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Specialty: Systems of Telecommunications

By

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Entitled

ELECTROMAGNETIC SIMULATION OF SHIELDING EFFECTIVENESS OF MATERIALS FOR EMC APPLICATIONS

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Before the Jury composed of:

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APPRECIATION

First of all, we thank the almighty God has all his compromises to get us to that level and for the courage and strength to continue and complete our studies.

We thank our parents for their sacrifices and help to make us succeed, for giving us importance, for always taking care of us, for always trusting us, and for showing us the love you have for us.

We are deeply grateful to Pr. BOUTOUT Farid, Professor in the Department of Electronics at BBA University, who was ready to lead this work during the trial period and the formation of the final document. we have not lacked much advice. we are happy to express our gratitude to him.

We would like to sincerely thank the members of the jury who do us the great honor of evaluating this work. Finally, from a personal point of view, our warm thanks go to all our comrades who have given us their moral and intellectual support throughout the academic year.

Thanks

To him who showed me the right way, remembering that the will always makes great men..

To my Father...

To those who have patiently waited for the fruits of his good education..

To my mother...

To my brothers...

To my partner ...

To all my friends ...

May God keep you

﴿وآخر دعواهم أن الحمد لله رب العالمين﴾

Not all letters can find the right words. . . Not all words can express gratitude, love, respect, recognition. . . Also, it is quite simply that..I dedicate this. . .

TO MY DEAREST MOTHER "SAIDI Fatiha"

As many sentences as expressive as they are cannot show the degree of love and affection I feel for you. You have filled me with your tenderness and affection throughout my journey. You have always supported me and encouraged me throughout the years of my studies, you have always been at my side to console me when necessary. On this memorable day, for me and for you, receive this work as a sign of my deep appreciation and appreciation. May the Almighty give you health, happiness and long life so that I can fill you in my turn

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As many sentences and expressions as eloquent as they are cannot express my gratitude and gratitude. You have taught me a sense of responsibility, optimism and self-confidence in the face of life's difficulties. Your advice has always guided me to success. Your endless patience, understanding and encouragement are the indispensable support you have always been able to give me. I owe you what I am today and what I will be tomorrow and I will always do my best to remain your pride and never disappoint you. may God the Almighty preserve you, grant you health, happiness, peace of mind and protect you from all evil.

TO MY GRANDMOTHER: AZIZI Fatima "rests her soul in peace"

being my first editor, and giving me the best upbringing I have ever received.

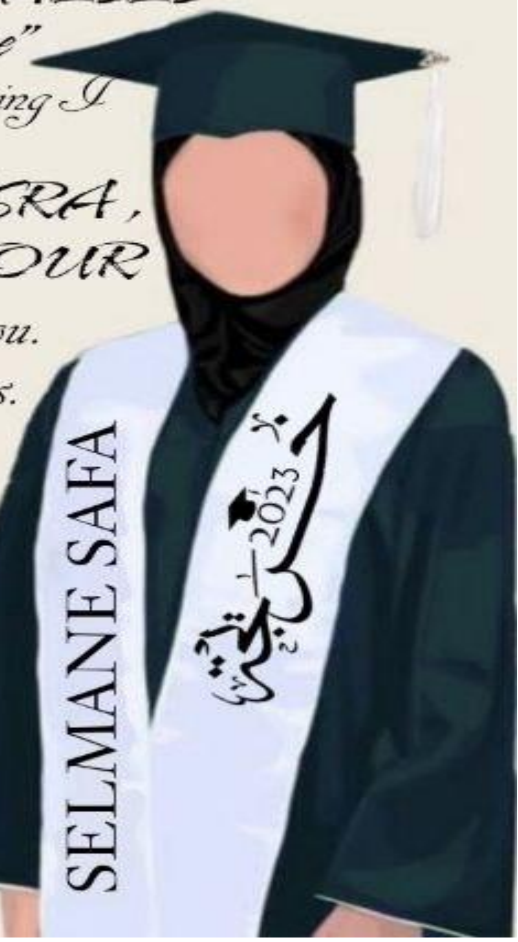
TO MY SISTERS : YOUSSRA , ROUMAISSA, NADA, NOUR

I know my success is very important for you. May God pay you for all your blessings.

TO ALL MY FRIENDS IN PARTICULAR SARA AHLEM ANFEL

TO ALL MY FAMILY AND ALL WHO LOVES ME

To My Partner God bless you



وآخر دعواهم أن الحمد لله رب العالمين

Abstract

This Master's thesis aims to study and discuss how to protect devices from electromagnetic interference using a special material called shielding. The focus of the research is on safety devices and ensuring that they are reliable. There are three main areas where electromagnetic interference can be limited, but for this work, the focus is on stopping noise from getting into the receiver. Radiation can be reduced by using a special shielding material. Shielding means protecting the equipment from unwanted electromagnetic interference and preventing it from leaking into other areas.

Keywords: Electromagnetic, Shielding effectiveness, Radiation, EMC

Résumé

L'objectif de ce mémoire est d'étudier et de discuter de la manière de protéger les appareils des interférences électromagnétiques à l'aide d'un matériau spécial appelé blindage. La recherche se concentre sur les dispositifs de sécurité et sur la garantie de leur fiabilité. Les interférences électromagnétiques peuvent être limitées dans trois domaines principaux, mais dans le cadre de ce travail, l'accent est mis sur l'empêchement du bruit de pénétrer dans le récepteur. Le rayonnement peut être réduit en utilisant un matériau de blindage spécial. Le blindage consiste à protéger l'équipement contre les interférences électromagnétiques indésirables et à empêcher qu'elles ne s'infiltrent dans d'autres zones

Mots clés : Électromagnétique, Efficacité du blindage, Rayonnement ,CME

ملخص

الهدف من مذكرة الماستر هذه هو دراسة ومناقشة كيفية حماية الأجهزة من التداخل الكهرومغناطيسي باستخدام مادة خاصة تسمى التدريع. ينصب تركيز البحث على أجهزة السلامة والتأكد من موثوقيتها. هناك ثلاث مناطق رئيسية يمكن أن يكون فيها التداخل الكهرومغناطيسي محدودًا، ولكن في هذا العمل ينصب التركيز على إيقاف الضوضاء من الوصول إلى جهاز الاستقبال. يمكن تقليل الإشعاع باستخدام مادة حماية خاصة. يعني التدريع حماية المعدات من التداخل الكهرومغناطيسي غير المرغوب فيه ومنعها من التسرب إلى مناطق أخرى

الكلمات المفتاحية : الكهرومغناطيسية، فعالية التدريع، الإشعاع ، EMC

Contents:

Chapter I : Definition of the study

Chapter II : Principal of the electromagnetic compatibility

Chapter III: Resultants et discussions

Chapter IV: Conclusion and perspectives

List of figures:

List of Symbols and Acronyms:

A
ANSYS widely used computer-aided engineering (CAE) software suite
B
$\boldsymbol{\beta_0}$ Propagation constant in free space
C
CAD Computer-Aided Design
CE Common Era
CI Continuous Integration
CR Credit Rating
$\boldsymbol{c_0}$ Speed of light in free space
D
dB Decibel
E
E Electric field
EDA Electronic Design Automation
EFT Electronic Funds Transfer
EM Electromagnetic
EMC Electromagnetic Compatibility
EMI Electromagnetic Interference
EMP Electromagnetic Pulse
ESD Electrostatic Discharge
EUT End-User Testing
F
FE Finite Element
G
GHz Gigahertz
H
HEMP High-Altitude Electromagnetic Pulse
HFSS High Frequency Structural Simulator
H Magnetic field
I
IC Integrated Circuit
J
Js Equivalent electric surface current
K
k0 Wavenumber in free space
M
MATLAB (Matrix Laboratory) is a programming language and environment developed by MathWorks

MHz	Megahertz
MoM	Method of Moments
O	
OATS	Oracle Application Testing Suite
P	
PCB	Printed Circuit Board
R	
RE	Real Estate
RF	Radio Frequency
RFI	Radio Frequency Interference
S	
SEA	Absorption Loss
SE**R**	Reflection Loss
SE**M**	Multiple Reflection Loss
SAE	Society of Automotive Engineers
SAR	Specific Absorption Rate
SE	Shielding Effectiveness
T	
TEM	Transverse Electromagnetic
Z	
Z	Impedance
Zs	Equivalent sheet impedance
#	
σ	Conductivity
η0	Impedance of free space
λ	Material wavelength
μ0	Permeability of free space
δs	Skin depth
$\in_0$	Permittivity of free space
$\in_m$	Permittivity of epox**y**
$\in_r$	Relative permittivity

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General introduction:

The rapid advancements in telecommunication and the proliferation of mobile electronic devices entail the development of high-performance electromagnetic interference (EMI) shielding materials to ensure the normal operation of equipment and protect humans from electromagnetic (EM) radiation pollution. In general, EMI shielding materials can be classified into reflection-dominant and absorption-dominant types according to the reflection and absorption contribution to the total shielding. Conventional metal-based materials with remarkable electric conductivity have high reflection loss of the EM wave, enabling them as representative reflection-dominant shielding materials to block EM radiation. However, the majority of the EM wave is reflected in general high-conductive materials which result in secondary electromagnetic pollution. Therefore, absorption-dominant shielding materials have become more desirable alternatives for EMI shielding applications.

Fundamentally, it is primary and crucial to evaluate the EMI shielding performance and quantify the reflection and absorption contribution to shielding correctly for analyzing the shielding mechanism and developing absorption-dominant shielding materials. EMI shielding refers to the attenuation of the propagating EM wave produced by the shielding material. EMI shielding effectiveness (SE) is an important index to evaluate the shielding performance quantitatively. It is defined as the logarithm of the ratio, expressed in decibels, of transmitted power when there is no shield to the transmitted power when there is a shield. The higher EMI SE, the less EM wave is transmitted through the shielding material. EMI SE is defined as the sum of three terms including reflection loss (SER), absorption loss (SEA) ,and multiple reflection loss (SEM) in most classical shielding the theory originally developed by Schelkunoff, while EMI SE is decomposed into two terms named reflection loss (SER') and absorption loss (SEA') in practice. The former and latter theories of EMI SE are called “Schelkunoff theory” and “Calculation theory” respectively in this paper for the sake of distinction. Confusion arises from that the terms in Calculation theory often use the same names or notations as the terms in Schelkunoff theory. The terms in Calculation theory are mistakenly regarded as the approximation of the terms in Schelkunoff theory when multiple reflection loss is negligible. They are different physical quantities. Although the reflection loss and absorption loss describe reflection and absorption in both Schelkunoff theory and Calculation theory, none of them represent actual levels of reflected and absorbed power. Many publications incorrectly determine the shielding types of materials by comparing the contribution of reflection loss (SER') and absorption loss (SEA') to the overall shielding effectiveness. Hence, some concepts connected with EMI SE urgently need clarification. The motivation of this paper is to elucidate the widely existing misconceptions and suggest appropriate comprehension of EMI SE. The Schelkunoff theory and Calculation theory are elaborated to explain correlative terms about the reflection and absorption after depicting the interaction of EM waves with shielding materials. comparing these two theories is implemented to demonstrate that the terms with the same names are different quantities.

Finally, the contributions of reflection and absorption to the total shielding performance and the appropriate method of determining their contributions are elaborated

Chapter I：

Definition of the study

I.1 Introduction

Electronic circuits are used in many devices we use every day, such as telephones, computers, and appliances. When these circuits are close together, they can sometimes cause problems for each other. This is called electromagnetic interference (EMI) and it's a big challenge for circuit designers. The problem is getting worse as more and more electronic devices are used. As technology advances, electronic devices are getting smaller and more complex, which means more circuits are packed into a smaller space, making interference more likely. Device clock speeds have also increased dramatically, with some computers running at over 1GHz.

Today, designers have to go beyond making their systems work perfectly under ideal conditions. They have to consider how their products will work in the real world, with other devices nearby. They also have to comply with government regulations for electromagnetic compatibility (EMC). This means that their equipment should not be affected by external electromagnetic sources and should not generate electromagnetic noise that can interfere with other equipment. Making sure their equipment works well with other equipment and doesn't cause electromagnetic problems is a top priority for designers.

I.2 Definition of the study

An electromagnetic shield or shielding is a conductive enclosure that separates space into two regions, one containing sources of electromagnetic fields and the other not containing sources of electromagnetic fields The purpose of shielding is either to protect the circuits inside the enclosure from external electric or magnetic fields, or to confine the fields generated by the circuits inside the enclosure to prevent any radiation to possible external victims The shielding involves placing a conductive surface around critical parts of the circuit so that the electromagnetic field that couples with the shield are attenuated by a combination of reflection and absorption The shield can be an all-metal enclosure if protection is required up to low frequencies, but at high frequencies 30 MHz is sufficient and a thin conductive coating deposited on plastic is suitable. metal enclosure if protection is required down to low frequencies, but for high frequencies 30 MHz is sufficient and a thin conductive coating deposited on plastic is suitable.

I.3 Organization of the manuscript

In this study, we had to develop, discover, and test the most suitable shielding material to protect against electromagnetic interference, then we followed a plan of action:

First, to define the basics of electromagnetic compatibility (EMC), understand how electromagnetic fields are generated and received, and to reduce electromagnetic interference (EMI) through proper shielding, grounding, planning, and design.

Second, we will learn about shielding, which is the basic principle of EMC and involves the use of conductive or magnetic materials to prevent the emission or reception of electromagnetic waves.

Third, we will know how to calculate the effectiveness of protection, which is a measure of the extent of the ability of the cover or the protected material to prevent the transmission of electromagnetic waves through it, and it depends on the frequency and fluctuation of the electromagnetic waves, the thickness of the arm, and the size and shape of the cover.

In the second chapter, we will study the efficiency of steel in protecting against electromagnetic interference

In the third chapter, we will study the effectiveness of steel in protecting against electromagnetic interference, and we will try aluminum, which was not sufficient in protecting against electromagnetic interference.

As for the fourth chapter, the article will be summarized and some opinions about the experience

I.4 The Objectives of the Study

Studying the shielding effect helps us make materials and designs that can protect against problems with electronics caused by electromagnetic waves. Electromagnetic waves can cause electronic systems to stop working properly, which can be expensive and dangerous. Shielding is the ability of a material or design to block or attenuate electromagnetic waves, which can help protect electronic systems. By studying shielding, we can make materials and designs that work better and help electronic systems work properly. We need to do this because electronic systems are important in many areas, such as space and defense.

We use electronic devices a lot in our daily lives. But electromagnetic waves can cause them to stop working. This is known as electromagnetic interference (EMI). EMI can cause problems and be dangerous. To protect electronic devices, we need to study the effect of shielding. Shielding materials and designs can block or weaken electromagnetic waves. This makes electronic equipment work better and safer. We need shielding in many areas, such as health care and transportation. The study of shielding is a mix of different fields. We need to know about electromagnetics, materials science, and design.

Chapter II

Formulation of the problem of shielding effectiveness

II.1 Introduction

When radiation from multiple devices collides, it can cause equipment failure, data loss, and other related problems. As we move into manufacturing, transportation, medical and military applications, the risk increases. In these situations, any equipment or device failure could result in severe financial loss or even loss of life. Placing electronic components inside a Faraday cage is a typical technique for protecting against incoming electromagnetic interference (EMI). Named after its creator, Michael Faraday, this cage consists of a continuous network of conductive material that grounds any current generated by an internal or external electromagnetic field, effectively blocking a significant amount of EMI. Historically, sheet metal enclosures used to protect electronic equipment have been made from materials such as aluminum, copper, and steel.

II.2 Principal of electromagnetic compatibility :

II.2.1 What Is EMC?

The design of electrical equipment and gadgets includes electromagnetic compatibility (EMC), which ensures that these systems work efficiently without interfering with their electromagnetic environment. Each device requires specific electromagnetic safety. Devices must limit their electromagnetic emissions to prevent interference with other nearby devices. EMC is essential for modern hardware and electrical systems. EMC ensures the coexistence and safety of electronic equipment by preventing disturbances and interference from external electromagnetic disturbances. EMC ensures that electronic systems and equipment have a reduced risk of electromagnetic interference. This is achieved by shielding and grounding, minimizing signal coupling, and effective circuit design. EMC is essential in electrical design, development, and testing to avoid serious consequences such as data loss, equipment malfunction, and safety hazards.

II.2.2 Difference between EMI and EMC:

	EMI (Electromagnétique Interférence)	EMC (Electromagnétique Compatibility)
Definition	The generation of electromagnetic energy by electronic devices that interferes with the operation of other nearby devices	The ability of an electronic device to function without causing or being affected by interference from other devices
Objective	To reduce or eliminate interference generated by the device	To enable the device to operate in its intended environment without causing or being affected by interference
Scope	Worried about radiation from your device	Concerned about both emissions and vulnerability
Standards	Compliance is usually measured against emission standards	Compliance is typically measured against both emission and vulnerability criteria.
Testing	EMI testing measures the electromagnetic energy emitted by a device.	EMC testing measures a device's emissions and susceptibility to external electromagnetic energy.
Example	Examples of electromagnetic interference include radio frequency interference (RFI) and electromagnetic radiation.	Examples of EMC are ensuring that medical devices are not affected by electromagnetic fields generated by nearby equipment, or computers do not interfere with nearby radios.

Table. II.1. The Difference between EMI and EMC.

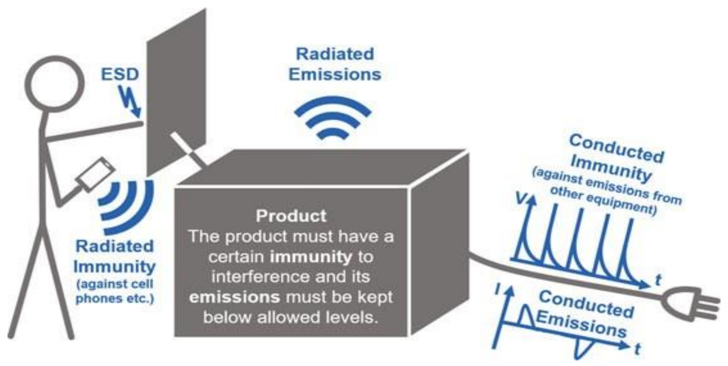


Figure. II.1 an EMC design engineer sees a product

II.2.3 A brief history of the importance of EMC:

EMC is fundamental as electrical equipment interference and disturbance can hurt individuals, the framework, and the environment. For example, in 1992 a lady kicked the bucket as a result of the ambulance's heart machine shutting down every time the specialists activated their radio transmitter to summon help[1]. Another case is the Texaco refinery explosion on 24 July 1994 in Milford Safe House, Joined Together Kingdom. This blast was caused by an electrical storm that caused control surges that disabled certain pump motors while leaving others operational. In addition to causing £48 million in damage, the catastrophe seriously injured 26 individuals. These two occasions are two of numerous that appear how an EMC-compliant plan is vital for more than fair item deals. It additionally suggests a world with dependable items and substance customers.

II.2.4 EMC Terms and Definitions :

Emission and immunity (or susceptibility) are the two basic divisions in the field of EMC. The most important EMC terms and definitions are shown in Figure II.2.

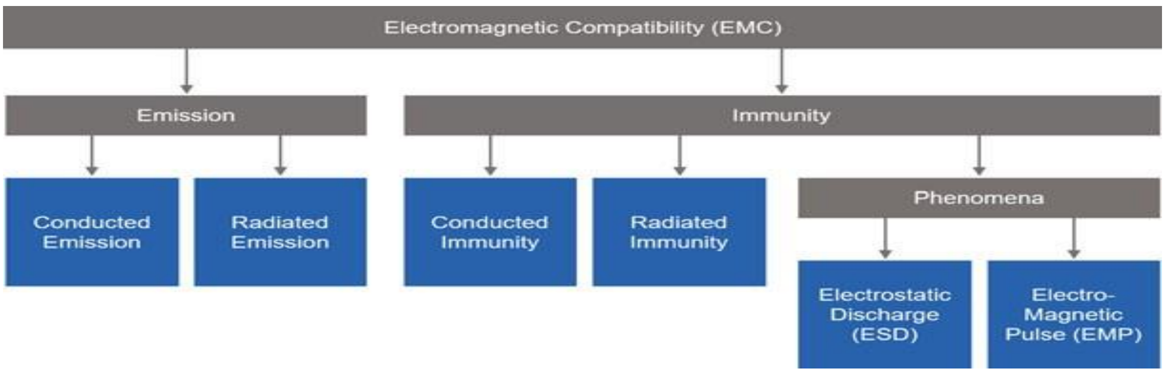


Figure. II.2 EMC terms and definitions

II.2.5 Emission:

CE and RE differ in that they are conducted emissions. Cables connected to the equipment under test (EUT) detect conducted emissions. RF conducted emissions are a concern for electrical and electronic equipment in industrial and commercial environments. Goal: Stop conducted emissions and equipment interference. RF leakage in commercial and mechanical products ranges from 150 kHz to 30MHz, (FCC 47 CFR Pt. 15, CISPR 32). The repetition rate varies for defense and military applications, ranging from 30Hz to 40GHz depending on the industry. MIL-STD-461G: Audio. Limitation of power line consonant currents for equipment with the non-sinusoidal input current. Objective: to limit voltage variations and a glint in low-voltage power supplies for public use. Glint is the identification of abrupt changes in brightness or appearance caused by a sudden shock. RF emissions to avoid the frustration of electromechanical and electrical systems. Radiation is measured in OATS or commercial chambers in the range of 30 MHz to 6 GHz. Frequency ranges vary by industry. They can range from 10 kHz to 40 GHz for defense and military equipment (MIL-STD-461G), or from 3 MHz to 40 GHz for FCC compliance (47 CFR Part 15) or CISPR 32.

II.2.7 Immunity:

The terms CI, CS, RI, RS, and insusceptibility to ESD and EMP describe different types of resistance. Conducted resistance refers to one of these types. Resistance tests are conducted on cables related to the EUT for electrical and electronic hardware used in industry and commerce, including RF-conducted resistance. Goal: Test conducted RF resistance of commercial and mechanical products from 150 kHz to 80 MHz (IEC 61000-4-6). EFT Objective: Protect against repeated electrical quick drifters, including those caused by transferring homeless people, such as inductive load interference and hand-off contact bounce. Sorry, there is no text provided for me to shorten. Please provide a text for me to help you with. Test voltages range from 5 kV to 4 kV. (IEC 61000-4-4). Surge. Goal: resist unidirectional surges from lightning and homelessness causing overvoltage. Test voltages range from 0.5 kV to 4 kV. IEC 61000-4-5 for surges. Objective: Resist sudden voltage drops, control blackouts, and voltage changes at supply ports with RF field resistance. Objective: Attain resistance to disruptive influences such as inductive control exchange frequencies of 9 kHz and 26 MHz or mains control frequencies of 50 Hz and 60 Hz according to IEC 61000-4-3911 and 61000-4-8, respectively, as well as ESD. Goal: Immunity to power release from nearby objects and administrators (IEC 61000-4-2). Test voltages range from 1 kV to 15 kV. EMP security objective. Atomic blasts or pulse-generating gadgets produce EMPs that create sudden, powerful energy fields, also known as HEMPs if they occur at high elevations. EMPs for military and defense, not for customers and commerce.

III.2.7 Design for EMC:

Planning for EMC involves taking EMC under consideration early on within the item improvement preparation instead of just at the exceptional conclusion. Venture delays and fetched invades happen if you test your item for EMC right sometime recently it is to be discharged. Figure II.3 demonstrates how costly it is to cure a botch at an afterward arrange within the item life cycle. The taking after is a few significant subtle elements almost EMC and product advancement:

An EMC thought ought to be characterized. The taking after focuses ought to be particularly characterized by this EMC concept:

Establishing. Characterize a framework establishing thought for the item, intersystem establishing for its components, and board-level establishing for PCBs.

Protecting. Clarify when and how to protect inside and outside wires as well as basic circuits. Portray how the shields are reinforced.

Sifting. Indicate whether and how to channel cables and wires (internal and outside cables). Take ESD, EFT, and surge into specific thought for cables that withdraw your item. For each cable, RF filtering ought to be taken into consideration. Iterative testing. Testing EMC execution (emission, immunity) amid different product development cycles is exhorted. Hardware development ventures ordinarily go through four cycles:

breadboard, model, pilot, and arrangement. Pre-compliance testing (conducted inside or at a lab that's not authorized) is suggested amid the model arrangement and completely compliant EMC testing all through the later extend stages (pilot, arrangement). Pre-compliance EMC testing could be an extraordinary way to cut costs and spare time. The development team's ongoing expansion of its EMC information is another advantage of in-house EMC testing.

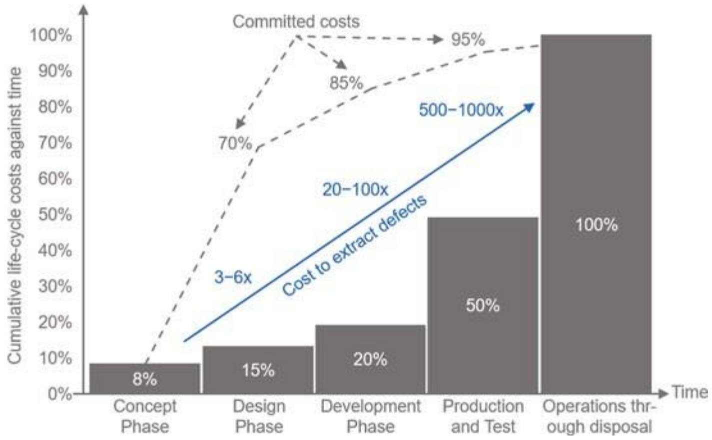


Figure. II.3 Life cycle costs [2]and the costs of fixing defects at different life cycle stages

II.3 Shielding:

A metal item called a shield divides two sections of space. It regulates how electromagnetic energies are moved from one place to another. If shields are positioned around the They may also contain electromagnetic fields, which is the source of the noise. All exposed electronics are shielded in this setup. To keep electromagnetic radiation from entering a specific area, a shield can be utilized. This method restricts the scope of protection to the specific equipment encased within the shield. From the standpoint of the entire system, shielding the noise source is more effective than shielding the receptor.

Noise voltages should be filtered from any cables that pierce the shield in order to preserve the integrity of the shielded enclosure. This strategy is appropriate for power cabs.

This chapter is made up of two parts, The operation of a strong screen without openings is portrayed to begin with. For the 1MHz copper.

II.3.1 NEAR FIELDS AND FAR FIELDS

The source (the antenna), the media around the source, and the separation between the source and the point of observation all have an impact on the characteristics of a field. The source features operate as the main determinants of the field properties at a position close to the source. When the field is far from the source, the medium it travels through largely determines how it behaves.

Two areas can be distinguished in the vicinity of a radiation source as a result. Near the source is where one finds the induction or near field. The wavelength (l) divided by 2π (or roughly one sixth of a wavelength) represents the distance between you and the radiation field. The separation between the close and far is approximately $1/2\pi$.

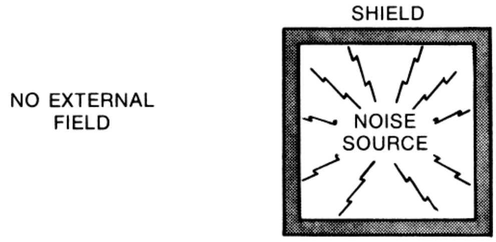


Figure. II.4. the noise source is protected, noise coupling to equipment outside the shield is prevented

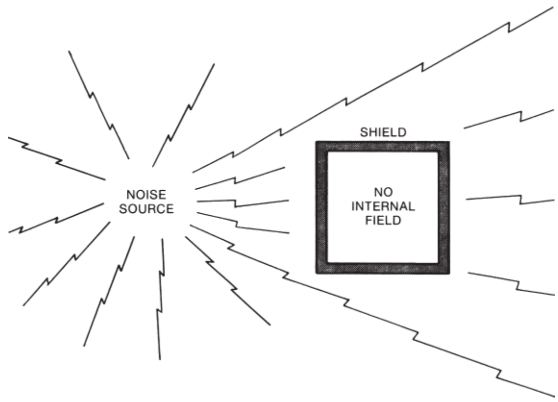


Figure. II.5. An application of a shield protects the receptor from noise incursion.

The wave impedance is governed by the electric field to the magnetic field (E/H) ratio. This ratio, for example, E/H = Z0 = 377 O for air or void space, shows the typical impedance of the medium in the far field. in close proximity

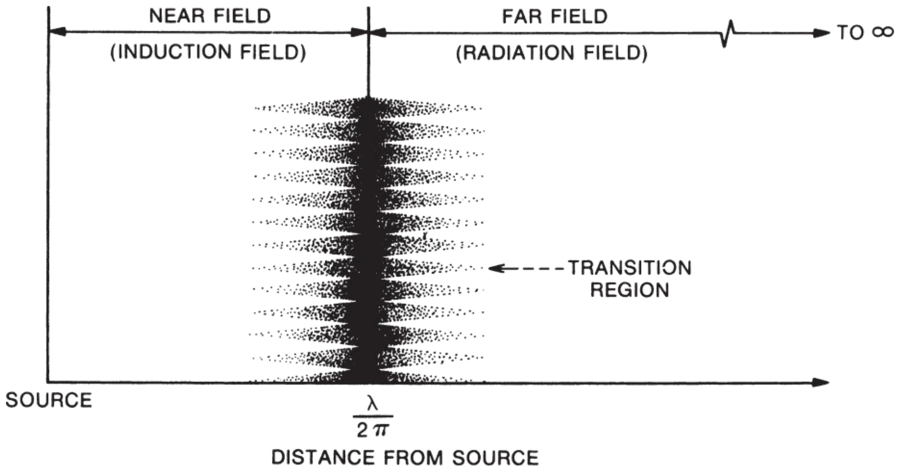


Figure. II.6. A radiation source may be found in either in close range or the far field. The shift from the near to distant field occurs at a distance of $1/2\pi$.

ratio is affected by both the properties of the source and the location of the field of observation with respect to the source If the source is high current and low voltage (E/H o 377), the near field is predominantly magnetic. However, if the source is high voltage and low current (E/H W 377), the near field is predominantly electrical.

Rod coils and straight wire coils have high source impedance. The characteristic impedance, which is primarily the electric field, is also important near the antenna. The electric field creates a complementary magnetic field to partially compensate for the drop in field strength with distance. The near-field magnetic field weakens by a factor of $(1/r)$, while the electric field weakens by a factor of $(1/r^2)$.

The electric and magnetic fields in the near field must be considered separately because of their varying relative intensities. In contrast, they combine in the far field to produce a plane wave with an impedance of 377 Ω. Therefore, it is assumed that when plane waves are described, they are in the far field. It is assumed that while addressing individual electric and magnetic fields, they are in the near field.

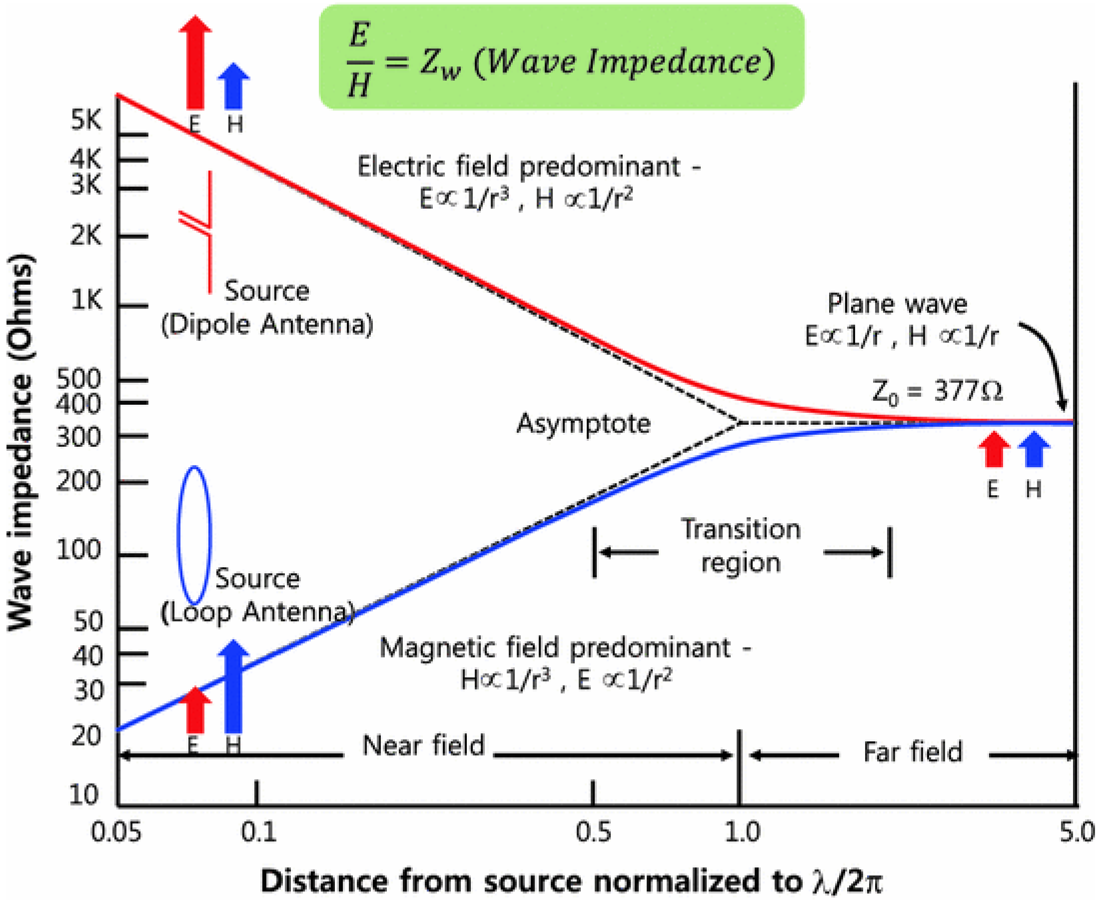


Figure. II.7. The distance from the source affects wave impedance

II.3.2 CHARACTERISTIC AND WAVE IMPEDANCES

These medium-specific constants are used in this chapter:

Permeability, Dielectric constant, Conductivity,	m($4\pi \times 10^{-7}$ H/m for free space). e(8.85×10^{-12} F/m for free space). s(5.82×10^{7} siemens/m for copper).

Any electromagnetic wave's wave impedance is defined as

$$Z_w = \frac{E}{H}$$

The following expression, according to Hayt (1974), represents a medium's typical impedance:

$$Z_0 = \sqrt{\frac{j\omega\mu}{\sigma + j\omega\varepsilon}}$$

Using Z_0 g and wave impedance Z_w are also equivalent in the case of a far-field plane wave. Frequency-independent insulators' characteristic impedance (s joe) transforms into

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

In a vacuum, is comparable to 377 Ohm . The shield impedance Z_s is what's called as the typical conductor impedance (s joe), and it becomes

$$Z_s = \sqrt{\frac{j\omega\mu}{\sigma}} = \sqrt{\frac{\omega\mu}{2\sigma}}(1 + j)$$

$$|Z_s| = \sqrt{\frac{\omega\mu}{2\sigma}}$$

3.68 $10^{-4}w$ is the value of $|Z_s|$ For copper wire 1 MHz. By changing the constants in Eq. 6-4b's constants with numbers, the results are as follows:

When copper:

$$|Z_s| = 3.68 \times 10^{-7}\sqrt{f}$$

Material	Relative conductivité s_r	Relative perméabilité m_r
Silver	1.05	1
Copper—annealed	1.00	1
Gold	0.7	1
Chromium	0.664	1
Aluminium (soft)	0.61	1
Aluminum (tempered)	0.4	1
Zinc	0.32	1
Beryllium	0.28	1
Brass	0.26	1
Cadmium	0.23	1
Nickel	0.20	100
Bronze	0.18	1
Platinum	0.18	1
Magnesium alloy	0.17	1
Tin	0.15	1
Steel (SAE 1045)	0.10	1000
Lead	0.08	1
Monel	0.04	1
Cometic (1 kHz)	0.03	25000
Meatal (1 kHz)	0.03	25000
Stainless steel (Type 304)	0.02	500

Table. II.2. typical values for the relative permeability (mr) and relative conductivity (sr)

Aluminum:

$$|Z_s| = 4.71 \times 10^{-7}\sqrt{f}$$

Steel:

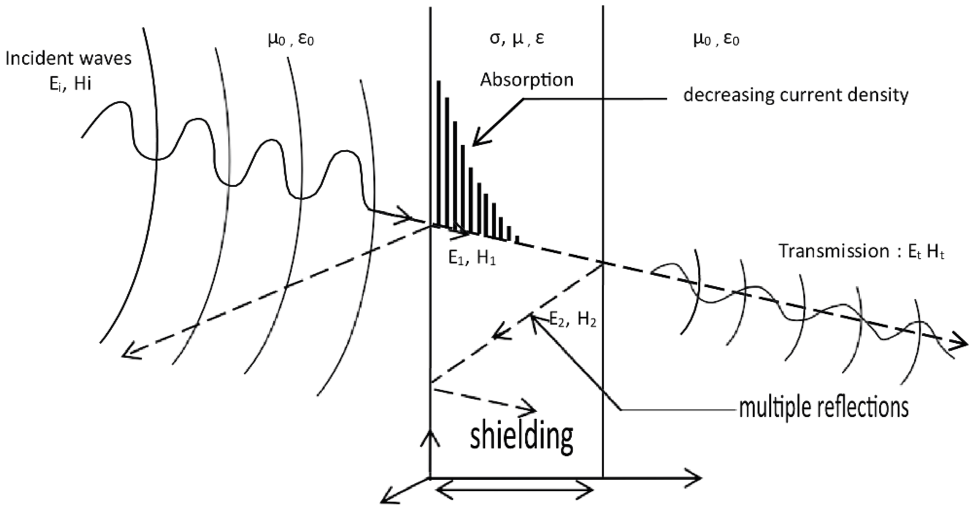
$$|Z_s| = 3.68 \times 10^{-5}\sqrt{f}$$

For any conductor, in general:

$$|Z_s| = 3.68 \times 10^{-7} \sqrt{\frac{\mu_r}{\sigma_r}} \sqrt{f}$$

II.4 Shielding effectiveness:

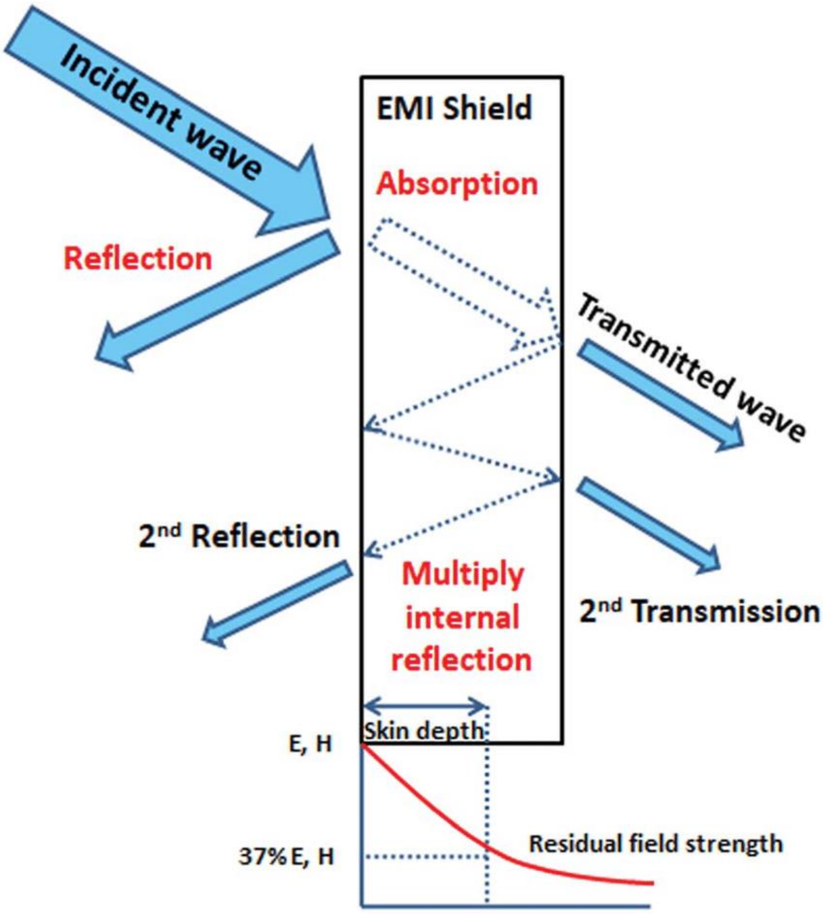
When an EM wave hits the front interface between the shielding fabric and free space, the EM wave is reflected. This is due to the impedance mismatch between the two different media. Waves that are not reflected propagate towards the interior of the material and their intensity decreases exponentially due to absorption. When the wave comes to the back interface, a portion of the wave passes through the shield and the rest is reflected, making a heap of different reflections between the two interfacing. Figure. II..8 shows a schematic diagram of the interaction between electromagnetic waves and shielding materials.



. **Figure. II.8** Illustration of the electromagnetic shielding

II.4.1 SCHELKUNOFF THEORY :

According to Schelkunoff's theory, which is mainly based entirely on the transmission line version of the antibodies and the well-known SE,, an incident plane wave striking on a homogenous and isotropic material sheet is typically considered here for simplification.



. **Figure. II.9** .Schematic of Representation of shielding mechanism_

measuring materials six times According to Schelkunoff's theory, reflection loss $SE_{R_{dB}}$, absorption loss $SE_{A_{dB}}$, and multiple reflection loss $SE_{M_{dB}}$ are added up to form SE, which is typically expressed on a logarithmic scale with decibels as the unit. EM) [3][4][5][6]

$$SE(\text{dB}) = 10\log_{10}\left|\frac{E_i}{E_t}\right| = 20\log_{10}\left|\frac{H_i}{H_t}\right| = SE_{R_{dB}} + SE_{A_{dB}} + SE_{M_{dB}}$$

$SE_{R_{dB}}$: Represents the reflection loss on the left side of the driver (R>0)

$SE_{A_{dB}}$: Represents the absorption loss of the conductor (A>0).

$SE_{M_{dB}}$: Represents additional multiple reflections and transmissions (M<0). Negative values of the latter factor reduce shielding efficiency.

E_i: The incident plane wave electric field " $\vec{\hat{E}}_I = \hat{E}_i . e^{-j\beta_0 z} . \overrightarrow{a_x}$ " v/m (unite of wave electric)

E_t: The transmitted plane wave electric field, " $\vec{\hat{E}}_t = \hat{E}_i . e^{-j\beta_0 z} . \overrightarrow{a_x}$ " v/m (unite of wave electric)

H_i: The incident plane wave magnetic field,

H_t: The transmitted plane wave magnetic field, where P_I ($E_i$or H_i) and P_t (E_t or H_t) are power (electric or the magnetic field of the incident or transmitted wave). In transmission line theory, it is the characteristic impedance (η) of the medium. defined as

$$\eta = \sqrt{\frac{j\omega\mu}{\sigma+j\omega\varepsilon}}$$

Where μ, σ and ε are permeability, electrical conductivity and permeability, respectively = $2\pi f$ is the angular frequency. Characteristic impedance in free space ; $Z_w \approx \sqrt{\frac{\mu_0}{\varepsilon_0}} = 377\ \Omega$,

where μ_0 and ε_0 are the vacuum permeability and permittivity, It is common to use the propagation constant (γ) in media such as resp.Of $\gamma = (\alpha + j\beta)$=$\sqrt{j\omega\mu(\sigma + j\omega\varepsilon)}$ where α is the damping constant and β is the phase constant. Eq. (2) and Eq. (3) is the general formula for the characteristic impedance, Propagation constant or $\sigma \gg\omega\varepsilon$, the characteristic impedance and propagation constant are $\eta \approx \sqrt{\frac{j\omega\mu}{\sigma}}$ and $\gamma \approx \sqrt{j\omega\mu\sigma}$

II.4.2 Reflection loss (SE_R):

Reflection loss refers to the transmission line return loss. It increases when the electromagnetic field impedance is much higher or lower than the shield impedance. In this situation, there is an imbalance between the two impedances and the power transfer from the field to the shield, putting the two in the same position.
contributions omitted. Multiple reflections between two interfaces and absorption in shielding materials Considering only the reduction of transmitted waves due to primary reflex. The intensity of reflected and transmitted waves from
From medium $Z1$ with impedance to medium $Z2$ with impedance, can be expressed by:

Er = ΓEi =$\frac{Z_2-Z_1}{Z_1+Z_2}Ei$ ………………………(4)

Er = TEi =$\frac{2Z_2}{Z_1+Z_2}Ei$ ………………………(5)

Where Ei, Er, and Et are the intensities of the incident, reflected, and transmitted waves.
Also; Γ and T = 1 + Γ are the reflection coefficient and transmission.
Factor for infinitely thick media timid.

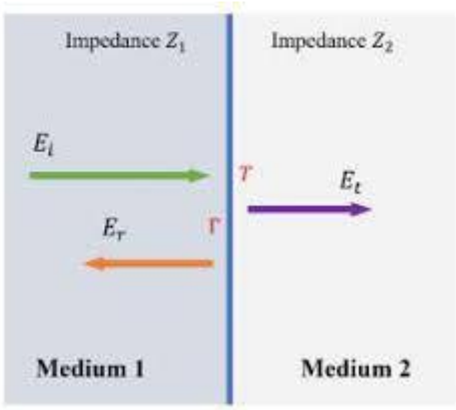


Figure. II.10. Reflection and transmission of the incident wave at an interface between two infinite thickness media

When an electromagnetic wave passes through one shield, it encounters two shields. The interface between matter and free space is shown in FigureII.10. . Reflection The coefficients and transmission coefficients at the front and rear boundaries are

$\Gamma_1 = \frac{Z_2 - Z_1}{Z_1 + Z_2}$,$\Gamma_2 = -\Gamma_1$, $T_{21} = 1 + \Gamma_1$, $T_{12} = 1 + \Gamma_2$.

Sent wave (E_t) given through the second interface

$E_t = T_{12}E_1 = T_{21}T_{12}E_i$

According to the definition of shielding effectiveness, reflection loss is defined as

$SE_{R_{dB}} = 20\log_{10}\left|\frac{E_i}{E_t}\right| = 20\log_{10}\left|\frac{1}{T_{21}T_{12}}\right|$

Reflection loss is equal to the reciprocal of the transmittance product. Coefficients at both interfaces in decibels indicating that only return loss occurs depends on media impedance value

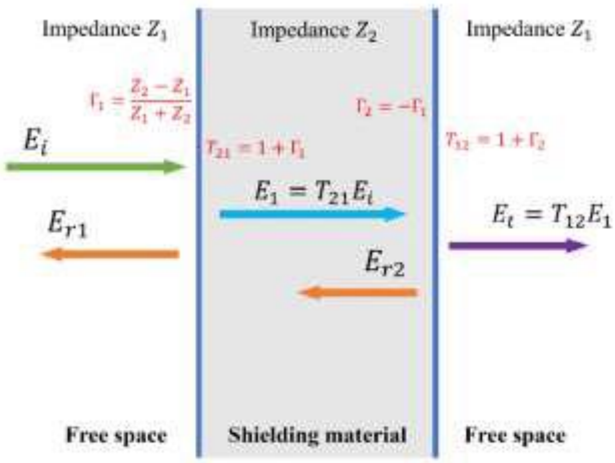


Figure. II.11. Partial reflection and transmission occur at both faces of a shielding material.

II.4.3 Absorption loss:

When an electromagnetic wave penetrates matter, its amplitude decreases exponentially. This reduction is due to dielectric loss, magnetic loss, and conduction loss of the material[7][8] Therefore, the electric field E at the distance (t) , within the material is

$$E = E_i e^{-\gamma t} \qquad (8)$$

Defines the distance required for a wave to decay to 1/e of its original value.

than the skin depth (δs). The absorption loss for a material of thickness t is expressed as

$$SE_{A_{dB}} = 20\log_{10}\left|\frac{E_i}{E_t}\right| = 20\log_{10}\left|e^{\gamma t}\right| \qquad (9)$$

Absorption loss is closely related to the constitutive parameters (μ, σ, and ε) and material thickness. This can be physically interpreted as attenuation of the transmitted wave due to losses inside the shield when the impedance of the shield simultaneously matches the impedance of the surroundings and no reflection occurs at both interfaces.

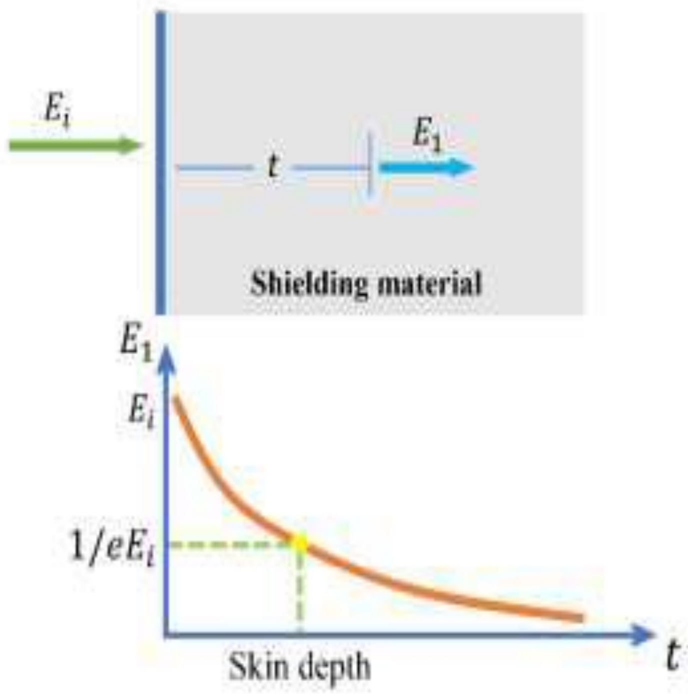


Figure. II.12. Electromagnetic wave passing through an absorbing medium is attenuated exponentially [9].

II.4.4 Multiple reflection loss :

If the shield is thin, the reflected wave will be reflected at the second boundary. Away from the first bound, then reflected the second bound again, as shown in Figure. II.13. With thick shields this can be ignored this is because the absorption loss is significant. The second time the wave reaches its second limit, it has passed through her three times the thickness of the shield by then, so its amplitude is negligible.

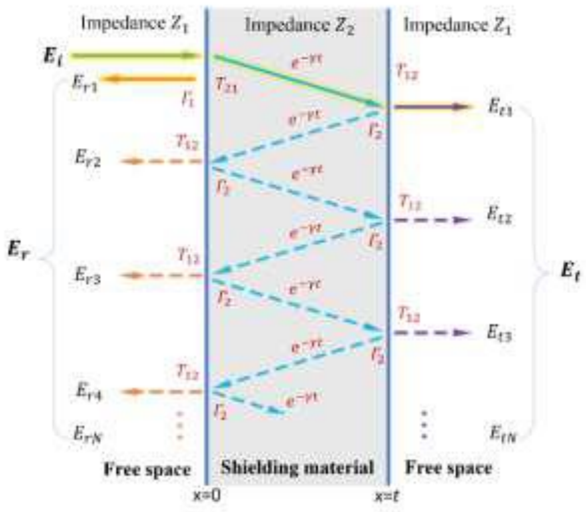


Figure. II.13. Multiple reflections occur in a material

Therefore, multiple reflections contribute to the total as well as reflections and absorptions. shield. "The total transmitted (reflected) wave is the sum of all partial waves. Pass through (reflect) the second (first) interface to the right (left)." [10][11]

$$\mathrm{E}_t = \mathrm{E}_{t1} + \mathrm{E}_{t2} + \cdots + \mathrm{E}_{tN} = \mathrm{T}_{21}\mathrm{T}_{12}e^{-\gamma t}\mathrm{E}_i + \mathrm{T}_{21}\mathrm{T}_{12}e^{-3\gamma t}\Gamma_2{}^2\mathrm{E}_i + \cdots + \mathrm{T}_{21}\mathrm{T}_{12}e^{-(2N-1)\gamma t}\Gamma_2{}^{(2N-2)}\mathrm{E}_i = \left(\frac{\mathrm{T}_{21}\mathrm{T}_{12}e^{-\gamma t}}{1-\Gamma_1{}^2e^{-2\gamma t}}\right)\mathrm{E}_i \quad (10)$$

$$\mathrm{E}_r = \mathrm{E}_{r1} + \mathrm{E}_{r2} + \cdots + \mathrm{E}_{rN} = \Gamma_1\mathrm{E}_i + \mathrm{T}_{21}\mathrm{T}_{12}e^{-2\gamma t}\Gamma_2\mathrm{E}_i + \cdots + \mathrm{T}_{21}\mathrm{T}_{12}e^{-(2N-2)\gamma t}\Gamma_2{}^{(2N-3)}\mathrm{E}_i = \Gamma_1\left(1-\frac{\mathrm{T}_{21}\mathrm{T}_{12}e^{-\gamma t}}{1-\Gamma_1{}^2e^{-2\gamma t}}\right)\mathrm{E}_i \quad (11)$$

Therefore, the corresponding coefficients of merit for transmittance (T) and reflectance (R) are that is:

$$\mathrm{T} = \frac{P_t}{P_i} = \left|\frac{\mathrm{E}_t}{\mathrm{E}_i}\right|^2 = \left|\frac{\mathrm{T}_{21}\mathrm{T}_{12}e^{-\gamma t}}{1-\Gamma_1{}^2e^{-2\gamma t}}\right|^2 \quad (12)$$

$$R = \frac{P_r}{P_i} = \left|\frac{\mathrm{E}_r}{\mathrm{E}_i}\right|^2 = \left|\Gamma_1\left(1-\frac{\mathrm{T}_{21}\mathrm{T}_{12}e^{-\gamma t}}{1-\Gamma_1{}^2e^{-2\gamma t}}\right)\right|^2 \quad (13)$$

By definition, SE(dB) is given by

$$\mathrm{SE(dB)} = 20\log_{10}\left|\frac{\mathrm{E}_i}{\mathrm{E}_t}\right| = 20\log_{10}\left|\frac{1-\Gamma_1{}^2 e^{-2\gamma t}}{1-\Gamma_1{}^2 e^{-2\gamma t}}\right| = 20\log_{10}\left|\frac{1}{\mathrm{T}_{21}\mathrm{T}_{12}}\right| + 20\log_{10}\left|e^{\gamma t}\right| + 20\log_{10}\left|1-\Gamma_1{}^2 e^{-2\gamma t}\right| = \mathrm{SE}_{\mathrm{R_{dB}}} + \mathrm{SE}_{\mathrm{A_{dB}}} + \mathrm{SE}_{\mathrm{M_{dB}}} \qquad (14)$$

where the correction term due to successive reflections (also called multiple return loss) is defined as:

$$\mathrm{SE}_{\mathrm{M_{dB}}} = 20\log_{10}\left|1-\Gamma_1{}^2 e^{-2\gamma t}\right| \qquad (15)$$

Multiple reflection losses are reflected and therefore important for electrically thin materials. Waves increase the transmitted energy, and the values of multiples of SE.36,37 decrease. Reflective effects can be safely ignored as the material thickness increases ($SEM \approx 0$). "Because the skin depth or absorption loss (SEA) is higher than 10 dB, the amplitude of the EM wave that reaches the second interface first is negligible. [12][13]

II.4.5 Calculation of shielding effectiveness from scattering parameters:

The behavior of wave propagation through the sample can be determined experimentally, recorded and measured by some technique (e.g. transmission/reflection method using various instruments (such as vector network analyzers) [14], [15],[16],[17].

The transmitted wave of a 2-port vector network analyzer can be expressed as complex scattering parameters (S-parameters), i.e. S_{11} (S_{22}) and S_{21} (S_{12})

This correlates with reflectance (R) and transmittance (T).

$$\mathrm{R} = \left|\frac{E_r}{E_i}\right|^2 = |S_{11}|^2 = |S_{22}|^2 \qquad (16)$$

$$T = \left|\frac{E_t}{E_i}\right|^2 = |S_{21}|^2 = |S_{12}|^2 \qquad (17)$$

The coefficient of reflection $\Gamma 1$ ($|\Gamma 1|$ 1) to the previous interface of the matter is given by

$$\Gamma_1 = \chi \pm \sqrt{\chi^2 - 1} \qquad (18)$$

Where

$$\chi = \frac{S_{11}{}^2 - S_{21}{}^2 + 1}{2S_{11}} \qquad (19)$$

The propagation coefficient $e^{-\gamma t}$ is

$$e^{-\gamma t} = \frac{S_{11} + S_{21} - \Gamma_1}{1 - (S_{11} + S_{21})\Gamma_1} \qquad (20)$$

We can then calculate the loss of reflection, the loss of absorption and the loss of multiple reflections, from Eq. (18) - (20).

II.4.6 Theory of calculating shielding efficacy:

In terms of electromagnetic energy when hit by an electromagnetic wave incident power can be divided into reflected power, absorbed power, and absorbed power[18][19] the corresponding power coefficients of transmission power Reflectance (R), absorption (A), and transmission (T) obey the law of balance of forces ($R + A + T = 1$).Therefore, high shielding performance (low EM transmittance energy) arises from two components, one of which is associated with high-energy reflections. (defined as reflection loss (SER')) and high energy absorption (defined as(SEA')).[19],[20] as absorption loss

$$SE = 10\log_{10}\left(\frac{P_i}{P_t}\right) = 10\log_{10}\left|\frac{1}{T}\right| = SE_R{}' + SE_A{}' \quad (21)$$

EM energy incidence at the front interface of the shield material is partial.

Reflected from the sample and partially transmitted by the sample. The latter is denoted here as follows:

"Available Power" ($P_{AV} = P_i - P_r$) indicates the net power available to load the material. reflection loss ($SE_R{}'$) is defined by

$$SE_R{}' = 10\log_{10}\left(\frac{P_i}{P_{AV}}\right) = 10\log_{10}\left|\frac{1}{1-R}\right| = 10\log_{10}\left|\frac{1}{1-S_{11}{}^2}\right| \quad (22)$$

$SE_R{}'$ is the ratio of the incident power to the available power and represents the reduction of an incident wave that penetrates a material by reflection .

The available power is absorbed by the material and the remaining power is Sent via the rear interface. Absorption loss($SE_A{}'$)s is defined as:

$$SE_A{}' = 10\log_{10}\left(\frac{P_{AV}}{P_t}\right) = 10\log_{10}\left|\frac{1-R}{T}\right| = 10\log_{10}\left|\frac{1-S_{11}{}^2}{S_{21}{}^2}\right| \quad (23)$$

$SE_A{}'$ is the ratio of available power to transmitted power, a material that by itself attenuates EM waves that pass through the material absorption[21][22][23]

II.5 CONCLUSION:

Reflection loss and absorption loss cannot represents the actual levels of reflected and absorbed power, hence it is unreasonable to determine the reflection and absorption contribution to the overall shielding by comparison of reflection loss and absorption loss. It is suggested to adopt power coefficients of reflectivity and absorptivity to describe the shielding mechanisms. Multiple reflection loss gives a negative contribution to shielding effectiveness for electrically thin materials while it can be negligible for thick materials. The concept of Multiple reflection loss does not exist in

Calculation theory since the multiple reflection effect is included in the reflection loss and absorption loss. Only accurate comprehension of the concepts of shielding effectiveness can allow a proper understanding of shielding mechanisms and the successful development of high-performance shielding materials.

Chapter III

Results and Discussions

III.1 Introduction

After the theoretical study of the of the **shielding effectiveness** has been presented in Chapter II, we describe in the presents Chapter the **simulation** procedure using the commercial electromagnetic software Ansys HFSS to calculate the **shielding effectiveness** of steel and aluminum materials. The **simulation** consists of modeling a 1x1 m **shielding material** with a thickness of 1mm and placing the transmitter and receiver on either side of the material. **The simulation** process uses a plane wave as the electromagnetic field source that interacts with the **shielding material**. A port performed on the side of **the receiver antenna** measures the intensity of the electromagnetic field penetrating the shielding material. By comparing the intensity of the electromagnetic field measured on the receiver side with the intensity of the plane wave on **the transmitter** side, the shielding effect of the material can be calculated. **Shielding effectiveness** is a measure of how effective a material is in reducing the strength of the electromagnetic field passing through it. The use of simulation software Ansys HFSS allows for a controlled and repeatable experiment without the need for physical hardware and equipment. The extensive material database of the software also enables to test and compare different materials. Overall, the simulation process can provide insights into **the effectiveness** of different shielding materials used in **security devices**.

III.2 Présentation du logiciel An soft ANSYS

ANSYS is an advanced engineering simulation software used for modeling and analyzing various physical phenomena. It offers capabilities for structural analysis, fluid dynamics, electromagnetics, acoustics, and more. Engineers can simulate real-world behavior, predict performance, and optimize designs before physical prototyping. ANSYS is widely used in industries such as aerospace, automotive, energy, electronics, and manufacturing. It helps accelerate product development, optimize performance, and solve complex engineering problems.

1. Enter the necessary antenna parameters: unit, resonance frequency, or parameters extra like gain, beamwidth, bandwidth, materials, size, etc...;
2. Select "Create Model" to create the antenna model in ANSYS.
3. Analysis of the model: After the creation of the antenna. The model scan can take 5-20 minutes to scan, depending on the machine and on the complexity of the analyzed structure (size of the model, number of frequency samples, mesh size, type of the solver,…).
4. Post-processing : Displaying the Results of an ANSYS Model: To Display the results in HFSS follow the steps

following: In Project Manager right button Result>Create Model Solution Data Report> or

Result>Create Far Fields Report> then choose the parameters you want to display:

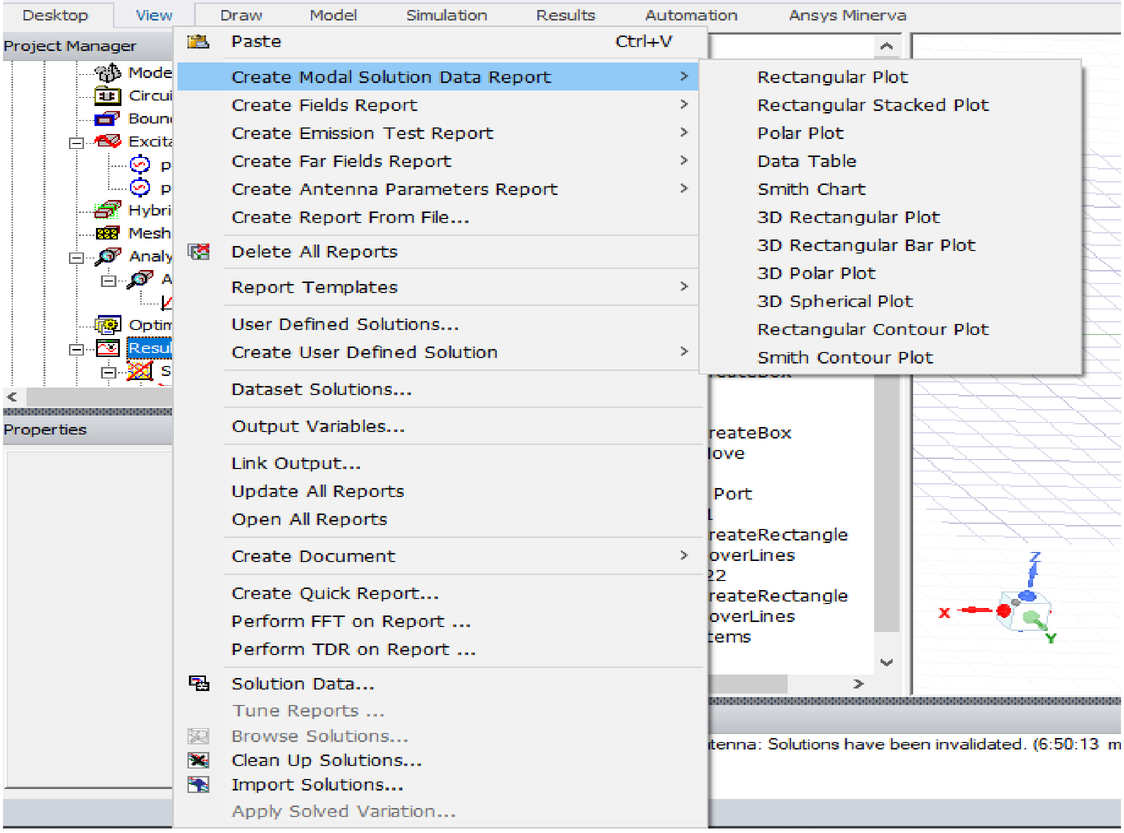


Figure. III.1 . Post processing stage in HFSS: visualizing simulation results.

III.3 Process of Simulation

The entire shielding effectiveness calculation process was carried out using ANSYS simulation software. This software was chosen for the experiment because it offers a wide range of materials in its database, making it suitable for simulating different shielding scenarios**.** Steel and aluminum were selected as representatives of shielding materials due to their availability and suitability for use in security devices. Additionally, both materials are relatively inexpensive.

The simulation process **starts** by creating a model of the shielding material with dimensions of 1x1m and a thickness of 1mm. The transmitter and receiver were positioned facing each other on opposite sides of the material. Both the transmitter and receiver were located at a distance of 0.5m from the material being tested. The source of the electromagnetic field is a plane wave or a radiated field by an actual dipole, and the probe was used to measure the intensity of the field that penetrated through the shielding material.

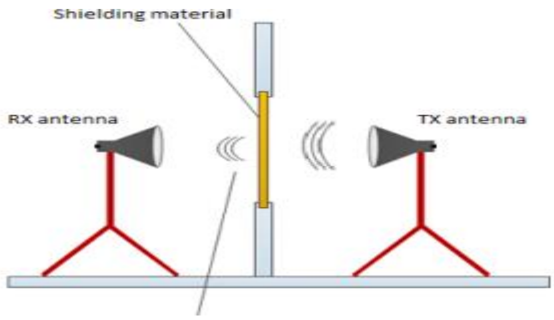


Figure. III.2. Principle of Testing of Shielding Effectiveness.

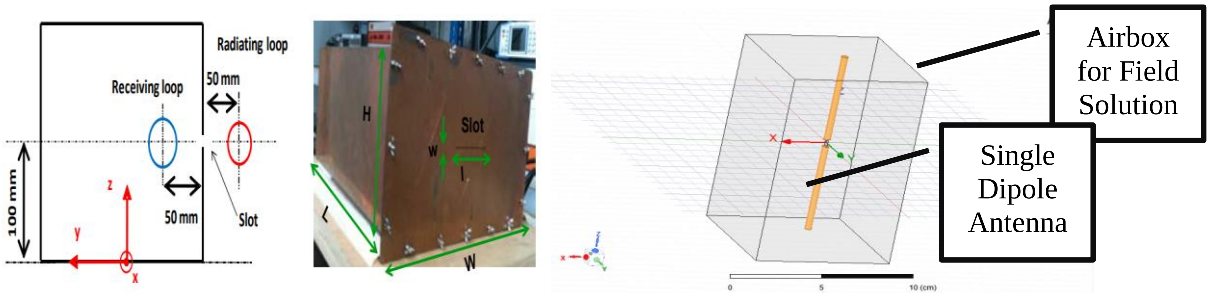


Figure. III.3. Modeled structure [24].

Figure. III.3.Present modeled structure [24].The size of the airbox in the other two dimensions should be large enough to provide accurate far field solutions at the frequency of interest.

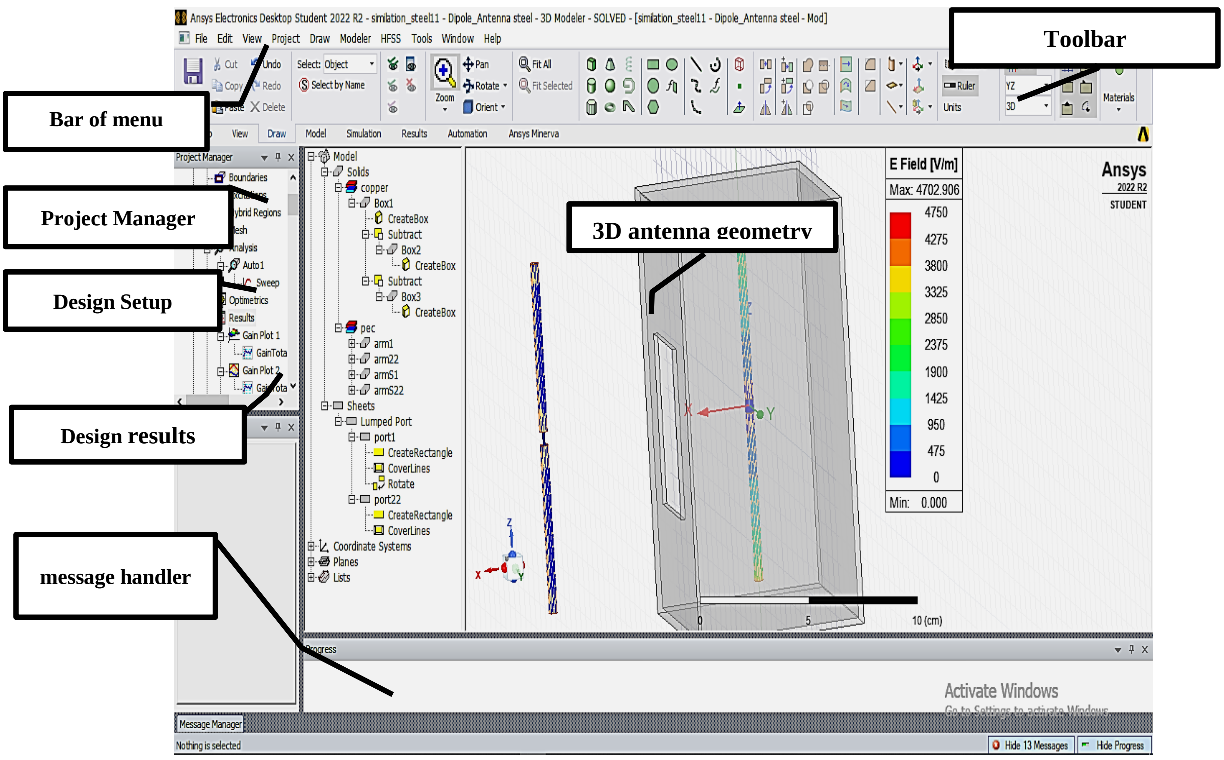


Figure. III.4. Interface Development Environment of the HFSS simulator

Figure. III.4. Interface Development Environment of the HFSS Simulator The user interface of

HFSS provides a graphical environment for creating and manipulating electromagnetic models, defining simulation settings, running simulations, and analyzing results.   to efficiently work with the software.

III.3.1 Study of the Aluminum material

Aluminum is a lightweight metal with a wide range of applications due to its favorable material properties. Here are some key properties of aluminum:

Lightweight: Aluminum has a low density, making it lightweight compared to many other metals. It is approximately one-third the weight of steel, which makes it ideal for applications where weight reduction is important.

Electrical Conductivity: Aluminum is an excellent conductor of electricity, second only to copper. It is widely used in electrical transmission and distribution systems due to its conductivity and lighter weight compared to copper.

Name	**Value**	**Unit**
Type	Lossy metal	-
Mue	1	-
Electrical conductivity	3.56e+007	S/m
Rho	2700	Kg/m^3
Thermal conductivity	237	W/(mK)
Heat capacity	0.9	kJ/(kgK)
Diffusivity	9.75309e-005	m^2 /s
Young's modulus	69	kN/mm^2
Poisson's ratio	0.33	-
Thermal expansion	23	1e-6/K

Table. III.1 Electrical and mechanical parameters of the aluminum material. [25]

Table.III.1. presents the electrical and mechanical parameters of the aluminum material. We used some of these parameters in MATLAB code for estimating the SE and the others in the HFSS for showing the results of absorbing the wave electromagnetic of the aluminum material.

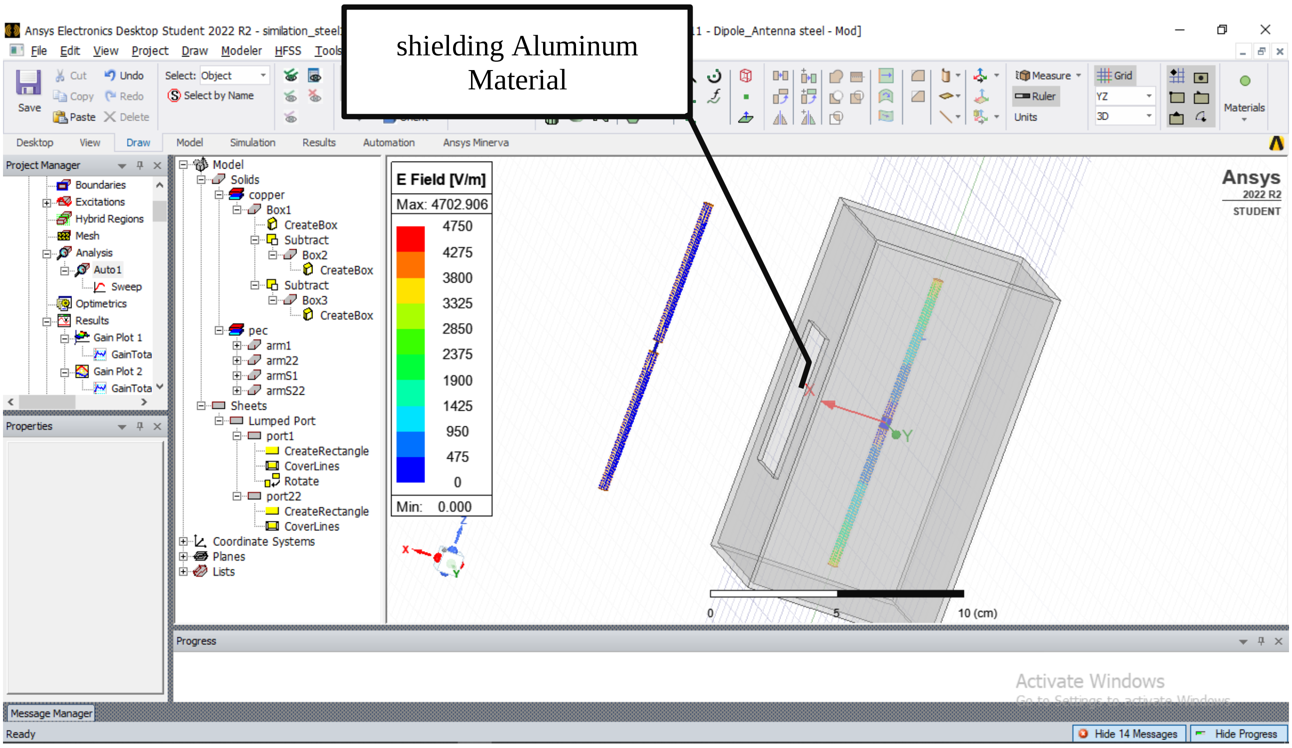


Figure. III.5. HFSS project used for shielding effectiveness simulation of Aluminum Material.

Figure. III.5. The HFSS project used for effective protection is represented by the use of aluminum material. The placement of two identical dipole antennas simulates the scenario of a receiving and transmitting antenna. The first used dipole Tx generates an interference wave where the dipole Rx receives the electromagnetic wave (the victim) the Rx antenna is surrounded by a closed metal box and we put a layer of aluminum to study its effectiveness in stopping electromagnetic waves .

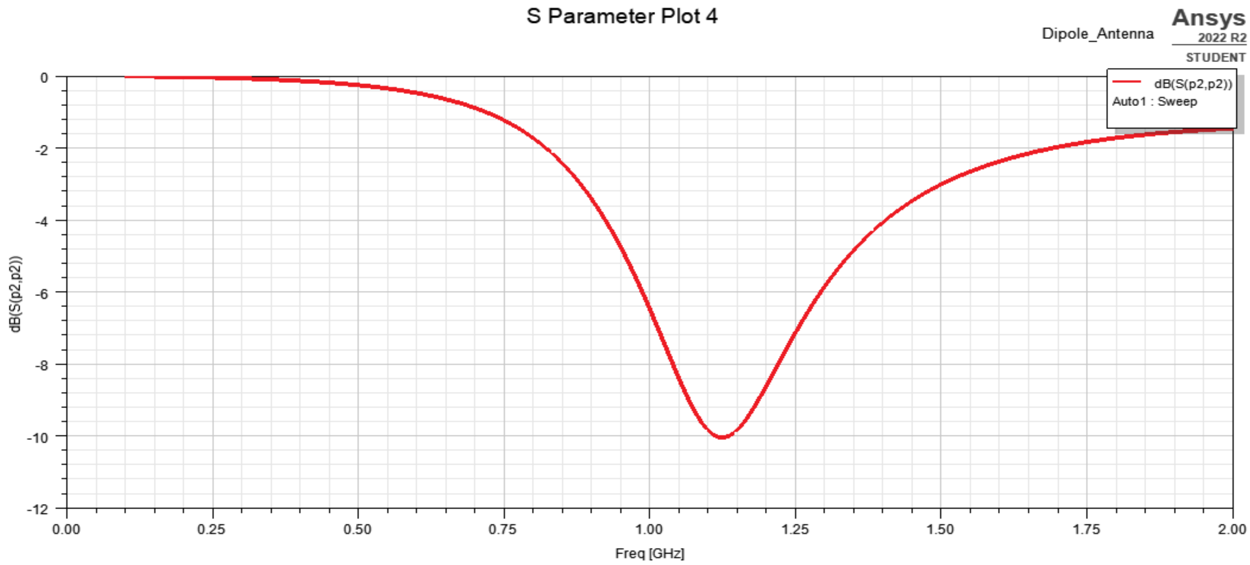


Figure. III.6. The frequency response curve of the dipole antenna.

Figure. III.6.represents a frequency response curve of one dipole. The frequency range included in the data is from 0.1GHz to 2GHz. This range covers a broad spectrum, including low and high frequencies. Attenuation values across the data range from about -7.76 dB at the low end to about -0.004 dB at the high-frequency range. The content of attenuation varies, with higher attenuation values observed at higher frequencies. The amplitude of the response decreases with increasing frequency, suggesting behavior akin to a high-pass. This means the dipole is more transparent at high frequencies while attenuating or blocking low frequencies. We also note that there’s resonance because the curve S stops at value -10db .

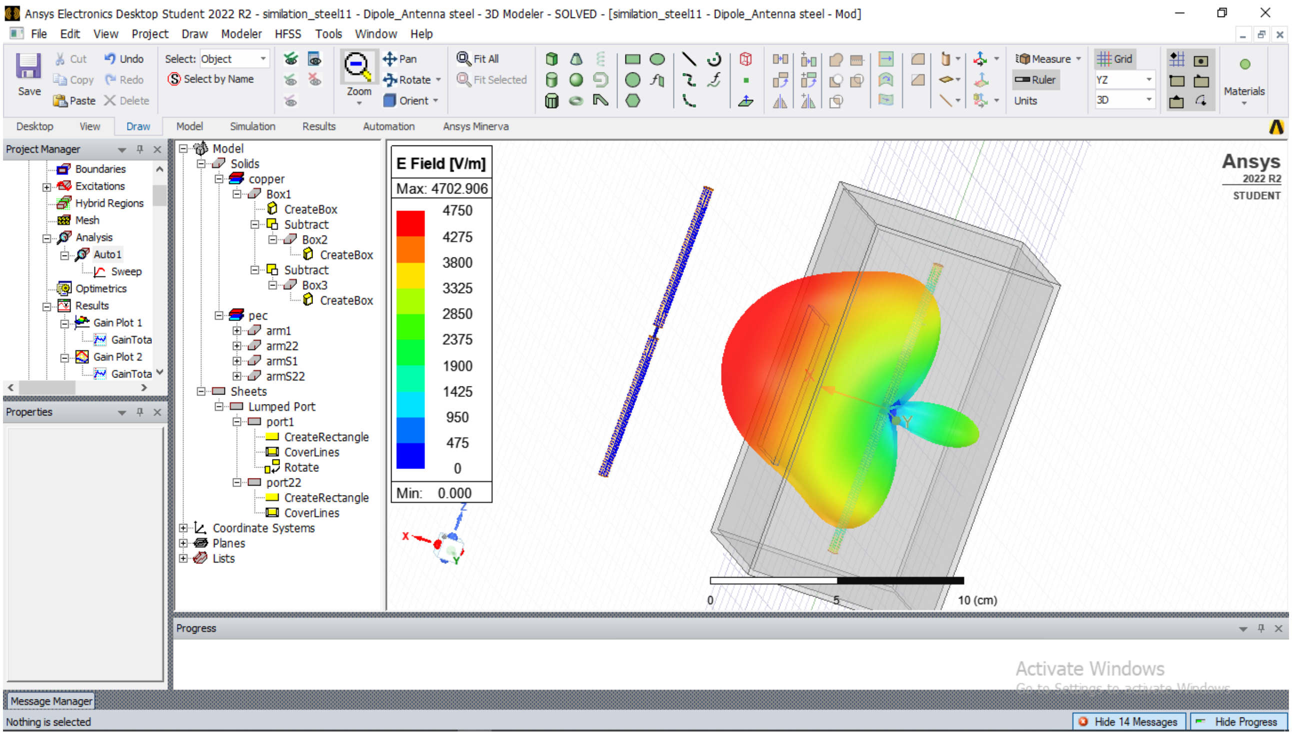


Figure. III.7.Shielding Effectiveness of Aluminum Material.

Figure III.7 presents the HFSS project used for simulating the Shielding Effectiveness of Aluminum Material. The figure shows the electromagnetic transit of the aluminum protection material. As it can be noticed, Aluminum does not provide high resistance to electromagnetic fields aluminum is a good conductor of electricity, it has a lower magnetic permeability. As a result, electromagnetic fields can pass aluminum with certain attenuation.

Matlab implementation of the shielding Effectiveness of materials

Case of Aluminium

The listing of the code used to simulate the Shielding Effectiveness is provided below. The implementation

```
clear;
clc;
sigma=3.8e7;
f=1.e8;
omega=2*pi*f;
eps0=1.e-9/36/pi;
mu0=4*pi*1.e-7;
d=1.27e-4;
SIGMSUROMEGAEPS=sigma/omega/eps0;
alpha=sqrt(pi*f*sigma*mu0);
alphadNP=alpha*d;
alphaddB=alphadNP*8.686;
[alphadNP alphaddB];
eta0=120*pi;
FREQ=linspace(1.e6,2.e10,10000);
%FREQ=2.e9;
ALPHA=sqrt(pi*FREQ*sigma*mu0);
DELTA=1./ALPHA;
ETA=ALPHA/sigma*(1+j);
R1=1/2*(1+eta0./ETA);
R2=1/2*(1+ETA/eta0);
R=R1.*R2;
R_dB=20*log10(abs(R));
A=exp(ALPHA*d);
A_dB=20*log10(A);
gamma=ALPHA*(1+j);
GAMMA=(eta0-ETA)./(eta0+ETA).*exp(-gamma*d);
M=1-GAMMA.^2;
M_dB=20*log10(abs(M));
%plot(FREQ,R_dB,'r');grid;figure(gcf);pause(10)
%plot(FREQ,A_dB,'g');grid;figure(gcf);pause(10)
%plot(FREQ,M_dB,'b');grid;figure(gcf);pause(10)
%plot(FREQ,A_dB,'g',FREQ,R_dB+A_dB+M_dB,'r');grid;figure(gcf);
SE=R_dB+A_dB+M_dB;
plot(FREQ,R_dB,'r',FREQ,A_dB,'g',FREQ,M_dB,'b',FREQ,SE,'k');grid;figure(gcf)
```

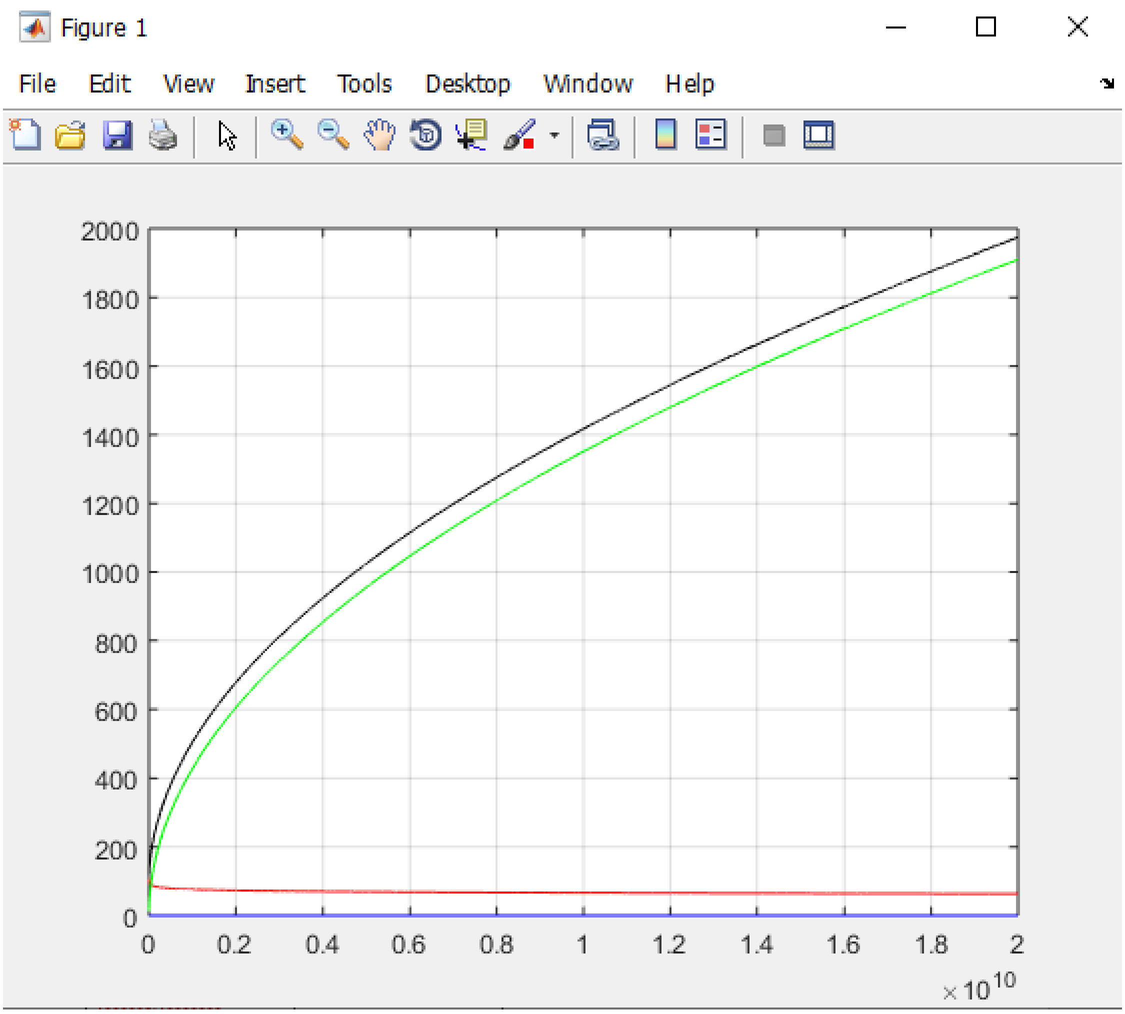


Figure. III.8. The shielding effectiveness of aluminum material versus frequency .

Figure. III.8 presents the shielding effectiveness of aluminum material verses frequency. The three traces present the Reflection coefficient, Attenuation coefficient, and power reflection coefficient together with the total attention are represented. We Note that for the aluminum case, the power reflection and the Reflection coefficient are almost negligible, the SE is dominated by the reflection term (R).

III.3.2 study steel material

Steel is an alloy of iron and carbon, and it is widely used in various industries due to its excellent mechanical properties and durability. Here are some key material properties of steel:

Strength: Steel is known for its high strength, which makes it suitable for structural applications.

Name	Value	Unit
Type	Lossy metal	-
Mue	1	-
Electrical conductivity	6.993e+006	S/m
Rho	7870	Kg/m3
Thermal conductivity	65.2	W/(mK)
Heat capacity	0.45	kJ/(kgK)
Diffusivity	1.84103e-005	m2 /s
Young's modulus	205	kN/mm2
Poisson's ratio	0.29	-
Thermal expansion	13.5	1e-6/K

Table. III. 2. The electrical and mechanical parameters of the steel material [25]

Table. III. 2. present the electrical and mechanical parameters of the steel material. Some of them are used in the Matlab code for estimating the SE and showing the results of absorbing the wave electromagnetic of the steel material. By comparing Aluminum and Steel. We notice that steel is a lossy metal with moderate electrical and thermal conductivity and energy loss. Its electrical conductivity is lower than aluminum, while its density is higher. Steel also has lower thermal conductivity, heat capacity, diffusivity, and Poisson's ratio compared to aluminum. However, it has a higher Young's modulus and lower coefficient of thermal expansion.

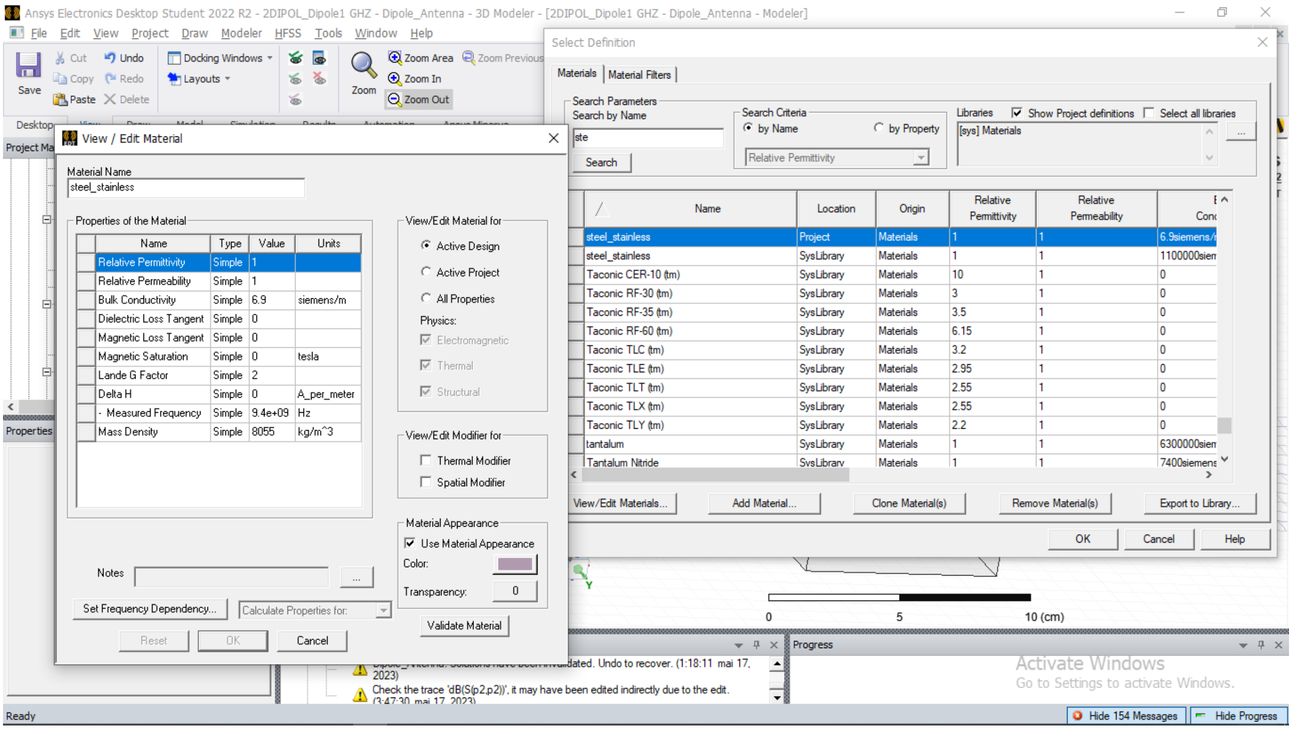


Figure. III.9 The properties of the steel material

Figure. III.9 presents the properties of the steel material. Modify the material properties: In the Material Editor, you can modify various properties of the selected material. These properties may include conductivity, permittivity, permeability, loss tangent, and other relevant parameters depending on the type of material.

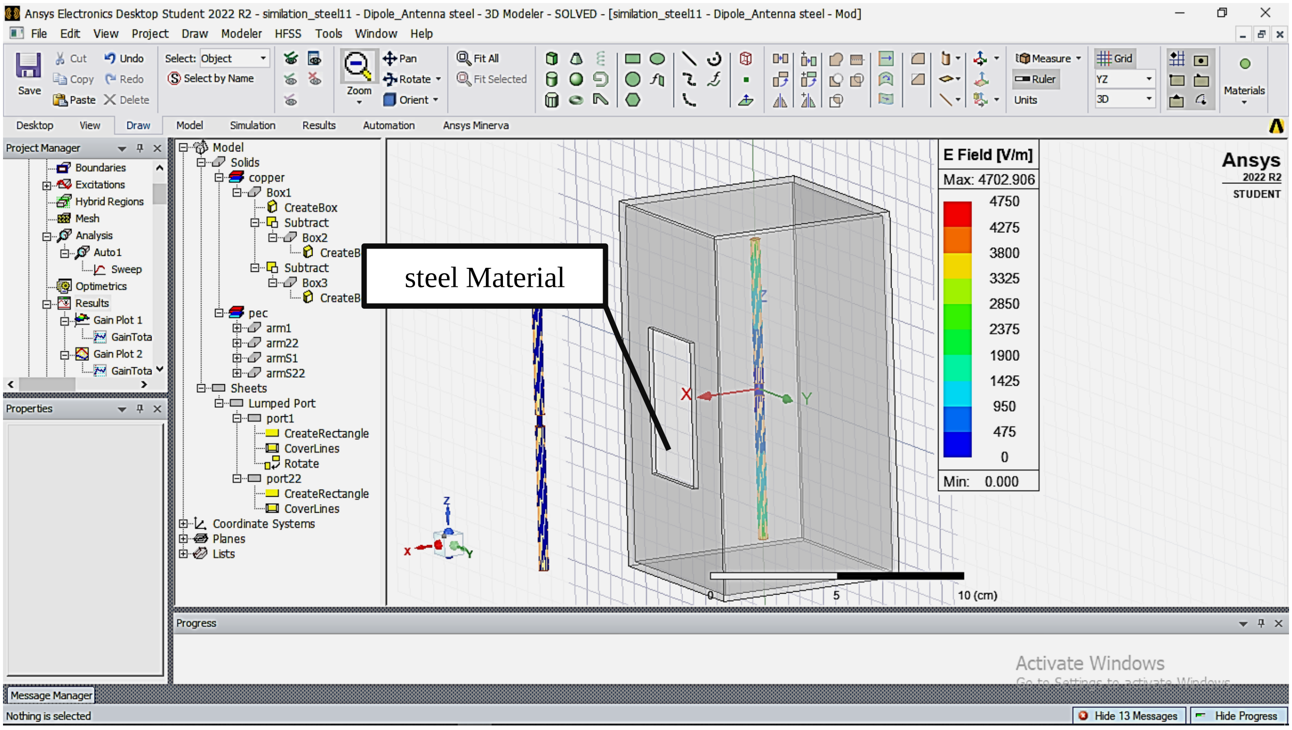


Figure. III.10 The Shielding material of steel

Figure.III.10 presents the shielding material of steel. The HFSS project used for effective protection is represented by the use of steel material. The placement of two identical dipole antennas simulates the scenario of a receiving and transmitting antenna. The first used dipole Tx generates an interference wave where the dipole Rx receives the electromagnetic wave (the victim) the Rx antenna is surrounded by a closed metal box and we put a layer of steel to study its effectiveness in stopping electromagnetic waves

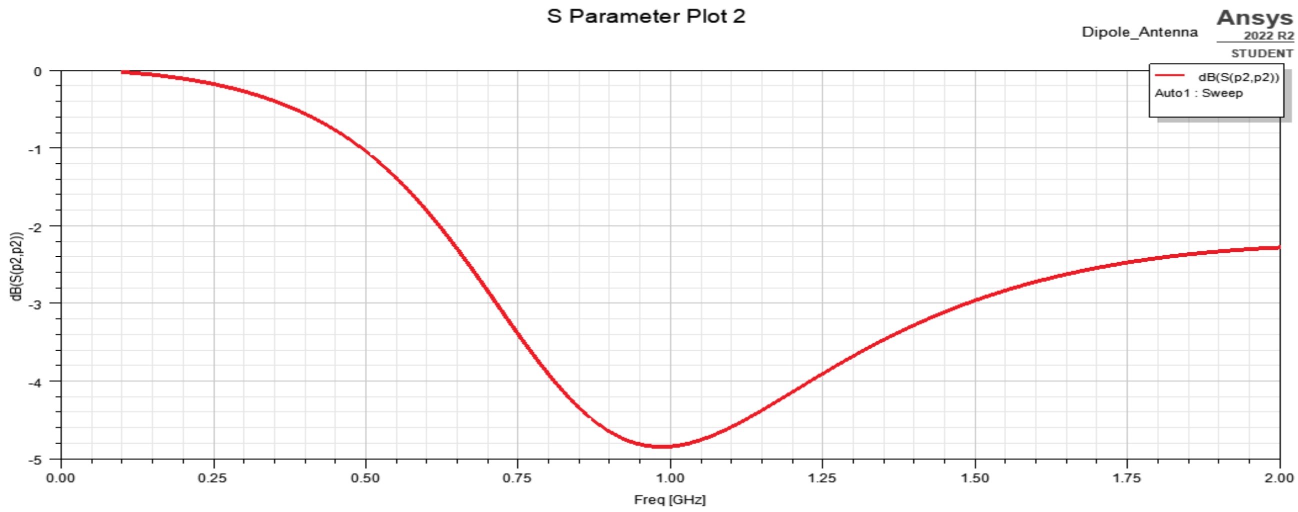


Figure. III.11. The frequency response curve of the dipole antenna.

Figure. III.11. presents The frequency response curve of the dipole antenna . We note that the antenna frequency is not transmitted in a good way, which indicates that the steel material used does not allow the passage of electromagnetic currents .We also note that there’s no resonance because the curve S stops at value -4db .

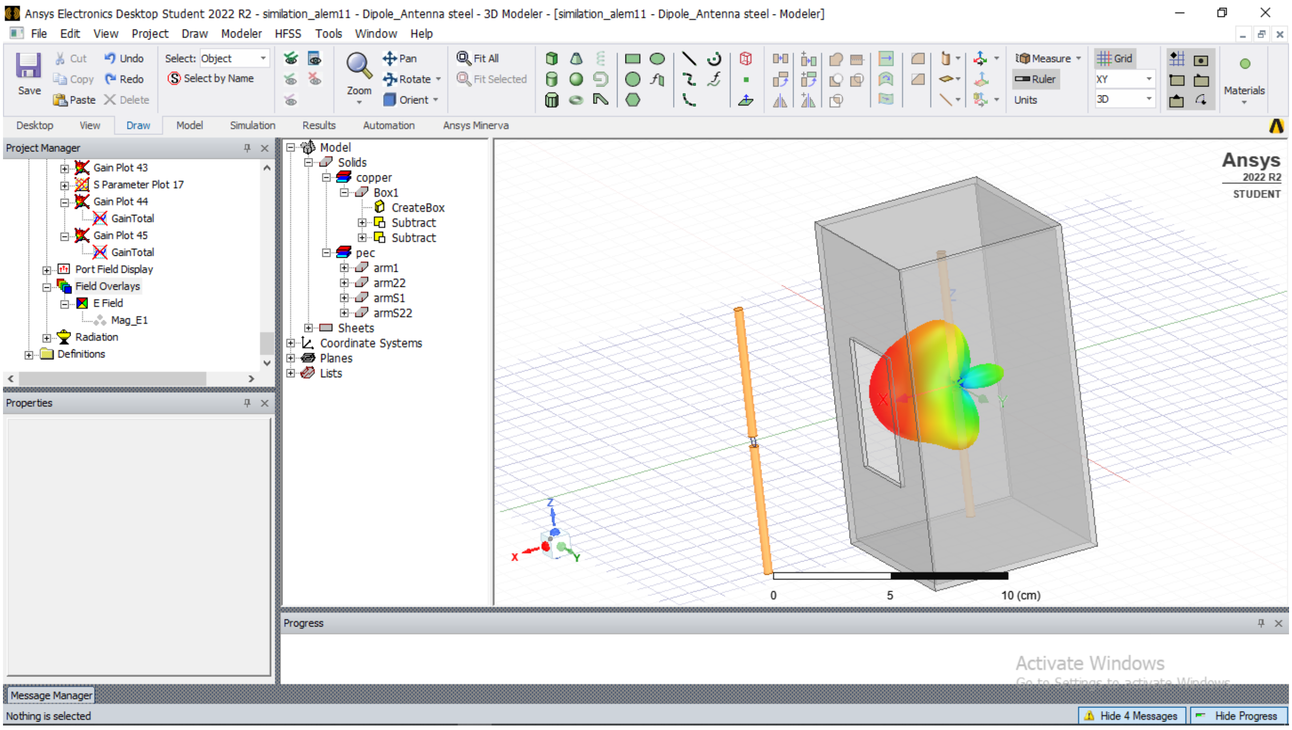


Figure. III.12. Shielding Effectiveness of Steel Material.

Figure. III.12. represents the Shielding Effectiveness of Steel Material. Steel is indeed a good protective material . Against electromagnetic fields due to its high magnetic permeability and conductivity. Compared to aluminum, steel offers higher resistance to electromagnetic penetration and provides more effective shielding.

Matlab implementation of the shielding Effectiveness of materials

Case of Steel

```
clear;
clc;
sigma = 6.99e6;  % Conductivity of steel (in Siemens per meter)
f = 1.e8;  % Frequency of the wave (in Hz)
omega = 2 * pi * f;
eps0 = 1.e-9 / (36 * pi);
mu0 = 4 * pi * 1.e-7;
d = 1.27e-4;
SIGMSUROMEGAEPS = sigma / omega / eps0;
alpha = sqrt(pi * f * sigma * mu0);
alphadNP = alpha * d;
alphaddB = alphadNP * 8.686;
[alphadNP, alphaddB];
 eta0 = 6.6e7;  % Intrinsic impedance of steel (in ohms)
FREQ = linspace(1.e6, 2.e10, 10000);
%FREQ = 2.e9;
ALPHA = sqrt(pi * FREQ * sigma * mu0);
DELTA = 1./ALPHA;
ETA = ALPHA / sigma * (1 + 1j);
R1 = 1/2 * (1 + eta0 ./ ETA);
R2 = 1/2 * (1 + ETA / eta0);
R = R1 .* R2;
R_dB = 20 * log10(abs(R));
A = exp(ALPHA * d);
A_dB = 20 * log10(A);
gamma = ALPHA * (1 + 1j);
GAMMA = (eta0 - ETA) ./ (eta0 + ETA) .* exp(-gamma * d);
M = 1 - GAMMA.^2;
M_dB = 20 * log10(abs(M));
 % Plotting
SE = R_dB + A_dB + M_dB;
plot(FREQ, R_dB, 'r', FREQ, A_dB, 'g', FREQ, M_dB, 'b', FREQ, SE, 'k');
grid;
figure(gcf);
```

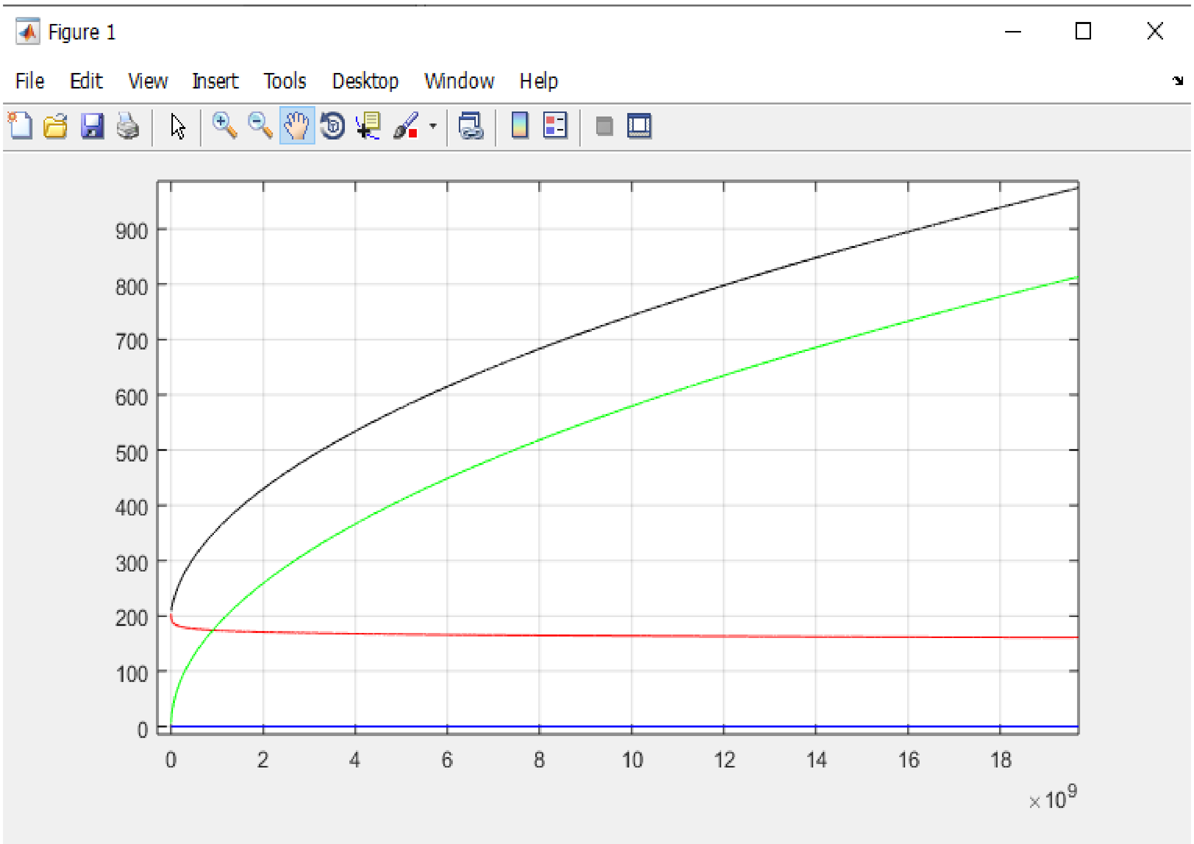


Figure. III.13. Different aspects of electromagnetic wave propagation and reflection

Figure. III.13. represents a different aspects of electromagnetic wave propagation and reflection**. The red** curve represents the reflection coefficient (R) as a function of frequency (FREQ) Reflection Coefficient (R).**The green** curve represents the attenuation coefficient (A) as a function of frequency (FREQ) Attenuation Coefficient (A),**The blue** curve represents the power reflection coefficient (M) as a function of frequency (FREQ) Power Reflection Coefficient (M),**The black** curve represents the overall system efficiency (SE) as a function of frequency (FREQ) Overall System Efficiency (SE)

III.4 Results:

The research suggests that steel is a suitable shielding material for protecting electronic and electric devices due to its high resistance to electromagnetic fields. Steel can withstand the effects of electromagnetic fields and provides effective shielding. On the other hand, aluminum does not offer the same level of resistance to electromagnetic fields as steel. As a result, electromagnetic fields can penetrate aluminum with a certain level of attenuation, meaning it may not provide as strong of a shielding effect as steel.

III.5 CONCLUSION:

The piece describes the shielding calculations, the material's effectiveness for the safety device, and why a critical factor of safety devices is reliability. Deserves special mention of Electromagnetic Immunity. This report summarizes ways to protect electronics and electrical devices. The simulation results indicate that steel is used the right way to back up your device because it can be resistant to electromagnetic fields. On the contrary, Aluminum, immune to electromagnetic fields is not as big as steel. The area comes from some cushioning. When a thread traverses the entire screen, the field can be connected with wire and passed through sealed material. So it has to use shielded wires to protect safety devices.– This report aims to extend the existing Knowledge of shielding materials for security devices..

Chapter IV:

General Conclusion

IV.1 General Conclusion:

This search focuses on identifying suitable materials for shielding security devices from electromagnetic interference (EMI). Using ANSYS, we have calculated shielding effectiveness and evaluated the attenuation of electromagnetic fields through different materials.

The demand for electromagnetic immunity in electronic devices is increasing due to electromagnetic interference, Shielding materials offer a solution for protecting devices against radiated electromagnetic emissions, Reliability in security devices necessitates effective electromagnetic shielding effectiveness is introduced as a parameter to evaluate a material's ability to eliminate electromagnetic radiation from an interference source, Three types of attenuation contribute to shielding effectiveness: reflection, absorbent attenuation, and attenuation caused by multiplied reflection, Simulation process: HFSS software is used to model shielding materials and calculate shielding effectiveness, Two selected materials, aluminum and steel, are evaluated for their shielding effectiveness, Steel is identified as a more suitable material for protecting devices compared to aluminum, This this search enhances understanding of shielding materials for security devices by, evaluating their shielding effectiveness against electromagnetic interference

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