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Calculation of EMI Shielding Effectiveness of Silicon Using COMSOL Multi Physics

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ABSTRACT.

Currently, electromagnetic interference constitutes one of the major complications for a function of electronic or electrical devices. Because these devices are constantly exposed to effects of electromagnetic radiation, it is desirable to increase the electromagnetic immunity of device. One of the possibilities is to incorporate the suitable shielding materials which can protect the device against the radiated electromagnetic emissions. This paper devotes to finding suitable materials for shielding security devices.

Keywords: COMSOL, EMI SE, RF Physics, Simulation

INTRODUCTION

By bringing the interference down below the point where it interferes with the correct operation of the electronic system or subsystem, electromagnetic compatibility is attained. Electronic filters and component or equipment shielding are typically used to achieve this compatibility. Figure 1 depicts a system that emits and receives electromagnetic interference. The receiver is a system or subsystem that is susceptible to electromagnetic waves, while the emitter is a system or subsystem that generates electromagnetic field. A system or subsystem can function as both an emitter and a receiver at the same time in the real world.[1]

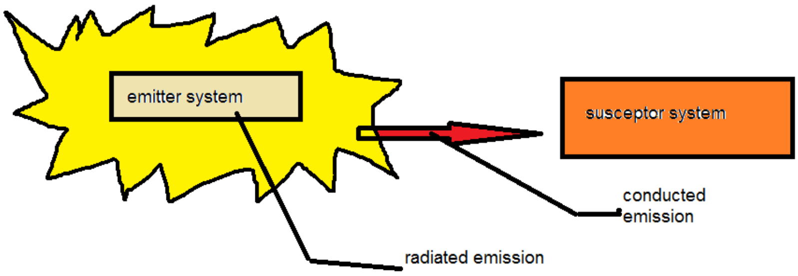

Figure 1: An example of an electromagnetic interference

There are two oscillating fields at right angles that make up electromagnetic waves. The magnetic field (H-Fields) is one of these fields, while the electric field (E-Fields) is the other. E-Fields are produced by high impedance voltage driven circuitry, such as a straight wire or dipole, and interact with it most easily. Electric circuits with low impedance, such as wire loops, are capable of producing H-Fields and interacting with them most easily.

The permeability, conductivity, and thickness of the barrier, as well as the frequency and the separation between the EMI source and the shield, all affect the losses in field strength caused by shielding barriers (Fig. 2). J.C. Maxwell [2, 3]created the fundamental differential equations that describe the classical electromagnetic field phenomenon and its interaction with conductive materials well over a century ago. Even for straightforward models, these differential equations typically have complicated analytical solutions. Their usage in shielding analyses has been discouraged as a result.

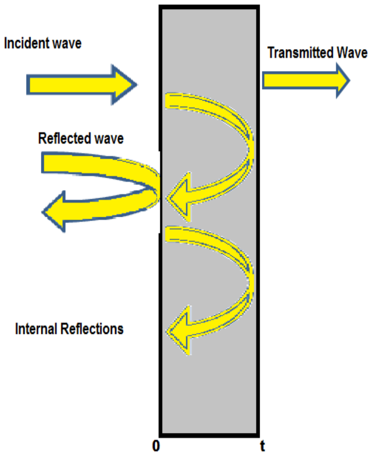

Figure 2: Drawing of system (t is the thickness of the shield material).

Principle of shielding Effectiveness

The ability of a material to attenuate electromagnetic waves is called shielding effectiveness (SE). It is illustrated in terms of the ratio between the entering power (Pi) and leaving power (Po) of an electromagnetic wave as (1):

$$SE = 10 \log \left(\frac{P_i}{P_o}\right) \quad (1)$$

The unit of electromagnetic interference SE is given in decibels (dB) [4-6]

Another definition states that the electric field shielding effectiveness is [7, 8]

$$SE = 20 \log \left(\frac{E_i}{E_o}\right) \quad (2)$$

GEOMETRY AND PHYSICAL MODEL ON COMSOL

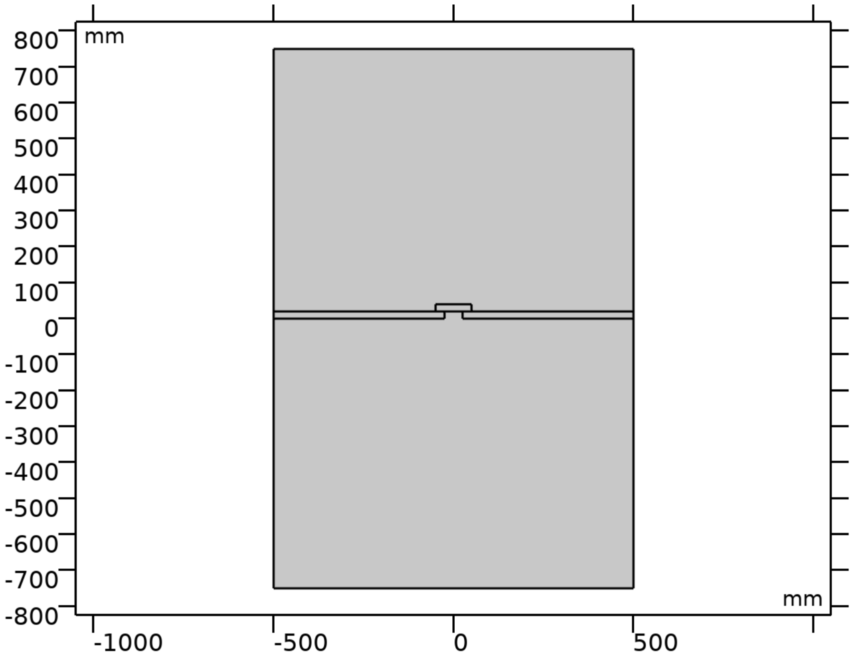

Figure 3: 2D Geometry

Materials

Air

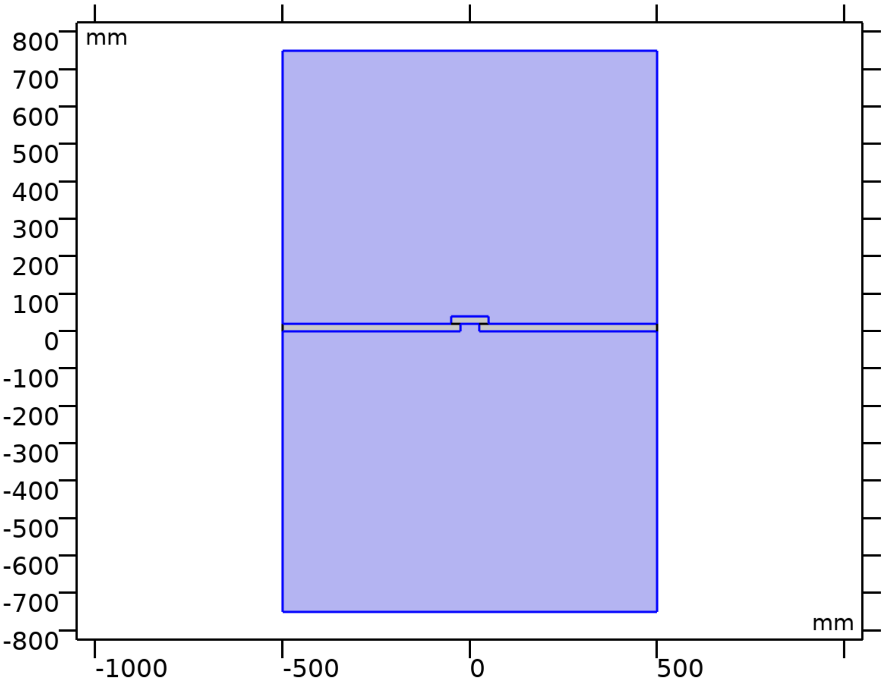

Figure 4: Air

Aluminum 3003-H18

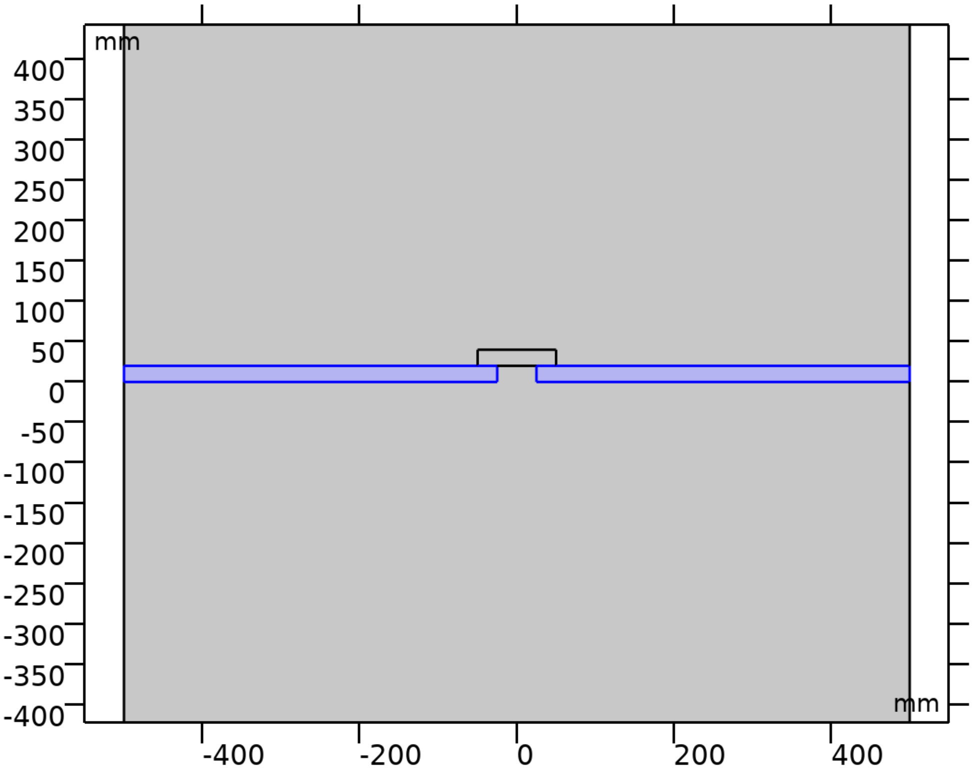

Figure 5: Aluminum 3003-H18

Silicon

-40 -20 0 20 40

Figure 6: Silicon

Table 1: Boundary conditions of the physical model

Material	Selection
Air (mat1)	Domain 1
Aluminum 3003-H18 (mat2)	Domains 2,4
Silicon (mat3)	Domain 3

Table 2: Selected Properties from materials

Property	Material	Property group
Relative permittivity	Air	Basic
Relative permeability	Air	Basic
Electrical conductivity	Air	Basic
Relative permittivity	Aluminum 3003-H18	Basic
Relative permeability	Aluminum 3003-H18	Basic
Electrical conductivity	Aluminum 3003-H18	Basic
Relative permittivity	Silicon	Basic
Relative permeability	Silicon	Basic
Electrical conductivity	Silicon	Basic

Comsol Multiphysics® Explanations

Using the Comsol Multiphysics® [9-11] Radio Frequency module, we modeled Silicon's electromagnetic response. The Maxwell-Ampère and Faraday laws serve as the foundation for the high-frequency wave formulations employed in this subject.

$$\nabla \times E = -\,\partial B/\partial t \qquad (3)$$

$$\nabla \times H = J\text{-}+\partial D/\partial t \qquad (4)$$

where the governing wave equation for the electric field intensity is: H the magnetic field intensity, J the current density, D the electric flux density, E the electric field intensity, and B the magnetic flux density. Then equation of E in the Electromagnetic Waves, Frequency Domain boundary is:

$$\nabla \times (\nabla \times E) = -k^2 n^2 E \qquad (5)$$

where *n* is the refractive index, and the wave number of free space *k0* is defined as

$$k_o = \omega\sqrt{\varepsilon_0 \mu_0} = \frac{\omega}{c_0} \qquad (6)$$

where ω the angular frequency, ε_0 free space permittivity, µ0 is permeability and c_0 the speed of light in vacuum.

Results and Discussion:

In this study, COMSOL has been used to determine silicon's response at shielding electromagnetic interference (EMI). The goal was to investigate silicon's ability to shield and its potential to reduce electromagnetic interference (EMI) in a variety of applications.

Results:

The COMSOL simulations give reflection of silicon's EMI shielding efficiency. The efficiency of the shielding was assessed for a spectrum of frequencies between 8GHz and 12GHz. The numerical outcomes were determined in terms of the incident power outflow (Pi) and the transmitted power outflow of electromagnetic field (Po) at various frequencies.

Table 3: Calculated shielding effectiveness values for silicon at X Band

Freq (GHz)	**Power (W/m) Without shield**	**Power (W/m) With shield**	**SE (dB) = 10 log $\left(\frac{P_i}{P_o}\right)$**
8.000	9.3E-29	1.9448E-28	26

8.5	7.1E-28	1.9448E-28	25
9.000	8.9E-29	6.6893E-29	26
9.5	9.0E-28	3.1729E-28	24
10.000	3.4E-28	317.59E-30	10
10.5	4.5E-25	686.79E-30	18
11.000	1.5E-28	4.19E-30	25
11.5	1.3E-28	5.5829E-29	13.7
12.000	2.3E-28	13.0E-30	22

Plot Groups:

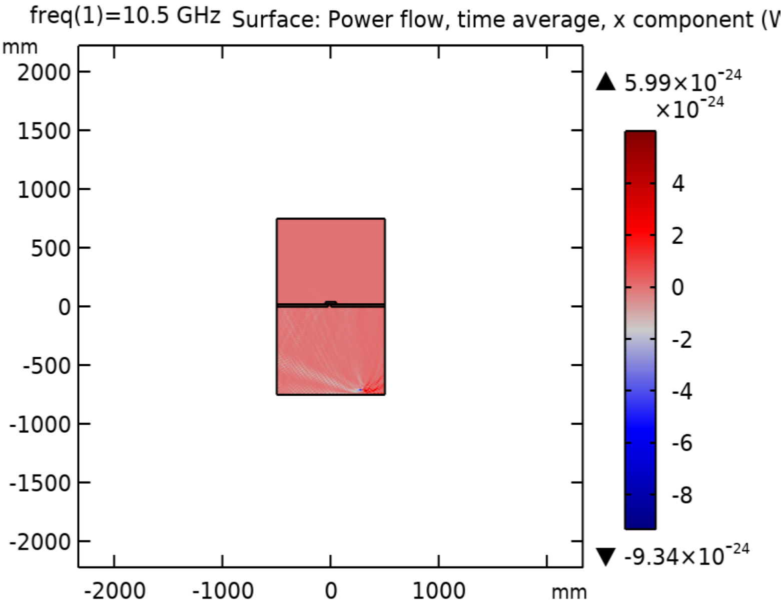

Figure 7: Power out with shield (W/m)

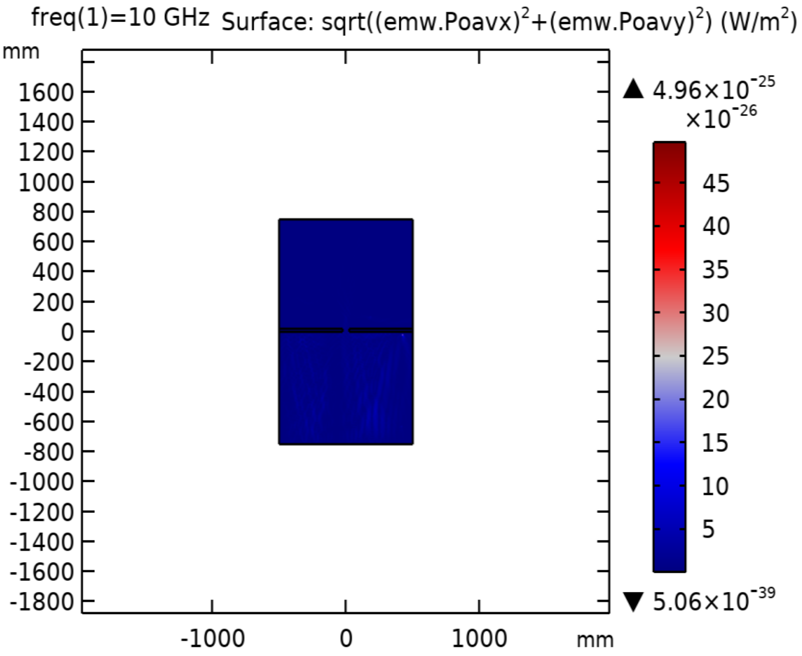

Figure 8: Average Power out without Shield (W/ m^2)

Shielding Effectiveness:

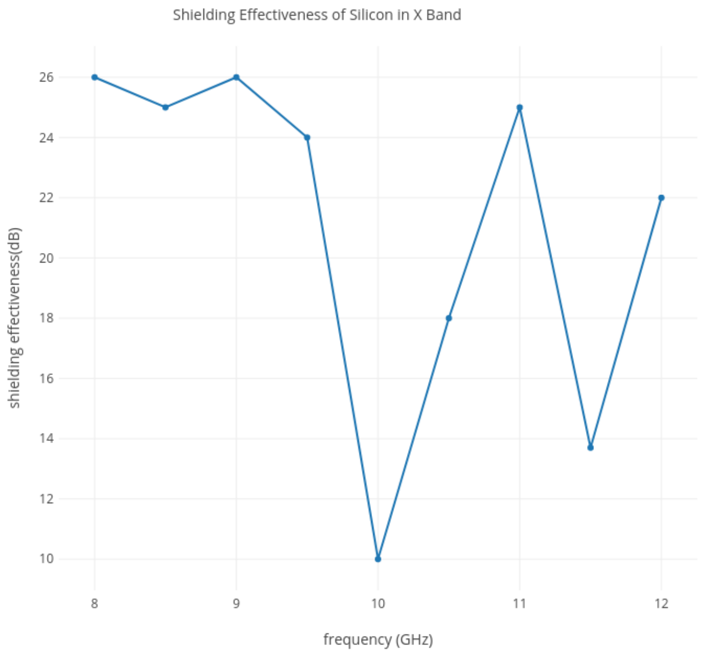

Figure 9: Calculated (dB) in X Band for Silicon

The trend of the shielding response as a function of frequency is shown in Figure 9. It demonstrates a progressive rise in shielding efficiency with frequency, suggesting silicon performs better in shielding at higher frequencies.

Discussion:

The findings obtained demonstrate silicon's efficiency at the X Band. Despite the fact that silicon is well known for its semiconducting properties, it also possesses considerable electrical conductivity, which contributes to the enhancement of its shielding. The trend in shielding response with frequency has numerous factors. It is easier for silicon to absorb and release energy from higher frequency electromagnetic waves because they have more concentrated energy. This behavior enhances the shielding's effectiveness and provides more EMI resistance.

Aside from having a high melting point and great mechanical strength, silicon possesses unique properties that make it a good choice for EMI shielding in a range of applications.

Conclusion

In conclusion, our simulation has shown to be effective in EMI shielding. Although simulated results show moderate performance of silicon for EMI shielding, it has other multiple benefits. It is widely available and works with current manufacturing techniques. Further investigation and experimental results are required to fully understand Silicon capabilities for EMI shielding effectiveness.

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