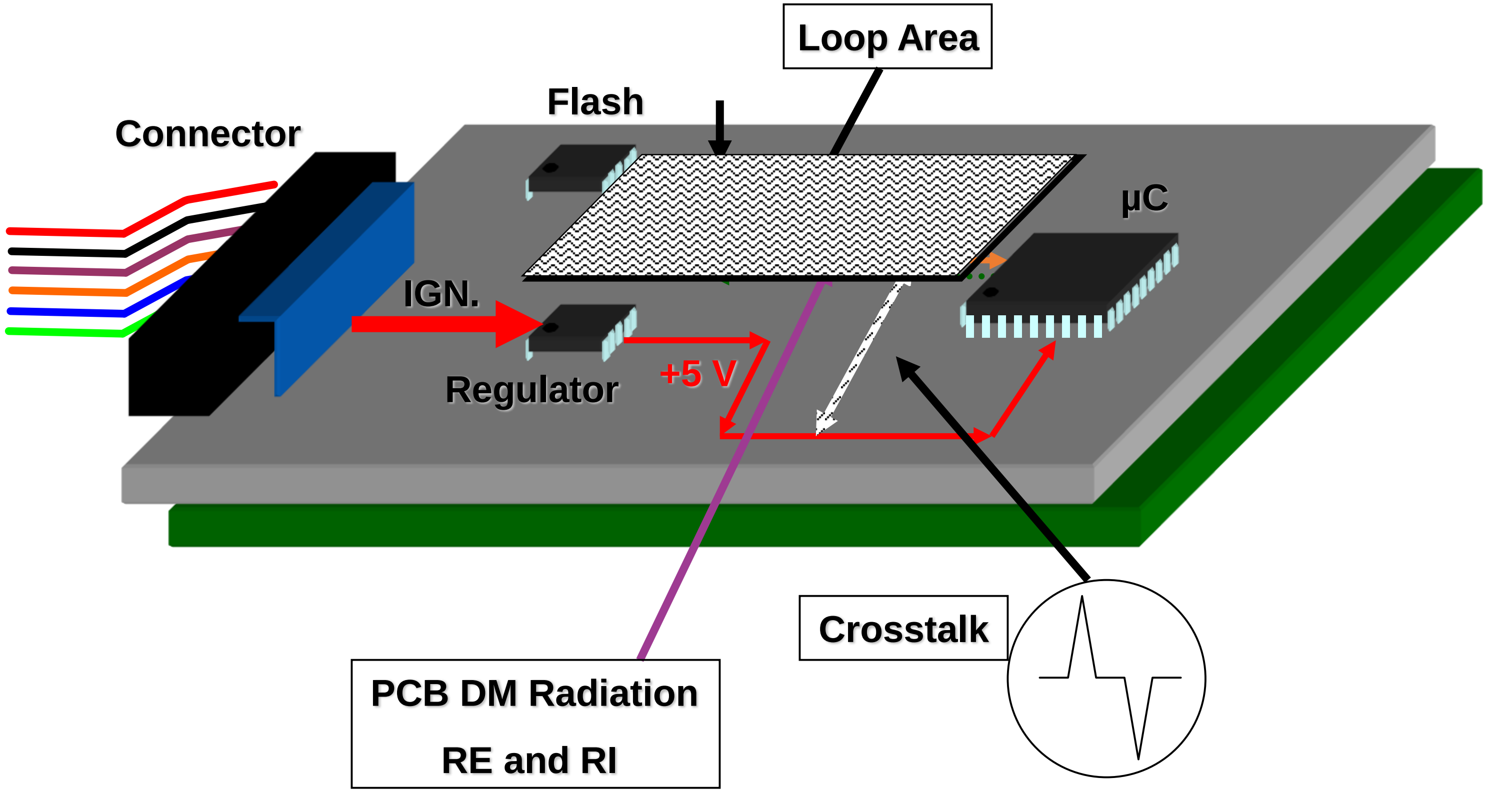

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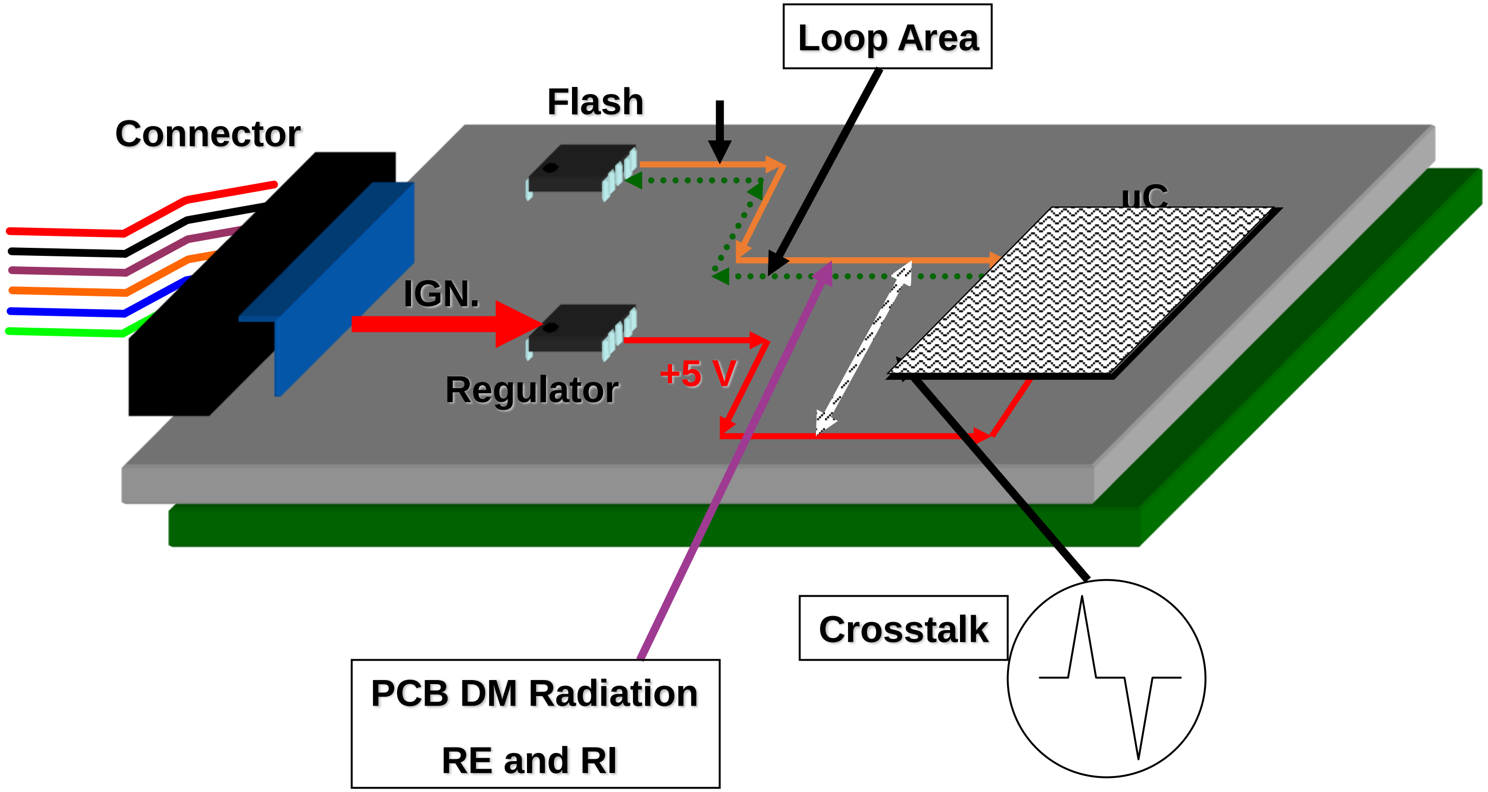
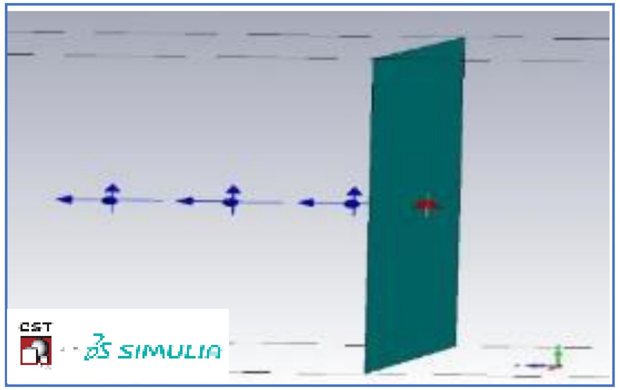


Approaches

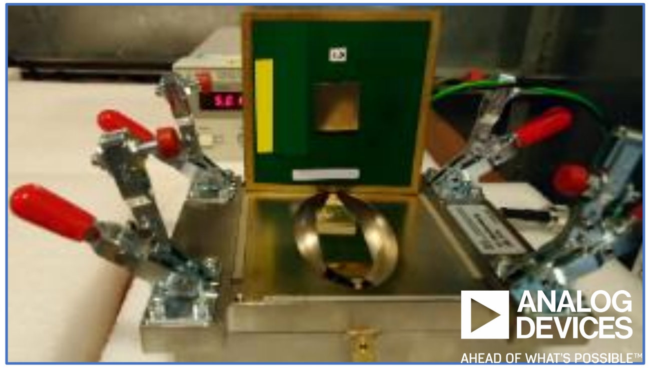
- Wide range of industry procedures to verify absorber effectiveness at GPS-Band

- 3D EM Simulation



- Radiation source
  - Dipole and Loop Antenna
- Antenna Distance
  - 5, 15, 25, 1e3 mm
  - 1 mm to absorber

- Near field IC measurement



- Radiation source
  - Stripline
- Antenna distance
  - 6.7 mm

- Far field RE measurement

- Radiation source
  - Horn-, Loop-, Rod-Antenna
- Antenna distance
  - 1 m

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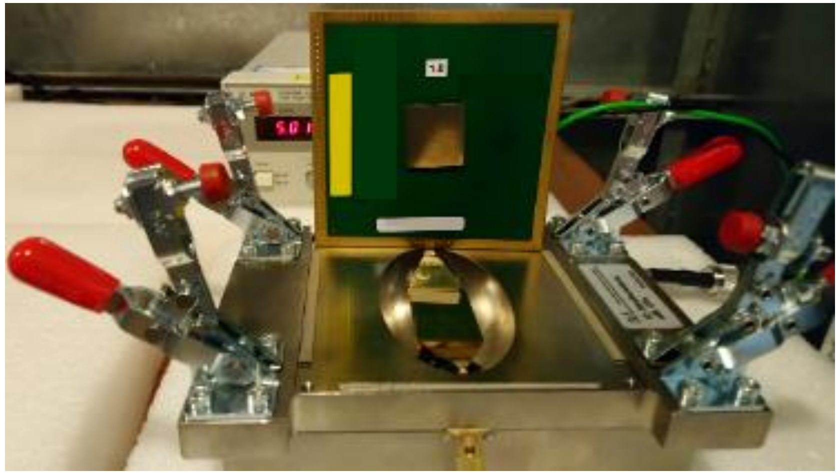
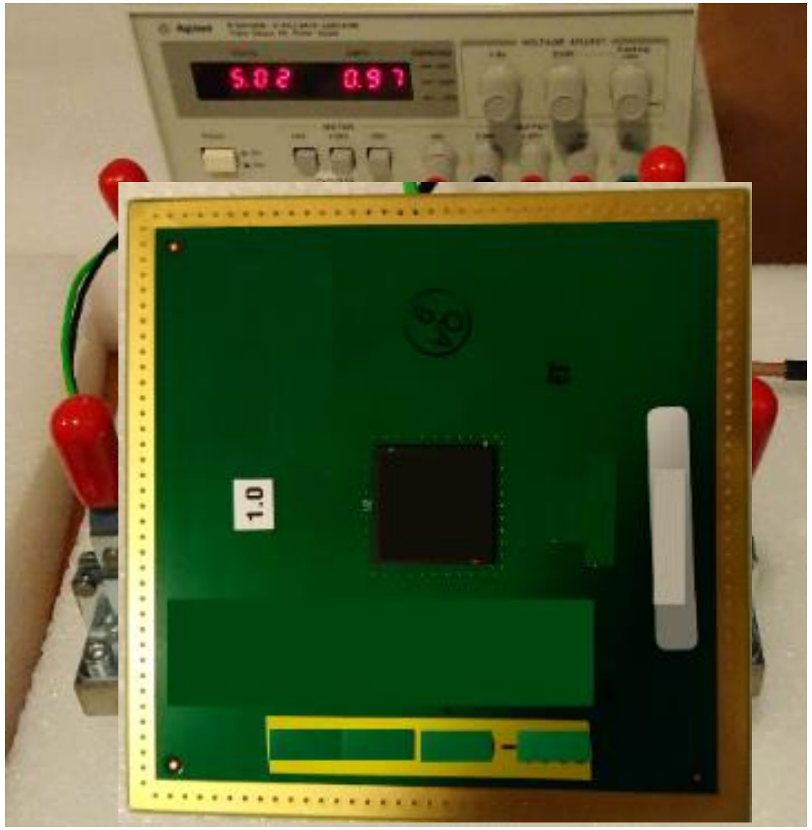
IC Stripline Emission Measurement

- IC-EMC PCB as per IEC 61967-1
- Stripline measurement as per IEC 61967-8





- TEM or GTEM cells could also be used
  → Stripline is more sensitive

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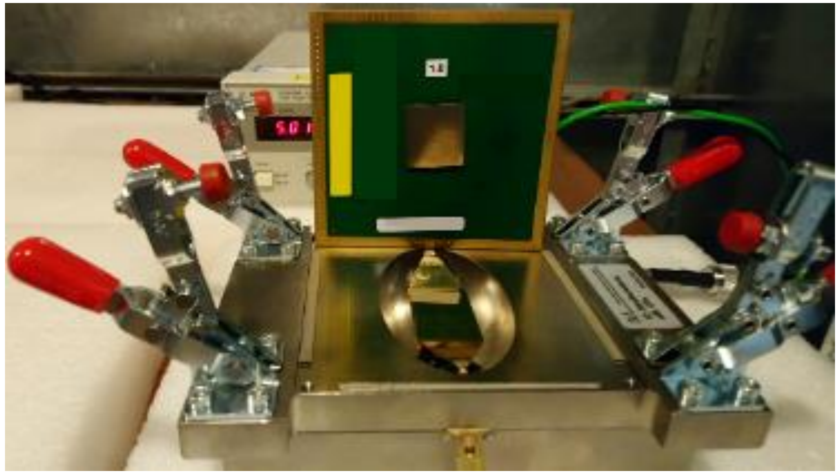
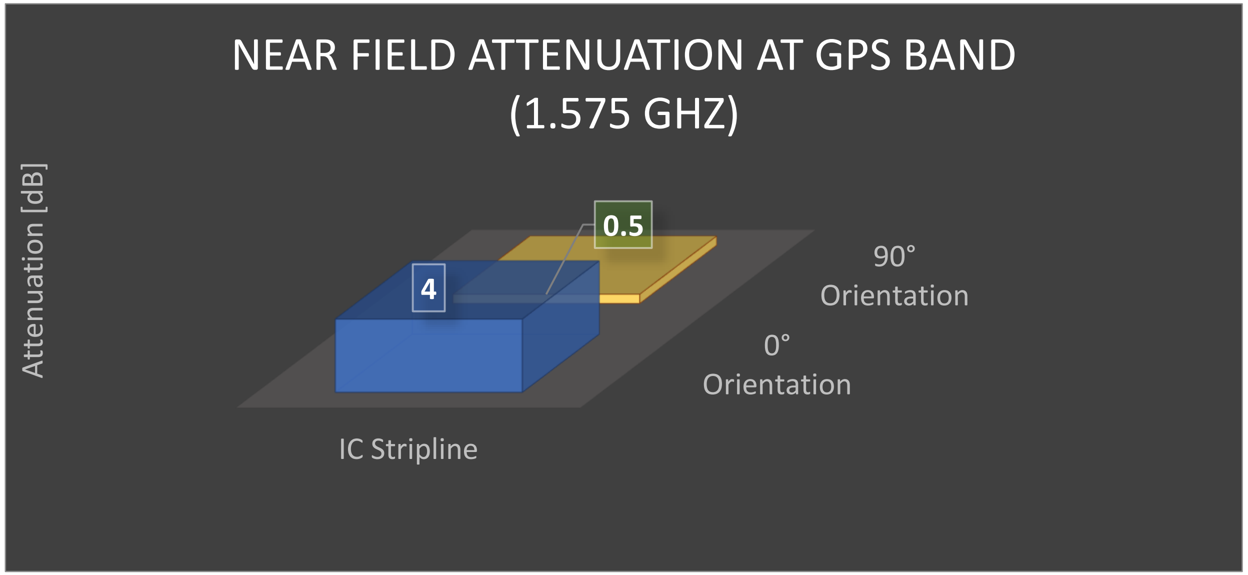
IC Stripline Emission Measurement

- IC-EMC PCB as per IEC 61967-1
- Stripline measurement as per IEC 61967-8





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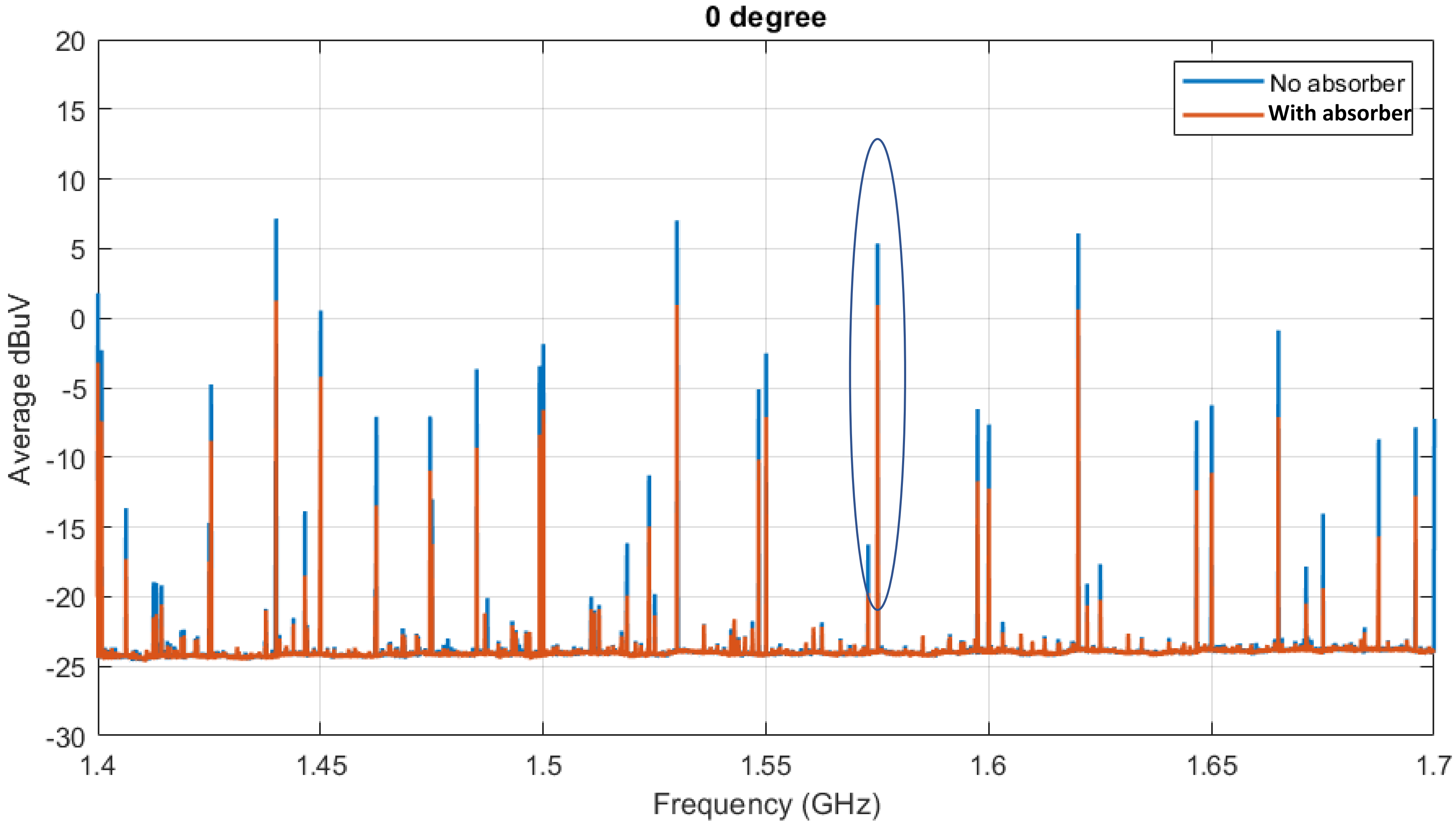
Emission Result – 0 Degree Orientation



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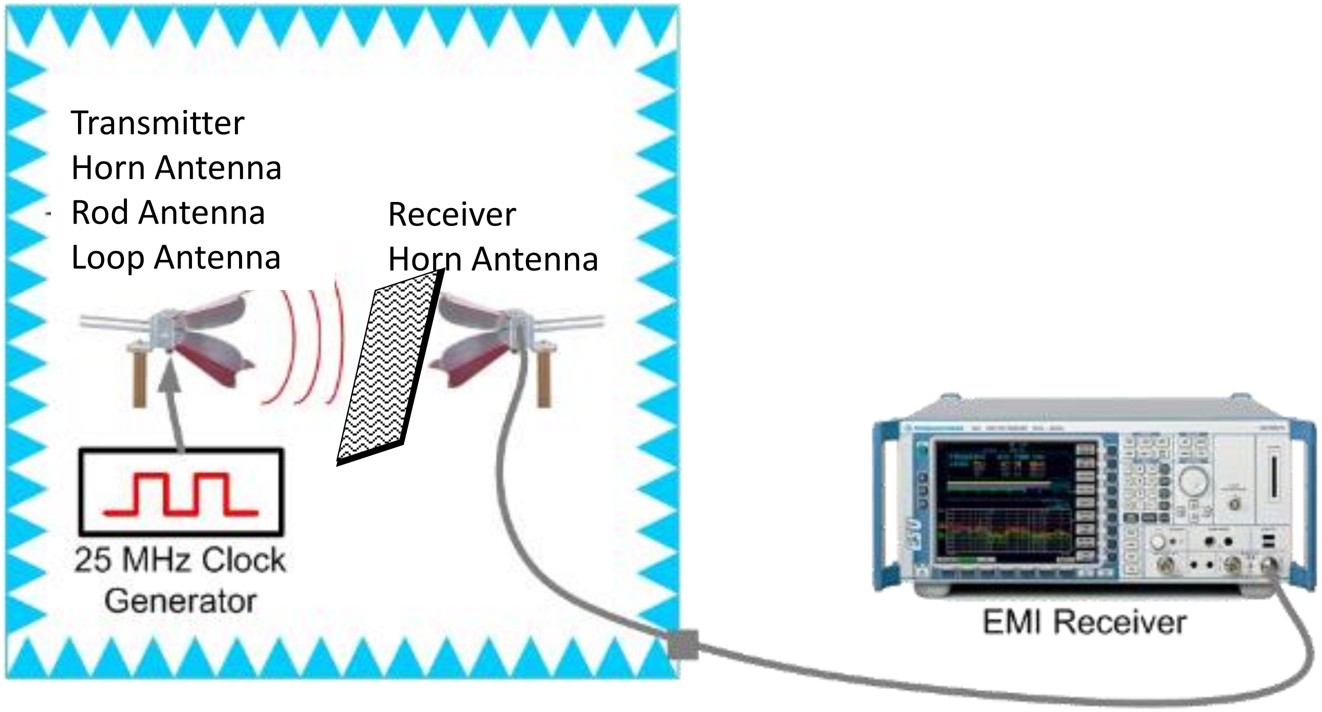
Approach – Far Field Measurement

- Reproduce Emission Setup
  - Vary transmitter to radiate
    - electric (rod antenna)
    - magnetic (loop antenna)
    - OEM compliant (ETS 3115 horn antenna)

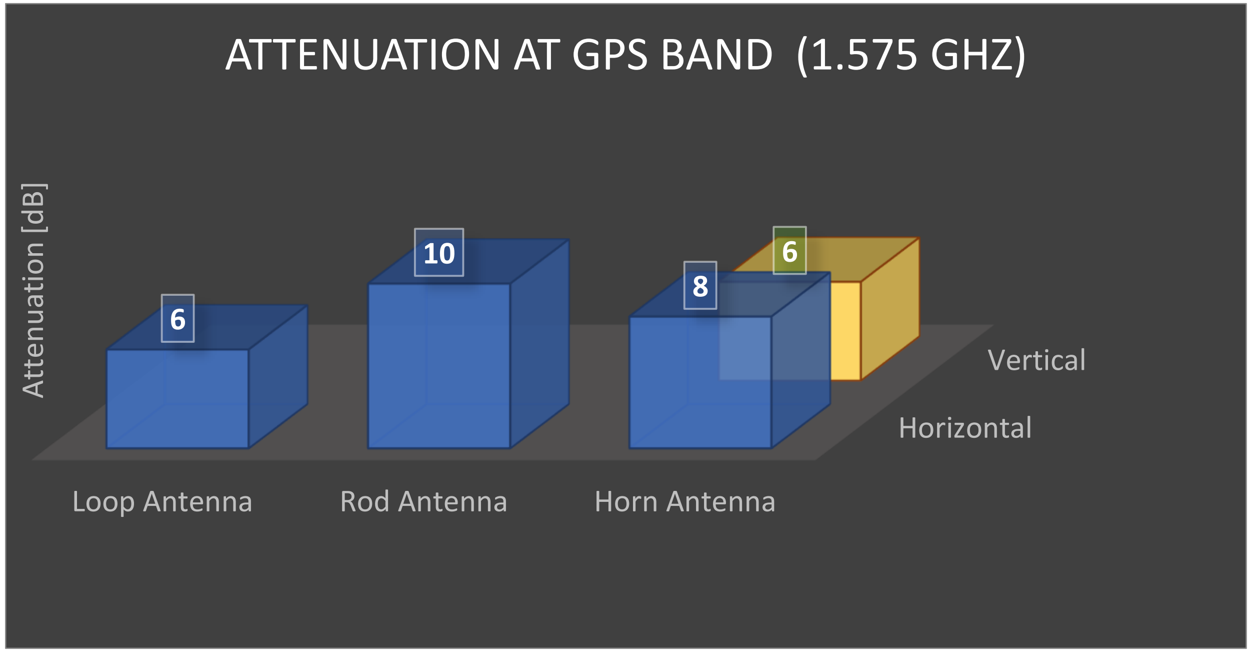
→ Measure with and without absorber gap pad → Derive attenuation by subtraction



Approach – Far Field Measurement

- Reproduce Radiated Emission Setup + Real ECU measurement
  - Unshielded Loop Antenna

  - Wrap transmitter with absorber



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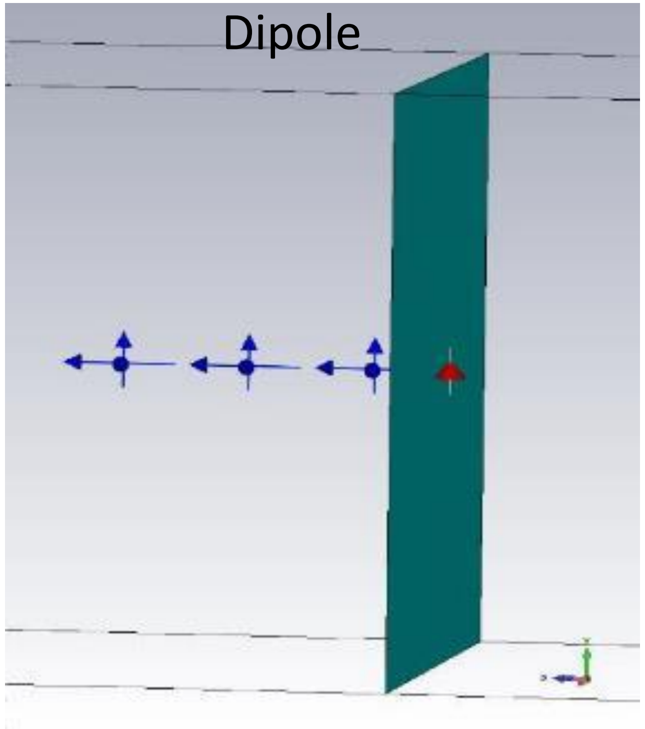
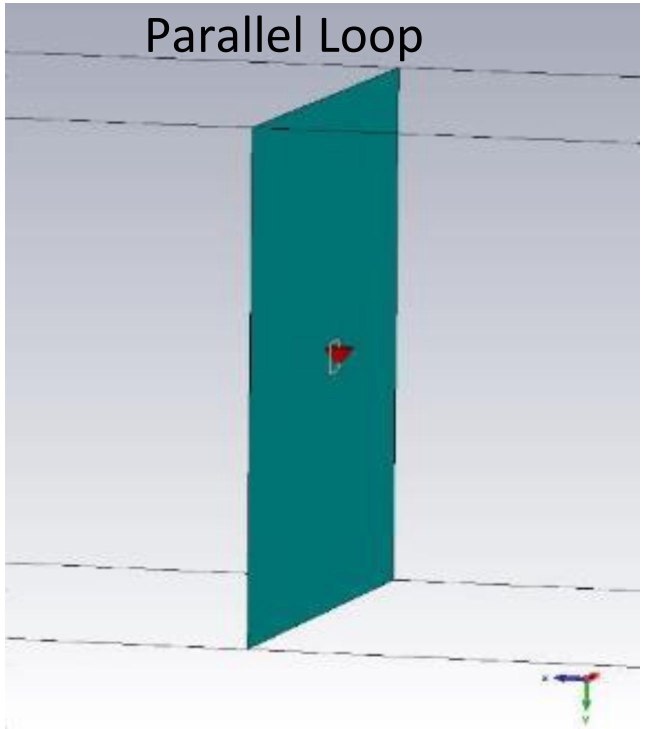
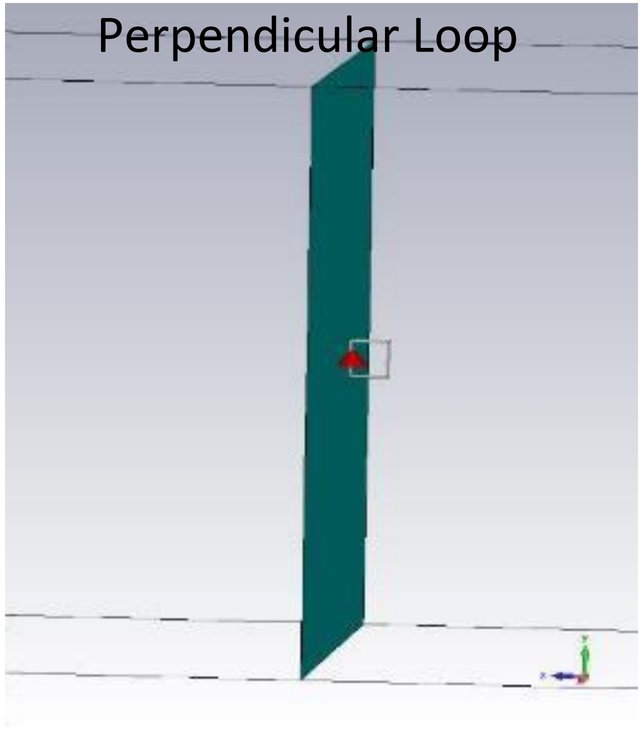
Simulation analysis of absorber, effect of source type

- Dipole (electric) and loop (magnetic) sources, close to absorber material (1mm separation distance)
- Absorber modelled as thin panel, with 0.2 mm thickness defined, with complex frequency dependent ε, μ
- Study field behaviour, E- and H- Field probes located 5, 15, 25 mm beyond absorber pad, and in Farfield (1m)

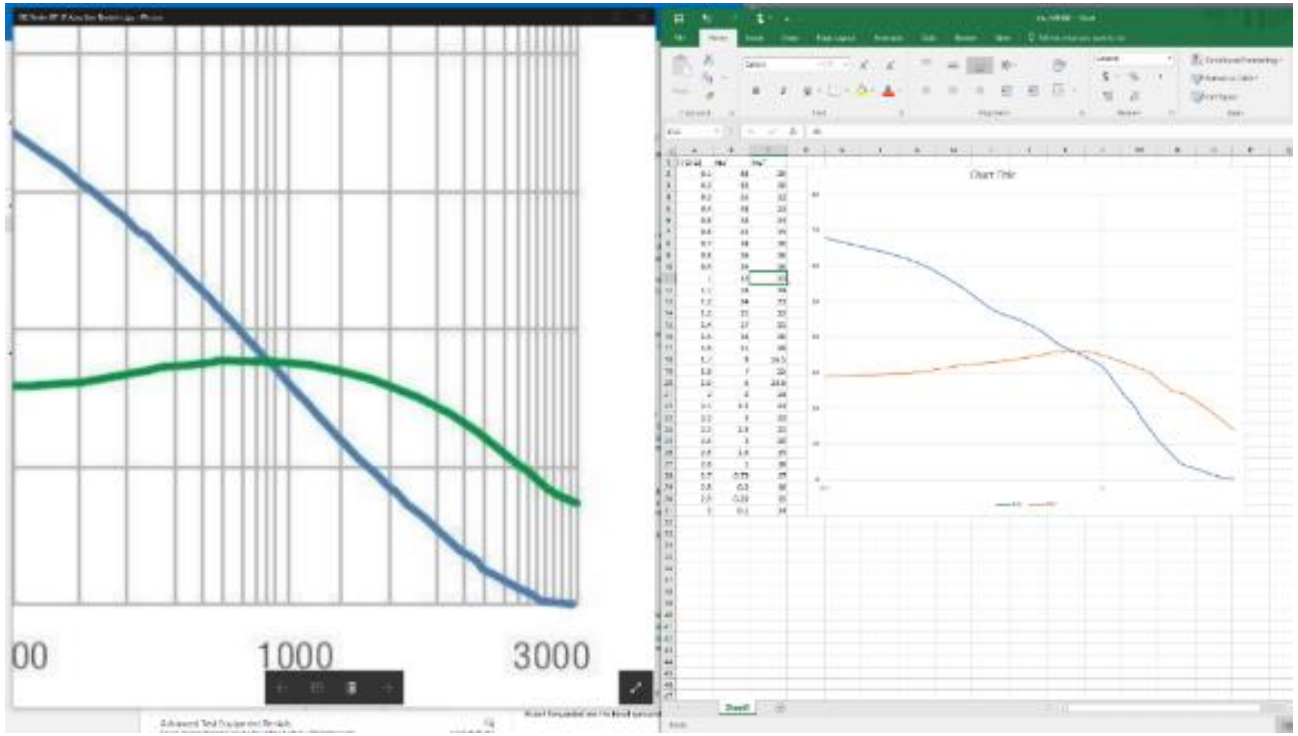






Simulation analysis of absorber, effect of source type

- Frequency dependent, complex permeability and permittivity data loaded into thin sheet material
- Material properties are approximate (only known to certain extent)



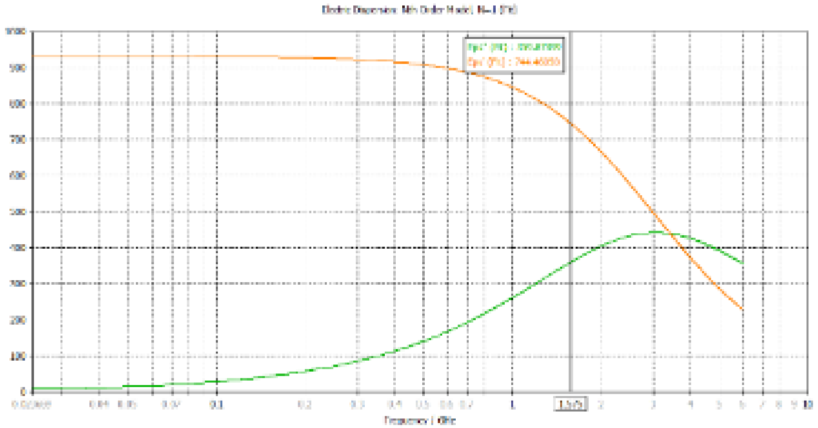
Permeability curves

Modeling approach adopted from following reference material:

354 IEEE TRANSACTIONS ON ELECTROMAGNETIC COMPATIBILITY, VOL. 59, NO. 2, APRIL 2017

Near-Field Shielding Performances of EMI Noise Suppression Absorbers

Stefano Piersanti, *Student Member, IEEE*, Francesco de Paulis, *Member, IEEE*, Antonio Orlandi, *Fellow, IEEE*, Sam Connor, *Senior Member, IEEE*, Qian Liu, *Member, IEEE*, Bruce Archambeault, *Fellow, IEEE*, Paul Dixon, *Member, IEEE*, Mohammad Khorrami, *Member, IEEE*, and James L. Drewniak, *Fellow, IEEE*



Permittivity curves

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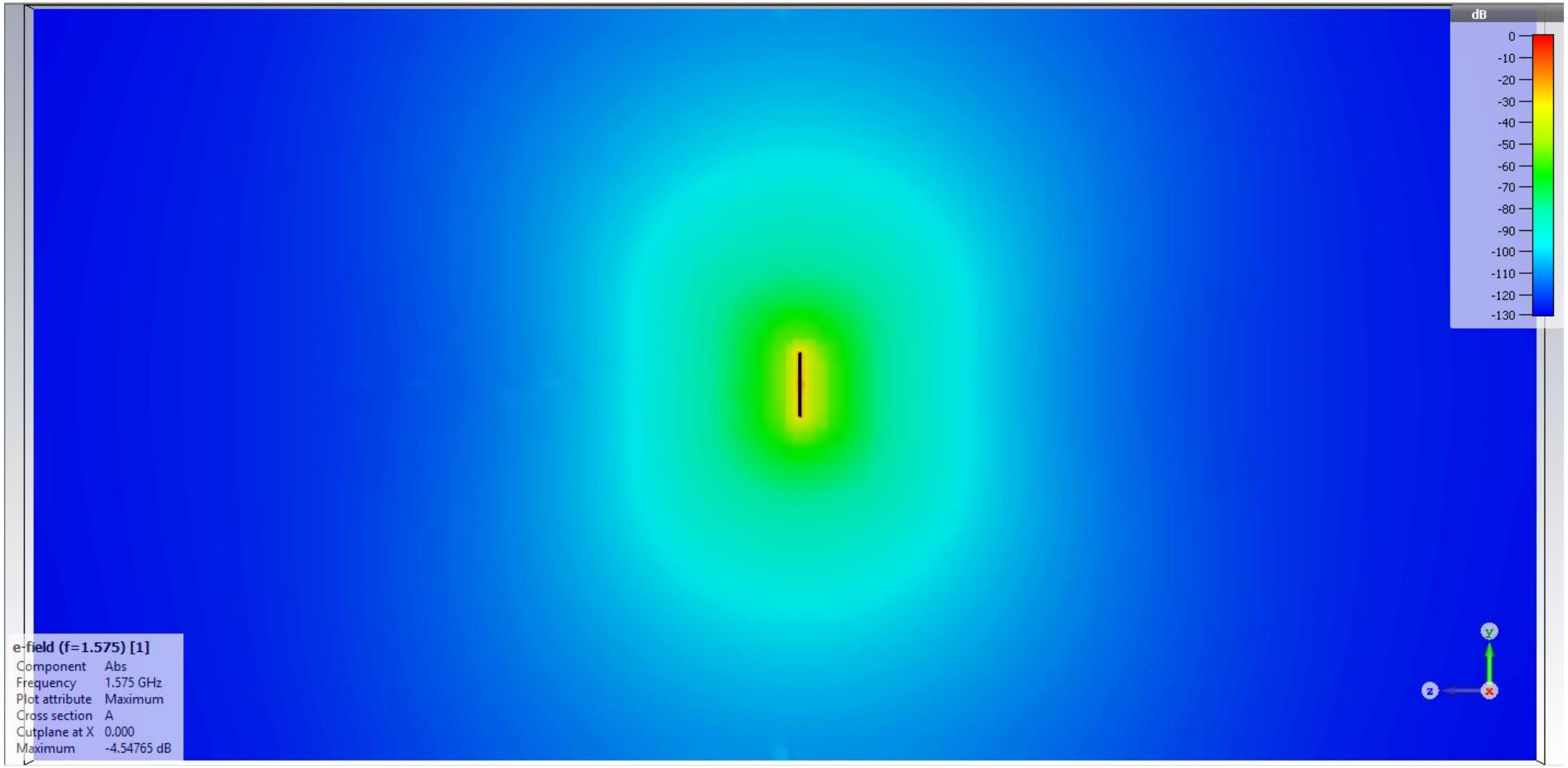
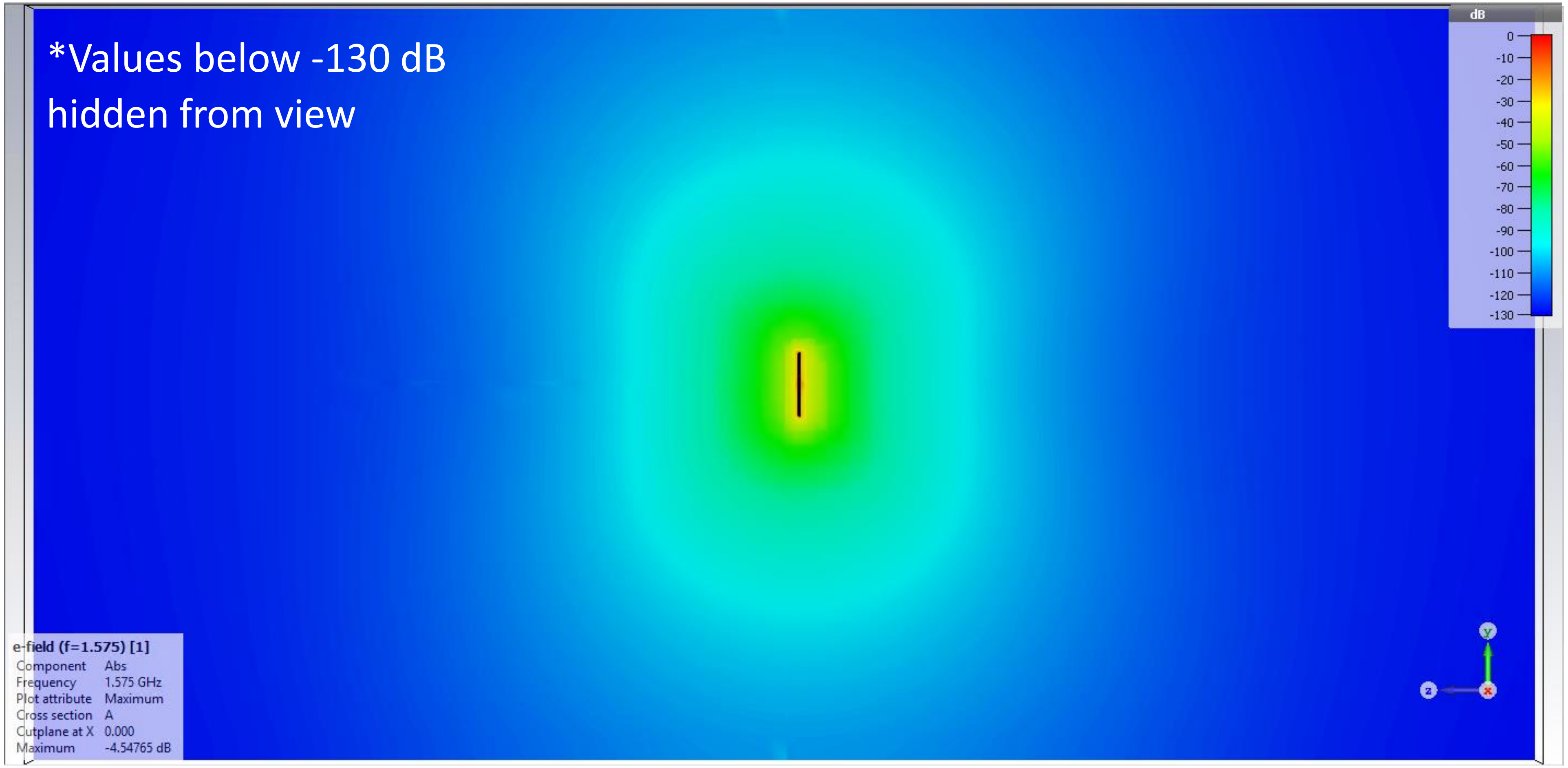
Simulation analysis of absorber, effect of source type

- Field plots provide insight into the nature of the noise source and its role in the absorber effectiveness



Simulation analysis of absorber, effect of source type

- Electric Field (dB V/m) at 1.575 GHz – dipole source, no absorber and with absorber



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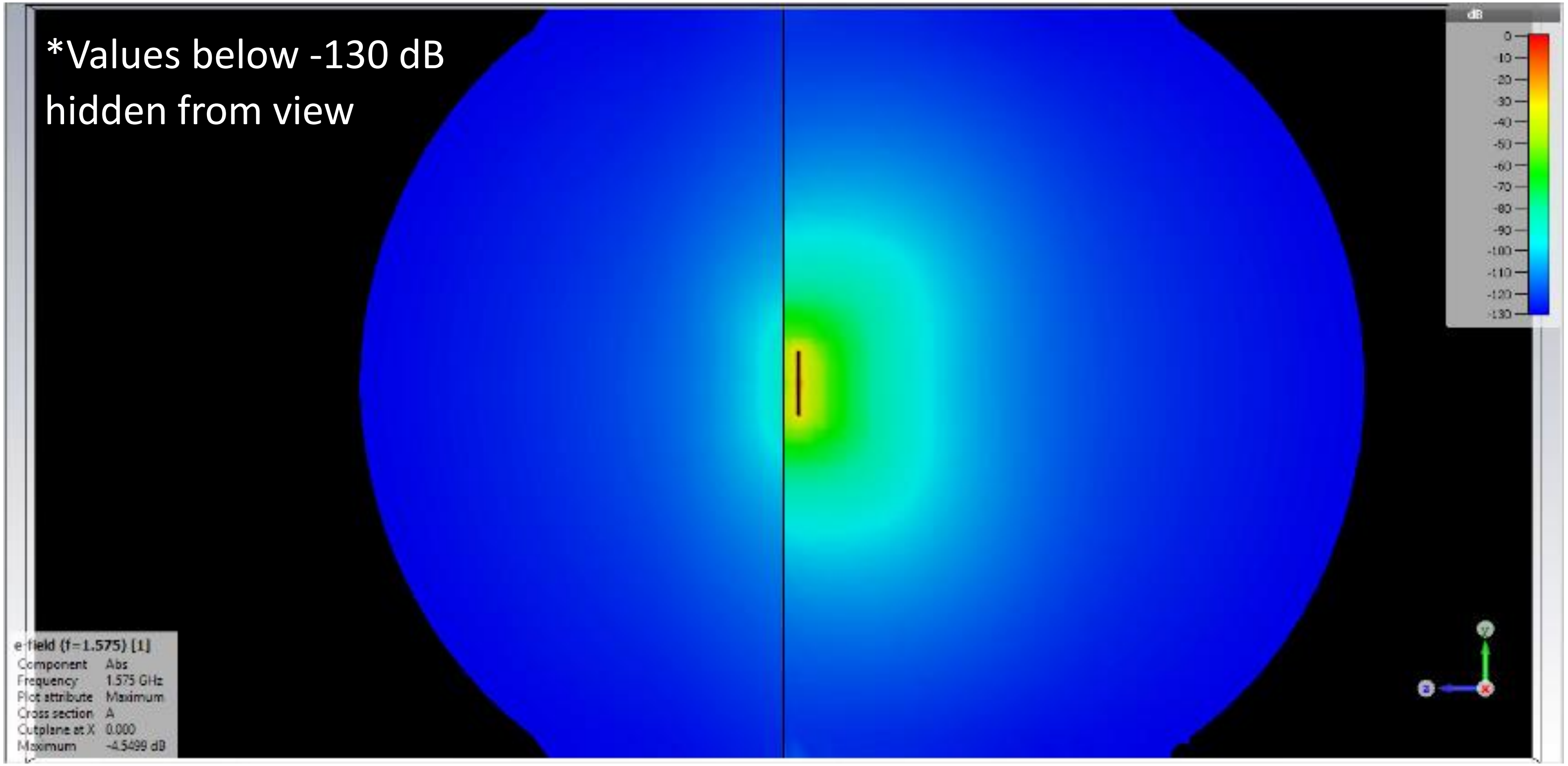

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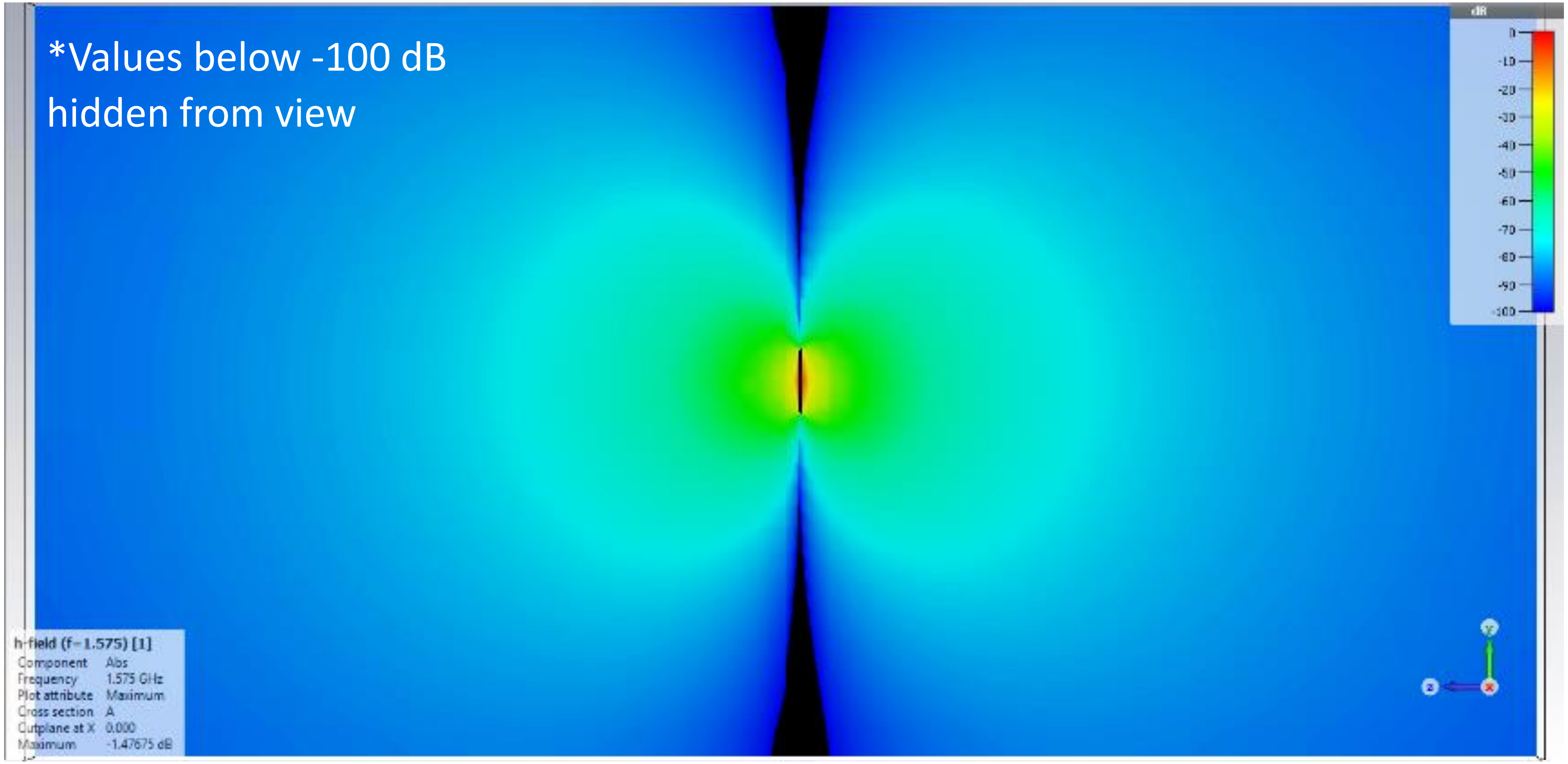

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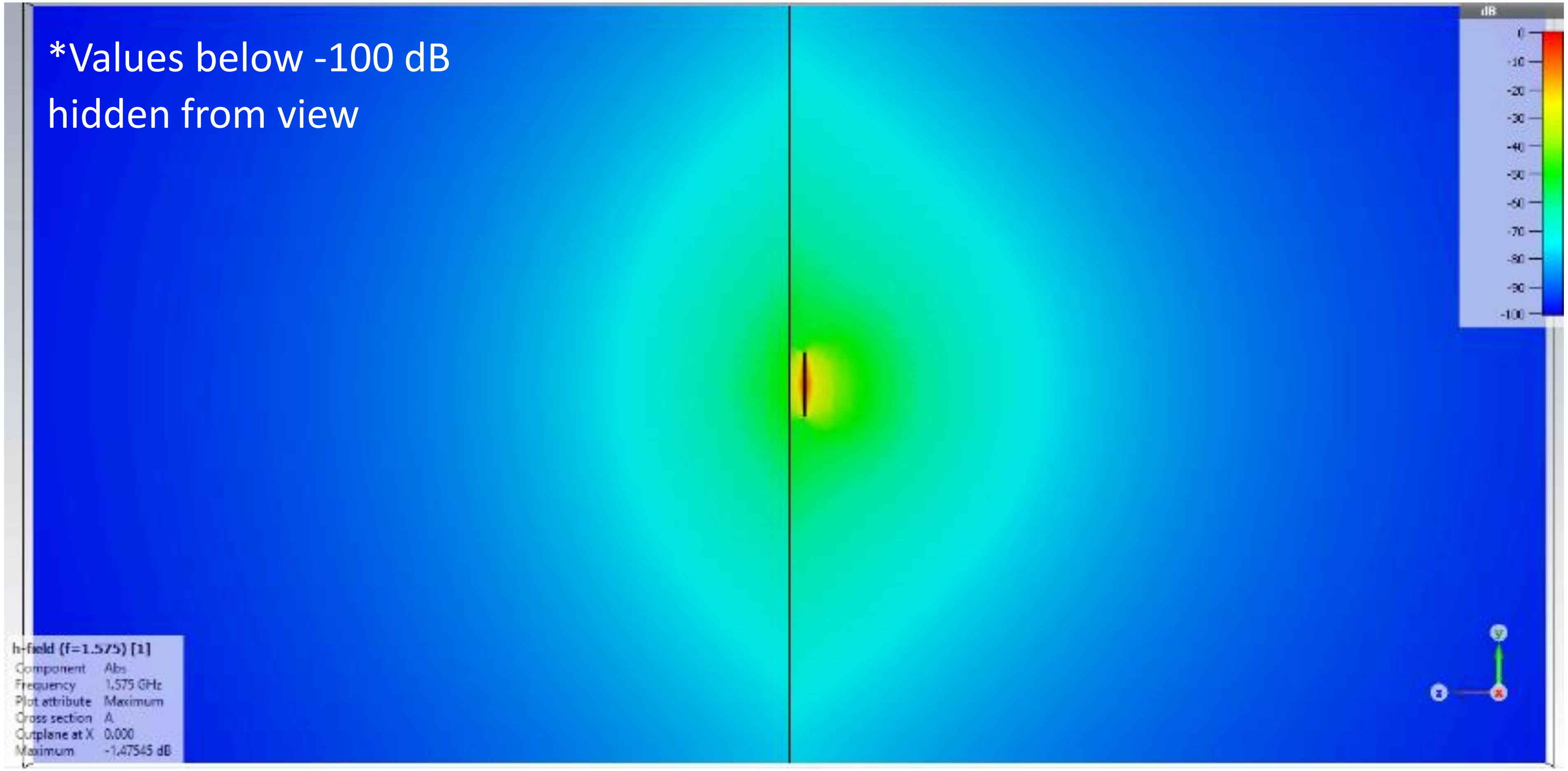

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Simulation analysis of absorber, effect of source type

- SE derived from field probe measurements, with and without absorber material present
- All values assessed at 1.575 GHz

Dipole Source	E (dB V/m) 5mm	E (dB V/m) 15mm	E (dB V/m) 25mm	E (dB V/m) 1 meter Farfield	H (dB A/m) 5mm	H (dB A/m) 15mm	H (dB A/m) 25mm	H (dB A/m) 1 meter Farfield
No absorber	25.1	5.08	-7.4	-42.89	-38.05	-51.78	-59.5	-94.4
With absorber	-2.7	-12.8	-18.7	-46.99	-45.63	-58.5	-66.79	-98.5
SE (dB)	27.8	17.88	11.3	4.1	7.58	6.72	7.29	4.1

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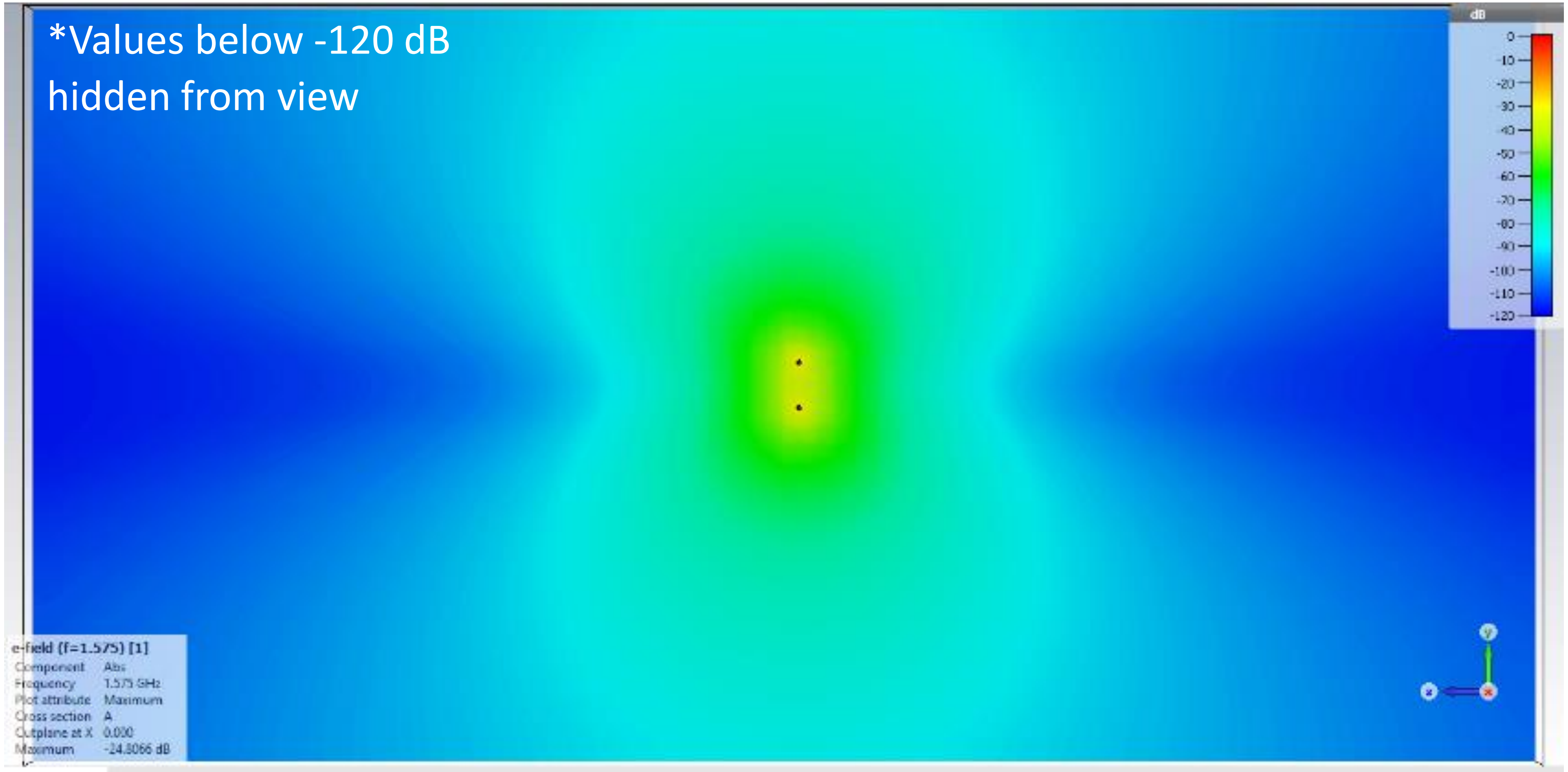
Simulation analysis of absorber, effect of source type

- Electric Field (dB V/m) at 1.575 GHz – loop source (parallel), no absorber and with absorber



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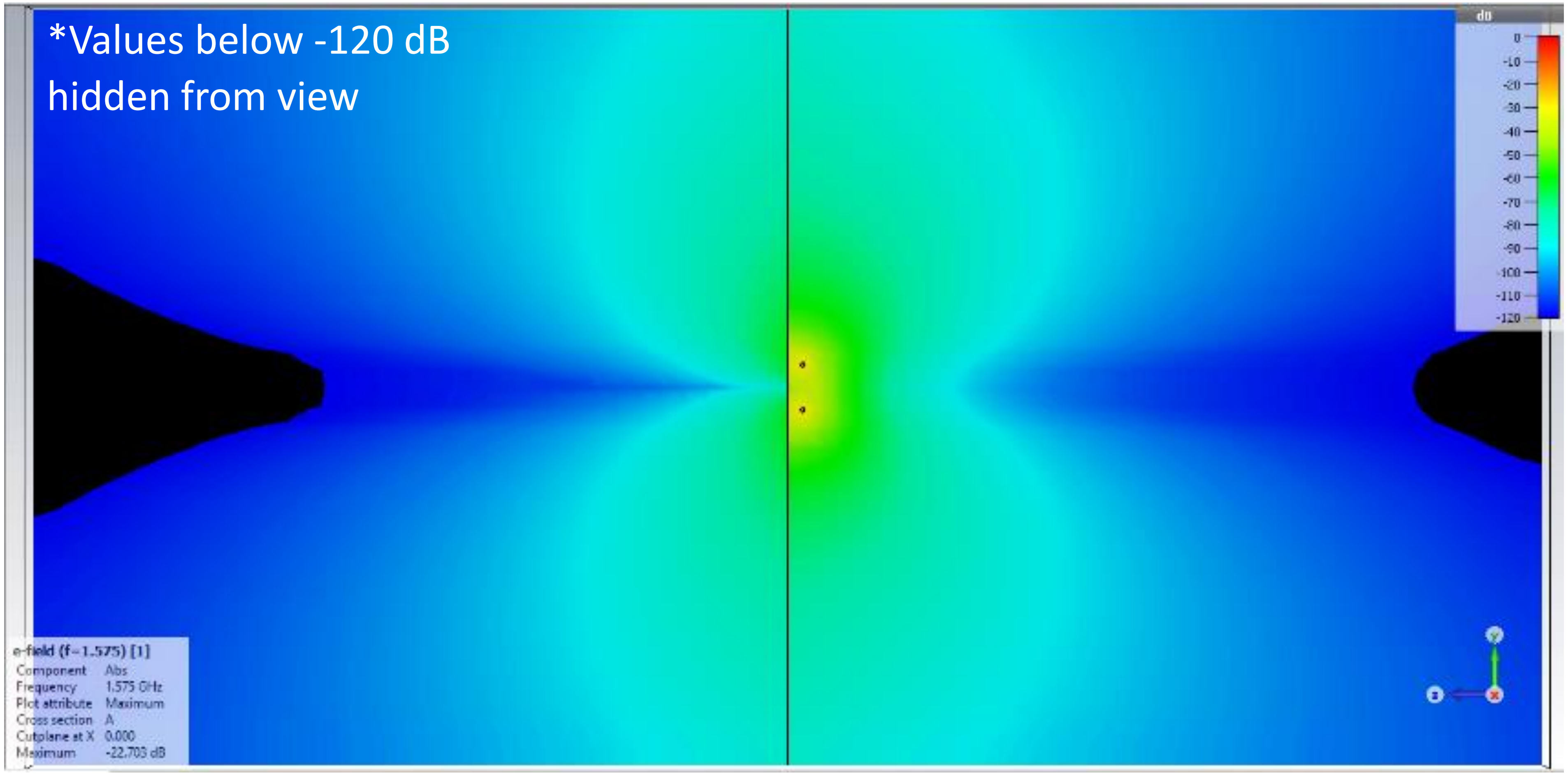

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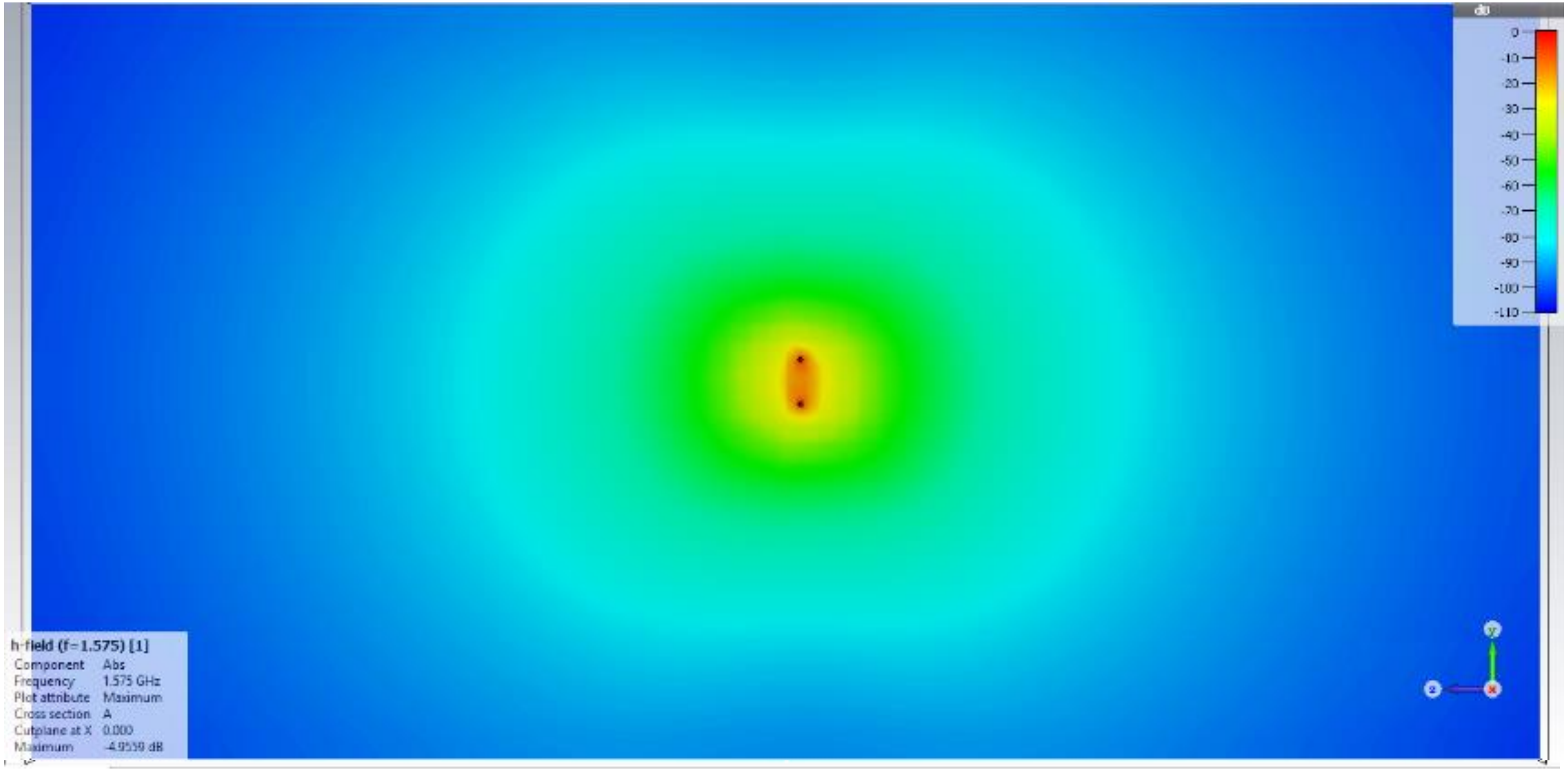

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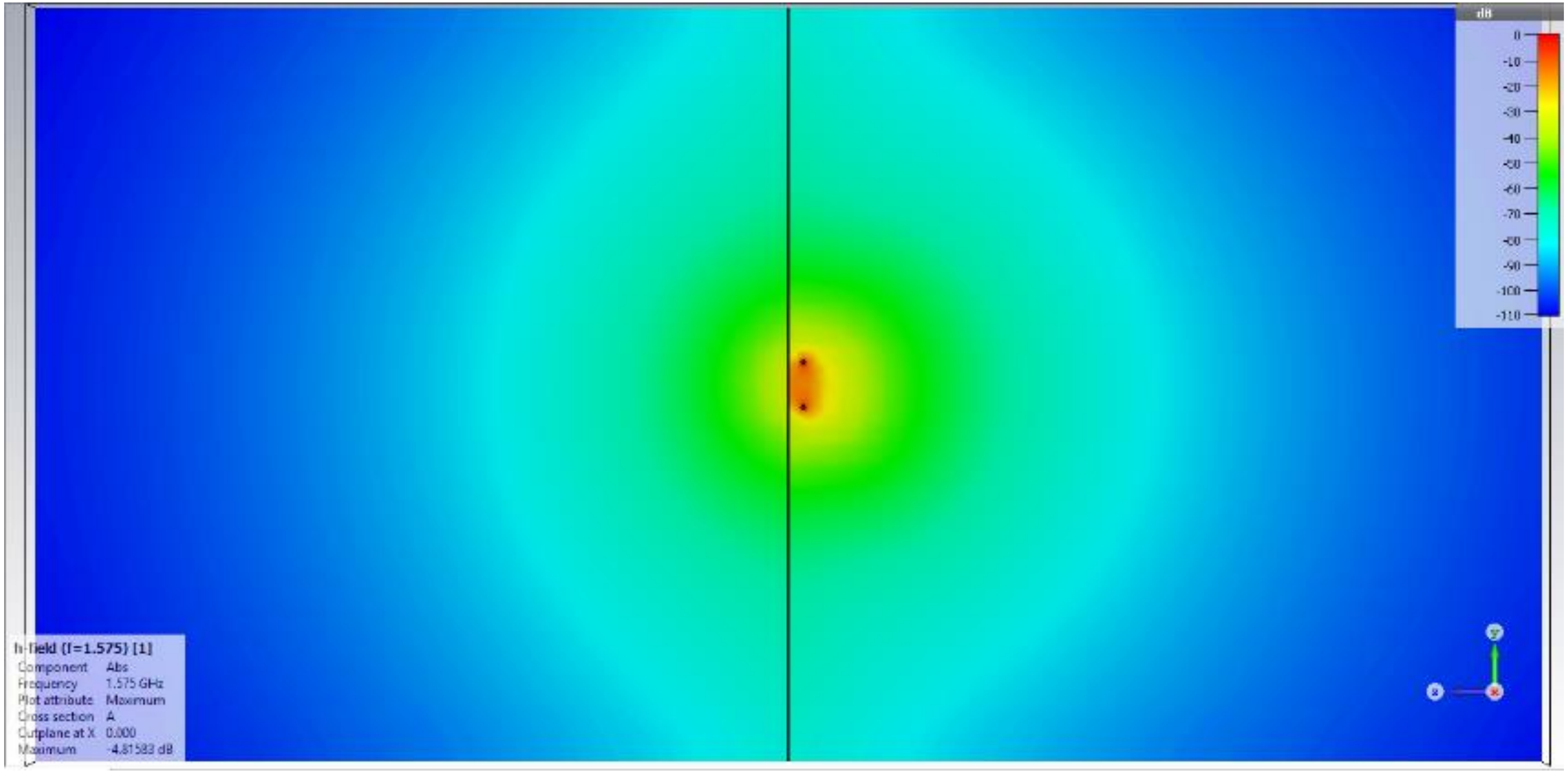
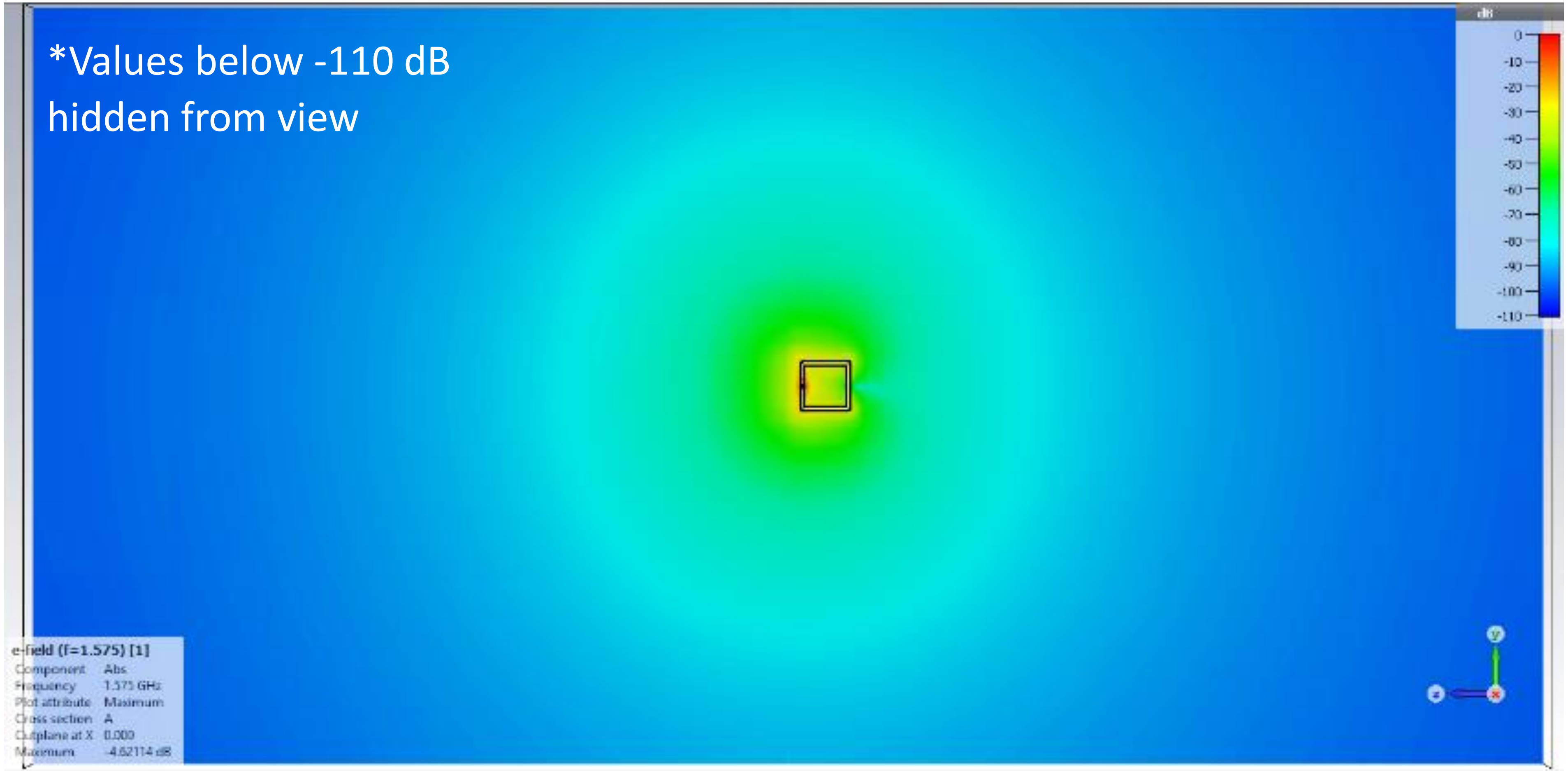


Simulation analysis of absorber, effect of source type

- Electric Field (dB V/m) at 1.575 GHz – loop source (perpendicular), no absorber and with absorber



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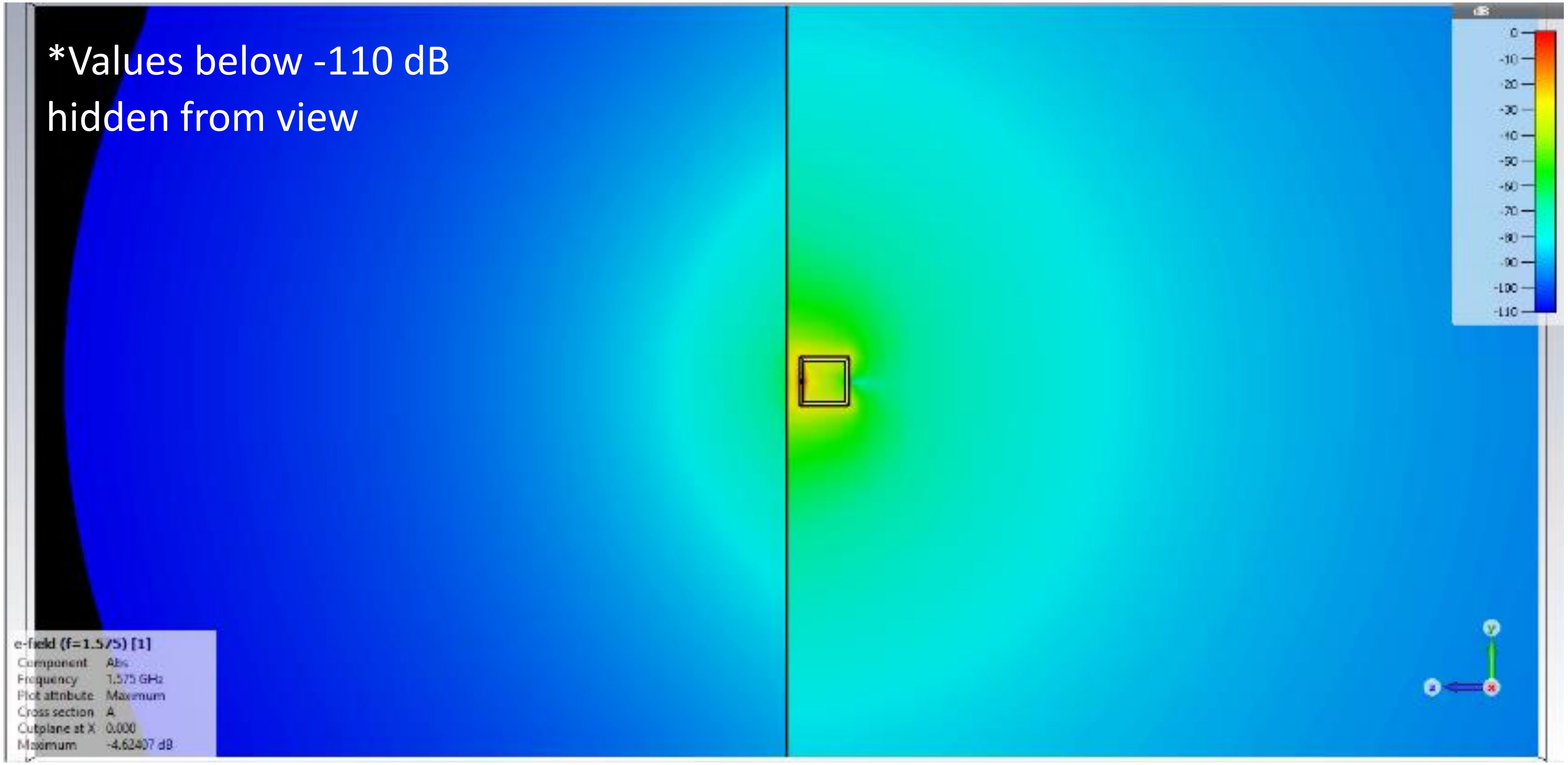

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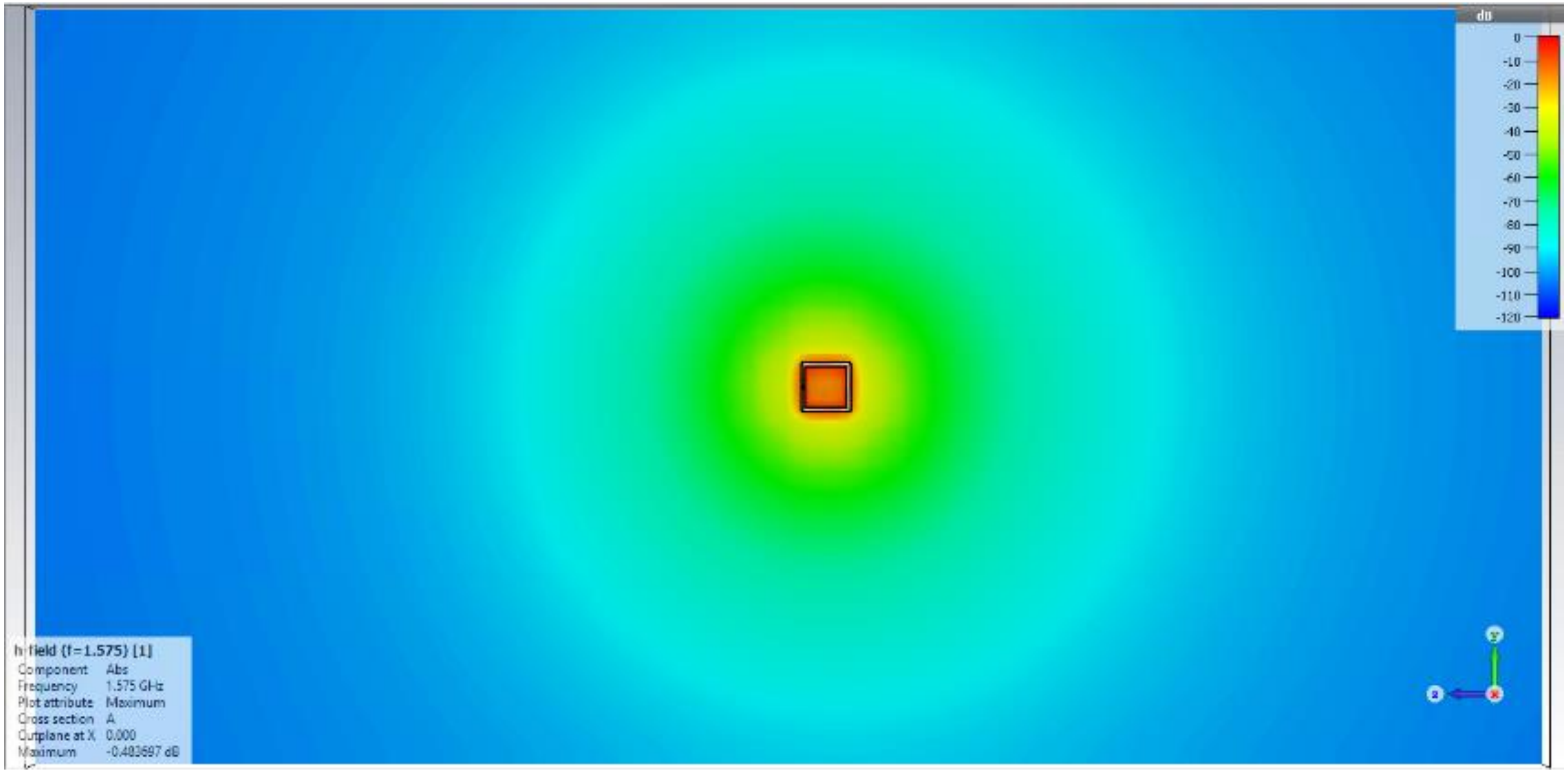

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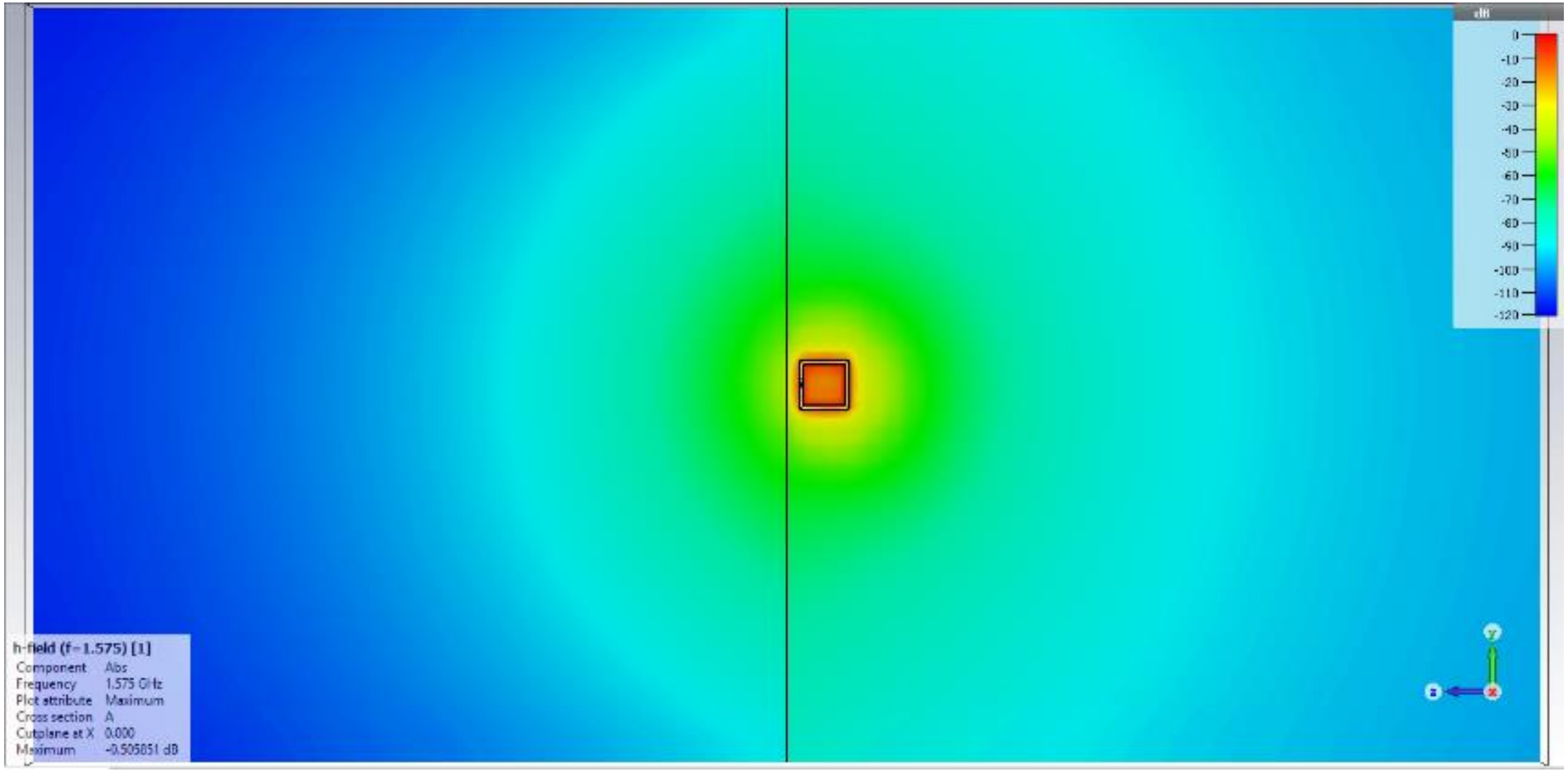

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- All values assessed at 1.575 GHz

Loop Source Parallel	E (dB V/m) 5mm	E (dB V/m) 15mm	E (dB V/m) 25mm	E (dB V/m) 1m Farfield	H (dB A/m) 5mm	H (dB A/m) 15mm	H (dB A/m) 25mm	H (dB A/m) 1m Farfield
No absorber	27.09	0.99	-10.24	-44.57	0.19	-24.9	-36.5	-95.28
With absorber	0.22	-13.13	-19.73	-47.59	-4.34	-26.26	-38.36	-95.5
SE (dB)	26.87	14.12	9.49	3.02	4.53	1.36	1.86	0.22

Loop Source Perpendicular	E (dB V/m) 5mm	E (dB V/m) 15mm	E (dB V/m) 25mm	E (dB V/m) 1m Farfield	H (dB A/m) 5mm	H (dB A/m) 15mm	H (dB A/m) 25mm	H (dB A/m) 1m Farfield
No absorber	32.36	15.77	7.58	-27.05	-10.63	-35.65	-47.15	-78.58
With absorber	20.78	6.33	-1.81	-29.22	-14.04	-35.09	-47.23	-80.73
SE (dB)	11.58	9.44	9.39	2.17	3.41	-0.56 (?)	0.08	2.15

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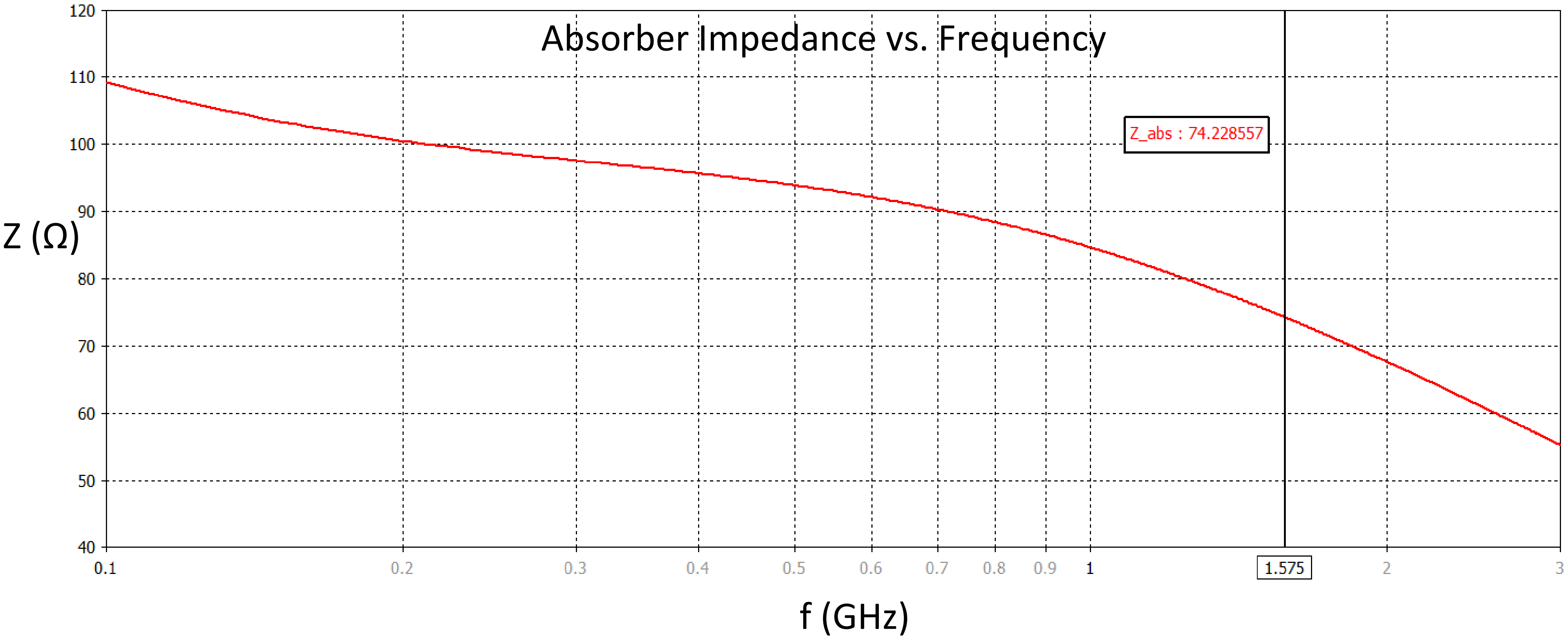
Simulation analysis observations and conclusions

- Wave impedance vs. Absorber's characteristic impedance – main factor for reflection loss
- Using modelled permittivity and permeability values, the absorber impedance can be calculated:

$$Z_0 = \sqrt{\frac{\mu}{\varepsilon}}.$$



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Simulation analysis observations and conclusions

- Absorber is non-conductive, meaning high frequency or high permeability values are needed for it to have high absorption loss
- Reflection loss will be very low if the source wave impedance closely matches the absorber's characteristic impedance

- E-field is highly attenuated in the nearfield in all cases, H-field slightly attenuated
- H-field is largely unaffected in the case of the loop sources, E-field slightly attenuated
- Never much SE in farfield (values range between 0.22 to 4.1 dB depending on field and source type)

- Dipole source E- and H- values equate to high wave impedance (> 377 Ω) in nearfield and converge to ~377 Ω in farfield
- Loop sources E- and H- values equate to low wave impedance (< 377 Ω) in nearfield and converge to ~377 Ω in farfield

Conclusion and Outlook

- Near field measurement (Stripline)
  - No significant improvement in measurement at 90 degree orientation of the IC w.r.t to the Stripline
  - Some improvement (in the order of 3 to 6 dB) is obtained at 0 degree orientation of the IC
  - To be correlated to simulations comparing nature of source (electric dipole or a magnetic loop) to see effectiveness of the material
- Far field (RE)
  - Similar attenuation at vertical and horizontal orientation (approximately 7 dB)
- Sources are never truly one or the other (electric or magnetic) in practice, this is also the case within the simulations
  - Would need idealized infinitesimally small sources
- Simulation results do make sense for what was modelled, with some peculiarities – accurate material model is critical for further investigation

Conclusion and Outlook

- Correlation to real ECU measurement to be performed in the future
- Understand impact of source wave impedance and achievable attenuation
- Investigate the location (separation distance) of the source with respect to the absorber (affects wave impedance at the interface of the absorber, thus influences reflection loss) – this was not studied in detail

References

[1] Automotive Audio Bus® (A²B®) digital audio bus networking technology. http://www.analog.com/a2b

[2] Automotive Ethernet, OPEN alliance, http://www.opensig.org

[3] Ford Motor Company (FMC1278) July 1, 2015.

[4] General Motors Corporation (GMW3097) June, 2015.

[5] Fiat Chrysler Corporation (cs.00054) Jan. 22, 2015.

[6] CISPR 25 Edition 4.0, IEC Central Office, Geneva, Switzerland, October 2016

[7] G. Y. Cho, J. Jin, H.-B. Park, H. H. Park, C. Hwang, "Assessment of integrated circuits emissions with an equivalent dipole moment method", *IEEE Transactions on EMC*, vol. 59, no. 2, pp. 633-637, Apr. 2017.

[8] J. Pan, X. Gao, J. Fan, "Identifying Interference From Multiple Noise Sources by Magnetic Near Fields Only", *IEEE Transactions on Electromagnetic Compatibility*, accepted for publication July 29, 2018.

[9] Piersanti, Stefano, et al. "Near-field shielding performances of EMI noise suppression absorbers." *IEEE Transactions on Electromagnetic Compatibility,* vol 59, No 2, pp. 654-661, 2017.

[10] H. Ott, Electromagnetic Compatibility Engineering, Hoboken, New Jersey, USA: Wiley, 2009.

[11] C. R. Paul, Introduction to Electromagnetic Compatibility, 2nd ed. New York, NY, USA: Wiley, 2006.

[12] NYSTEIN®, http://www.nystein.com/

[13] D. Johns, A. Wlodarczyk, A. Mallik, "New TLM models for thin structures", Proc. IEEE Int. Conf. on Comp. in Electromagnetics, Publ. 350, 1991.

[14] Johns P. B., "A symmetrical condensed node for the TLM method", IEEE Trans. MTT, Vol. MTT-35, No. 4, pp. 370-377, 1987.

[15] CST Studio Suite version 2018, Dassault Systèmes, https://www.3ds.com/products-services/simulia/products/cst-studio-suite/

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