

EMR Assignment - Emma Biggs

by Emma Biggs

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Electromagnetic Radiation (OME):
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Abstract

This paper investigates the use of High Frequency Simulation Software [HFSS] (Ansys Electronics) to model the electromagnetic propagation patterns produced by Rectangular Waveguides of differing materials including a vacuum and Teflon. The results of these simulations were compared to assess the propagation characteristics of each material. The paper also explores the use of this software to generate the radiation patterns of electromagnetic waves from a Halfwave Dipole Antenna. The parameters of both the Rectangular Waveguides and the Halfwave Dipole Antenna were derived using the student number assigned to the researcher (2308431).

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1 Introduction

To investigate the use of High-Frequency Simulation Software (HFSS) Ansys Electronics to model the propagation patterns of electromagnetic waves through Rectangular Waveguides of differing materials and the electromagnetic radiation pattern produced by a Halfwave Dipole Antenna, a conceptual understanding of Waveguides and Antennas is required. A fundamental knowledge of Electromagnetic Theory is also necessary. This introduction will cover the information relevant to this paper.

1.1 What is Electromagnetic Theory?

Electromagnetic theory establishes the interaction between electric and magnetic fields governed by Maxwell's Equations [1]. The 4 equations constituting to Maxwell's Equations define the spatial characteristics of electric and magnetic fields and their associated interrelations are as follows [2] [3] [4]:

- Gauss' Law for Static Electric Fields
 - The electric field produced by an electric charge diverges from the positive charge and subsequently converges upon a negative charge.
- Gauss' Law for Static Magnetic Fields
 - The divergence of the magnetic field at any point in time is zero, magnetic field lines form closed loops.
- Faraday's Law of Induction
 - A time dependent changing magnetic field induces a circulating electric field.
- Ampere-Maxwell's Law
 - A time varying electric field induces a circulating magnetic field.

The physical phenomena created by this interaction is referred to as an electromagnetic field, in which energy is transported by electromagnetic waves [5]. Electromagnetic waves travel at the speed of light in a vacuum and do not require a medium to propagate, meaning they are able to travel through vacuums and materials.

1.2 What is a Waveguide?

A Waveguide is a physical hollow structure used to guide an electromagnetic wave in a specific direction with minimal loss of energy [6]. They are traditionally used as transmission lines to connect microwave transmitters and receivers to their associated antennas [6].

There are different profiles of waveguides, each designed with specific applications in mind, most commonly circular or rectangular cross sections but also including elliptical and square [7]. The dimensions of the waveguide play a critical role in determining the cut-off frequency of the waveguide – the frequency below which a satisfactory propagation of electromagnetic waves cannot be achieved. The dimensions also facilitate the desired mode (distribution of electromagnetic energy within the channel) to be propagated without allowing the propagation of undesired modes [7].

1.3 What is an Antenna?

Within a wireless communication system, a method of broadcasting the desired electromagnetic waves through the air is required. An antenna is the component within the system responsible for the transmission and reception of these signals. There are various designs of antenna such as halfwave dipoles, helical, small loop and horn antennas [8], which possess varying properties including radiation pattern, directivity, input impedance and receiving cross section [1].

This paper specifically investigates the emission pattern of a Halfwave Dipole antenna – an antenna designed for widespread radiation patterns suitable for mobility applications [9]. The main characteristics of interest are the omnidirectional radiation pattern and gain (all be it limited due to the lack of directivity).

2 Method

2.1 Overview of Task 1a

Using Ansys Electronics, a HFSS environment was created to facilitate the modelling of electromagnetic propagation patterns. Within this environment, a Rectangular Waveguide with dimensions derived using the researcher's assigned student number was created using the inbuilt drawing tools. A Perfect Electric Conductor (PEC) material was assigned to the peripheral walls of the waveguide, with the contained space being filled with a vacuum.

Excitements were assigned to either end of the waveguide to replicate the generation and subsequent propagation of electromagnetic waves through the model. A frequency sweep ranging from 2GHz to 30GHz was completed to ensure behaviour regarding the propagation of electromagnetic waves was analysed across a large frequency range. From the simulation, data regarding the modes propagating through the waveguide; magnitude and vectors of both the electric and magnetic fields and cut off frequencies was collated.

2.2 Calculations Pertaining to Task 1a

2.2.1 Deriving the Dimensions of the Waveguide

The dimensions (in mm) of the waveguide were derived as follows:

- *Width = first two numbers of the researcher's assigned student number*
- *Height = $\frac{\text{Third and fourth numbers of the student number}}{2}$ (rounded to the nearest integer)*
- *Length = 50mm*

In this case the, the researcher's student number was 2308431. From this, the dimensions used to create the Rectangular Waveguide were as follows:

- *Width = 23mm*
- *Height = $\frac{08}{2} = 4mm$*
- *Length = 50mm*

2.2.2 Calculating the Cut-Off Frequency of Mode 1 Using Theoretical Formulas

$$f_c = \frac{c}{2} \sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2}$$

Equation 1 - Theoretical Formula for Cut-Off Frequency

Where f_c is the cut-off frequency (Hz), c is the speed of light passing through the material (ms^{-1}), m and n are mode numbers, a is the width of the Rectangular Waveguide (m) and b is the height of the Rectangular Waveguide (m).

In the case of Mode 1:

$$f_c = \frac{3 \times 10^8}{2} \sqrt{\left(\frac{1}{0.023}\right)^2 + \left(\frac{0}{0.004}\right)^2}$$

$$f_c = 1.5 \times 10^8 \sqrt{\left(\frac{1}{0.023}\right)^2}$$

$$f_c = 6.52 \times 10^9 \text{ Hz}$$

$$f_c = 6.52 \text{ GHz}$$

2.2.3 Calculating the Cut-Off Frequency of Mode 2 Using Theoretical Formulas

In the Case of Mode 2:

$$f_c = \frac{3 \times 10^8}{2} \sqrt{\left(\frac{2}{0.023}\right)^2 + \left(\frac{0}{0.004}\right)^2}$$

$$f_c = 1.5 \times 10^8 \sqrt{\left(\frac{2}{0.023}\right)^2}$$

$$f_c = 1.304 \times 10^{10} \text{ Hz}$$

$$f_c = 13.04 \text{ GHz}$$

2.2.4 Calculating the Cut-Off Frequency of Mode 3 Using Theoretical Formulas
In the case of Mode 3:

$$f_c = \frac{3 \times 10^8}{2} \sqrt{\left(\frac{3}{0.023}\right)^2 + \left(\frac{0}{0.004}\right)^2}$$

$$f_c = 1.5 \times 10^8 \sqrt{\left(\frac{3}{0.023}\right)^2}$$

$$f_c = 1.957 \times 10^{10} Hz$$

$$f_c = 19.57 GHz$$

2.3 Overview of Task 1b

The same dimensions of Rectangular Waveguide and parameters of simulation were used in task 1b, however, the materials assigned to the waveguide were altered. In this simulation, the space between the PEC walls of the waveguide was filled with Teflon, a material with a Relative Permeability of 1 and Relative Permittivity of 2.1.

2.4 Calculations Pertaining to Task 1b

2.4.1 Calculating the Cut-Off Frequency of Mode 1 Using Theoretical Formulas

$$c = \frac{1}{\sqrt{\epsilon\mu}}$$

Equation 2 - Theoretical Formula for the Speed of Light Through a Material

Where c is the speed of light through a material (ms^{-1}); $\epsilon = \epsilon_0\epsilon_r$ where ϵ_0 is the permittivity of free space ($8.854 \times 10^{-12} \text{ F/m}$) and ϵ_r is the relative permittivity of the material and $\mu = \mu_0\mu_r$ where μ_0 is the permeability of free space ($4\pi \times 10^{-7} \text{ H/m}$) and μ_r is the relative permeability of the material.

In the case of Teflon:

$$c = \frac{1}{\sqrt{8.854 \times 10^{-12} \times 2.1 \times 4\pi \times 10^{-7} \times 1}}$$

$$c = 2.07 \times 10^8 \text{ ms}^{-1}$$

$$f_c = \frac{2.07 \times 10^8}{2} \sqrt{\left(\frac{1}{0.023}\right)^2 + \left(\frac{0}{0.004}\right)^2}$$

$$f_c = 1.035 \times 10^8 \sqrt{\left(\frac{1}{0.023}\right)^2}$$

$$f_c = 4.5 \times 10^9 \text{ Hz}$$

$$f_c = 4.5 \text{ GHz}$$

2.4.2 Calculating the Cut-Off Frequency of Mode 2 Using Theoretical Formulas

$$f_c = \frac{2.07 \times 10^8}{2} \sqrt{\left(\frac{1}{0.023}\right)^2 + \left(\frac{0}{0.004}\right)^2}$$

$$f_c = 1.035 \times 10^8 \sqrt{\left(\frac{2}{0.023}\right)^2}$$

$$f_c = 9 \times 10^9 Hz$$

$$f_c = 9 GHz$$

2.4.3 Calculating the Cut-Off Frequency of Mode 3 Using Theoretical Formulas

$$f_c = \frac{2.07 \times 10^8}{2} \sqrt{\left(\frac{1}{0.023}\right)^2 + \left(\frac{0}{0.004}\right)^2}$$

$$f_c = 1.035 \times 10^8 \sqrt{\left(\frac{3}{0.023}\right)^2}$$

$$f_c = 1.35 \times 10^{10} Hz$$

$$f_c = 13.5 GHz$$

2.5 Overview of Task 2

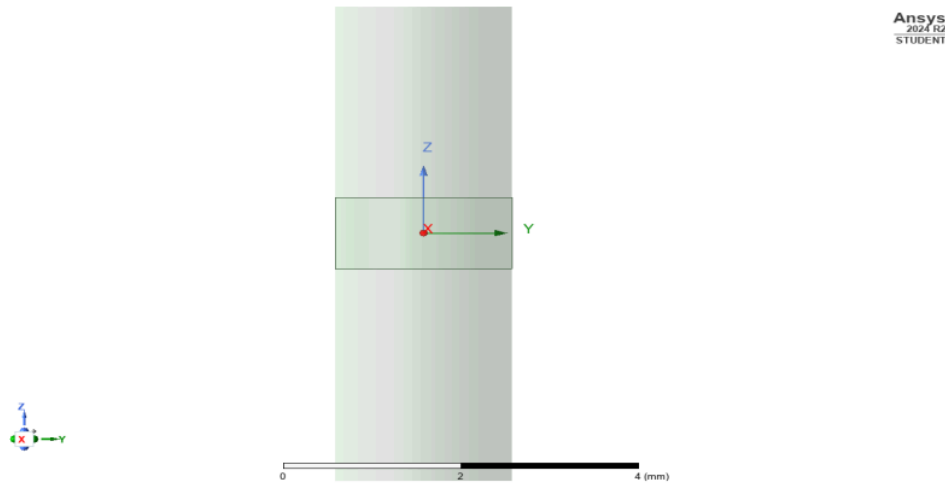


Figure 1 - An Image Showing the Gap Created to Simulate the Feed Point as well as the Rectangular Plane to which the Lump Port Excitement was Assigned.

Using the HFSS, a Halfwave Dipole Antenna with a radius of 1 mm was designed using the inbuilt drawing tools. The desired emitting frequency of operation and subsequent required length of antenna was derived using the researcher's student number. A PEC material was assigned to the main body of the antenna, with a gap being left in the centre to replicate the feed port.

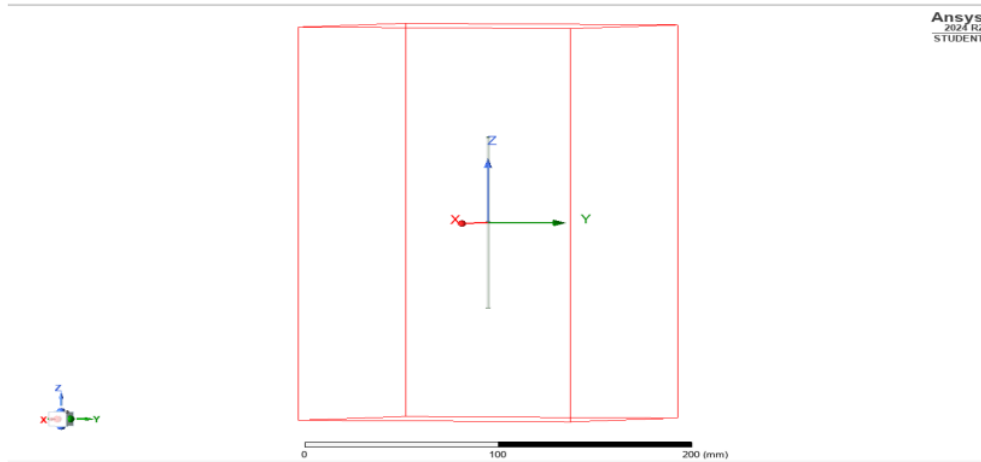


Figure 2 - An Image Showing the Full Length of the Halfwave Dipole Antenna as well as the Rectangular Radiating Surface Surrounding it.

Within the feed port, a rectangular plane was created, to which a lumped port excitation with a Port Impedance of 50 Ohms was assigned to replicate the centre conductor within the antenna. A rectangular radiating surface was then constructed around the modelled antenna in order to create an area in which to capture the electromagnetic transmission pattern during the frequency sweep of the simulation.

2.6 Calculations Pertaining to Task 2

2.6.1 Deriving the Dimensions of the Halfwave Dipole Antenna Using Theoretical Formulas

$$L = \frac{\lambda}{2}$$

Equation 3 - Theoretical Formula for the Length of a Halfwave Dipole Antenna

Where L is the length (mm) of the antenna and λ is the wavelength (mm) of the electromagnetic waves the antenna was designed to emit. In the case of this simulation λ was given as the first three digits of the researcher's student number.

$$L = \frac{230}{2}$$

$$L = 115 \text{ mm}$$

2.6.2 Calculating the Operating Frequency of the Halfwave Dipole Antenna Using Theoretical Formulas

$$f = \frac{c}{\lambda}$$

Equation 4 - Theoretical Formula for Operating Frequency

Where f is the operating frequency (Hz), c is the speed of light passing through the material (ms^{-1}), and λ is the wavelength (mm) of the electromagnetic waves the antenna was designed to emit.

$$f = \frac{3 \times 10^8}{0.23}$$

$$f = 1304348000 \text{ Hz}$$

$$f = 1.3 \text{ GHz}$$

3 Results and Discussion

3.1 Results and Discussion of Task 1a

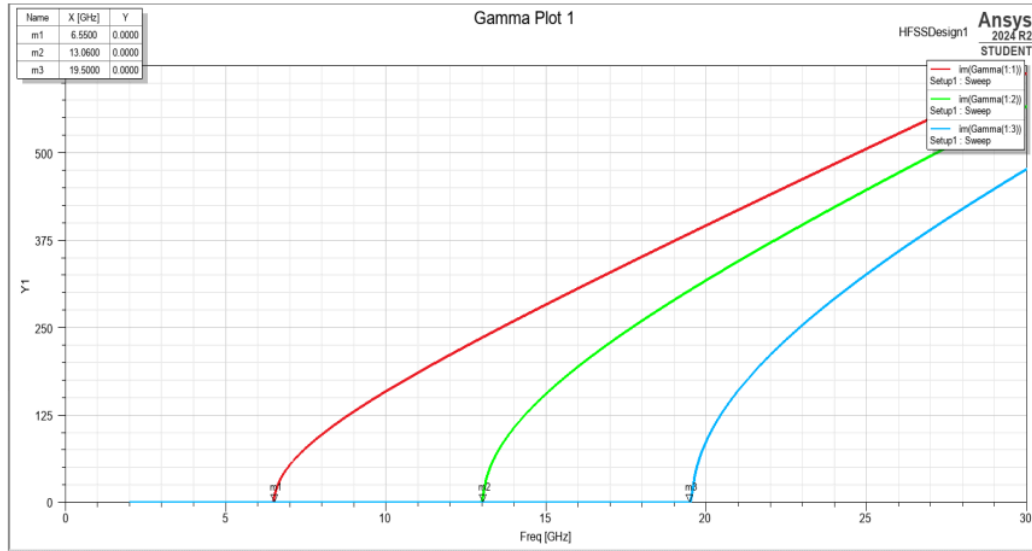


Figure 3 - A Graph Showing the Cut-off Frequencies of the Rectangular Vacuum Waveguide Obtained During the Frequency Sweep Simulation.

In order to obtain simulated data pertaining to the cut-off frequency of each mode within the Vacuum Rectangular Waveguide, a Gamma Plot was generated within the results tab of Ansys Electronics. A Gamma Plot is a visual representation of the system's frequency response, demonstrating how phase constant and attenuation constant change as frequency nears the cut-off point [10]. This plot is shown in Figure 3 with mode 1 being represented in red, mode 2 in green and mode 3 in blue.

The simulated cut-off frequency of each mode was measured by inserting markers at the point where the graph intersected with the x axis. From doing this, it can be seen in Figure 3 that the cut-off frequency for modes 1, 2 and 3 respectively are 6.55GHz, 13.06GHz and 19.50GHz. The calculations completed in Section 2.2 determined that the theoretical cut-off frequency for modes 1, 2 and 3 respectively are 6.52GHz, 13.04GHz and 19.57GHz.

Differences in cut-off frequencies obtained using theoretical formulas and the simulation were due to variations in complexity of mathematical formular used by the simulation software compared to the researcher [11].

As Mode 1 has the lowest cutoff frequency, it can be determined that this is the dominant mode of the waveguide.

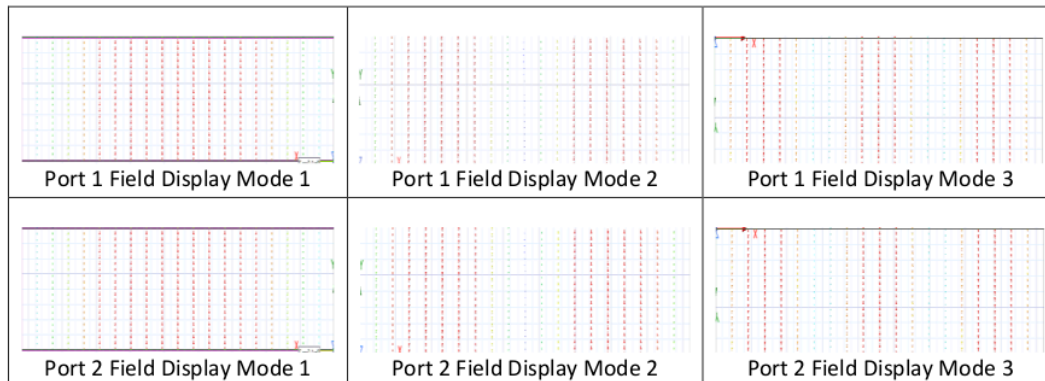


Table 1 - A Table Comparing the Different Field Displays of Each Port and Subsequent Mode Obtained from the Frequency Sweep Simulation.

To gather data relating to the modes of each port, Port Field Displays were generated within the results tab of Ansys Electronics. It can be observed in Table 1 that identical field displays were produced for the corresponding modes at each port. The identical nature of the displays was used to form the basis of the assumption that the subsequent electric and magnetic field overlays created for each mode would be similar at both ports.

Using the Port Field Displays shown in Table 1, the classification and number of each mode was determined, with Mode 1 being Transverse Electric (TE_{10}), Mode 2 being TE_{20} and Mode 3 being TE_{30} . The mode classification represents the way in which the electromagnetic field can oscillate within the bounded region of the waveguide [12]. In the case of this simulation, the electric field oscillates in a direction transverse to the direction of propagation of the signal in all modes. The mode number describes the resonant pattern of an electromagnetic field, indicating the number of half wavelengths that fit within the boundary conditions of the waveguide [12]. The mode numbers collected from this simulation show that Mode 1 has 1 half wavelength in the x direction and none in the y; Mode 2 has 2 half wavelengths in the x direction and none in the y and Mode 3 has 3 half wavelengths in the x direction and none in the y.

As previously determined using Figure 3, the dominant mode of the waveguide is TE_{10} .

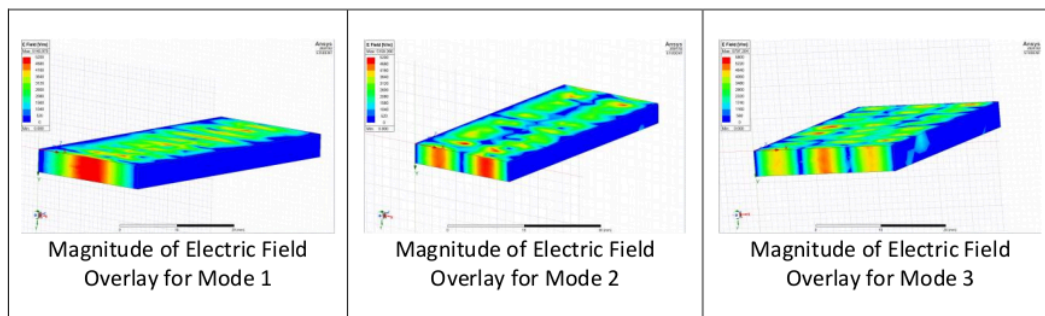


Table 2 - A Table Comparing the Magnitude of Electric Field Overlays for Each Mode Obtained from the Frequency Sweep Simulation.

From Table 2, a comparison of the propagation patterns created by the magnitude of the electric fields within each mode can be observed. All three modes successfully propagated the electric field through the length of the waveguide meaning it functions as intended despite the non-typical

dimensions used. The clearest, most consistent propagation pattern can be seen in Mode 1 with clarity decreasing as mode number increases.

The decrease in clarity observed with increasing mode number is due to a combination of increased modal dispersion (different modes traveling different paths at different speeds through the waveguide, with higher modes taking longer paths than the dominant mode, causing the signal to spread out during propagation) and attenuation (the loss of signal to the boundary of the waveguide reducing the signal strength) [13].

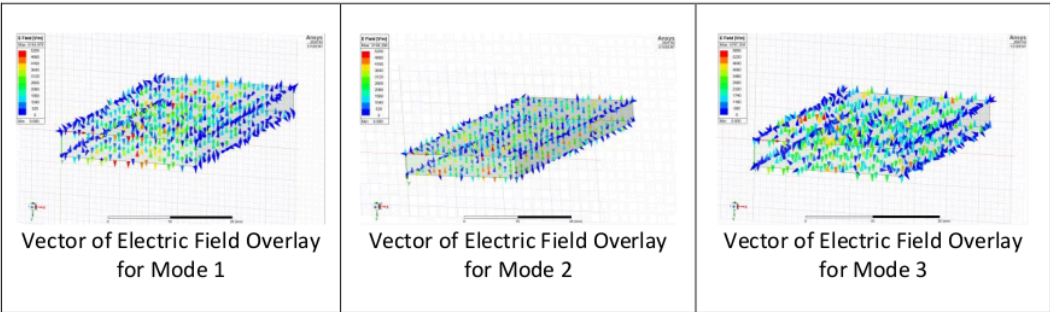


Table 3 - A Table Comparing the Vector of Electric Field Overlays between Each Mode Obtained from the Frequency Sweep Simulation.

Looking at the direction of the arrows displayed on the vector of electric field overlays shown in Table 3 demonstrates that the direction of radiation of the electric field is transverse to that of the direction of propagation. The majority of arrows point in either the positive or negative y direction due to boundary conditions imposed by the PEC walls resulting in all electric field lines being perpendicular to the wall denoting the width of the waveguide [14]. This is to be expected across all modes given their previous transverse electric classification.

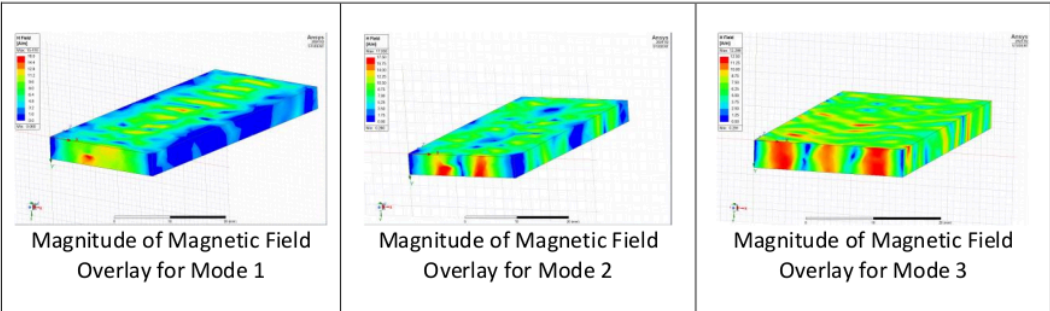


Table 4 - A Table Comparing the Magnitude of Magnetic Field Overlays for Each Mode Obtained from the Frequency Sweep Simulation.

The magnitude of magnetic field overlays shown in Table 4 demonstrate that the wave guide was less efficient at propagating magnetic fields than electric fields. This is highlighted by the increase in signal attenuation visible along the boundaries of the waveguide when compared to the magnitude of electric field overlays shown in Table 2. This is due to the magnetic field propagating parallel to the wall representing the width of the waveguide, creating currents on the inner surface of the PEC walls [15]. This can lead to loss of signal due to the resistance of the material that the waveguide is made from that are not seen in the electric field due to the differing interactions with the walls [15].

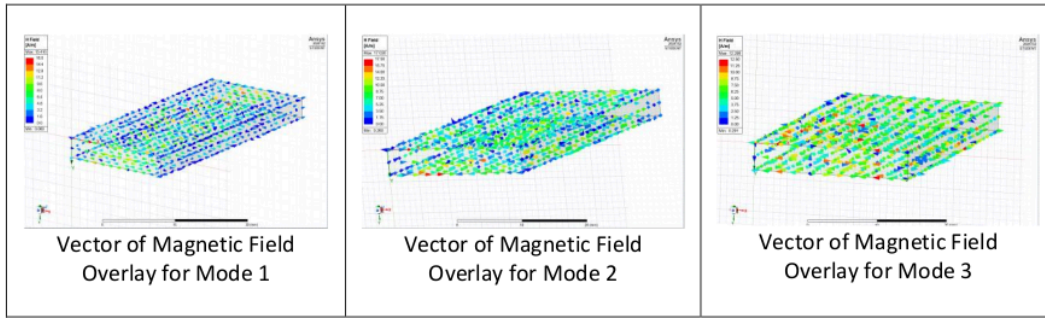


Table 5 - A Table Comparing the Vector of Magnetic Field Overlays between Each Mode Obtained from the Frequency Sweep Simulation.

From Table 5, the longitudinal component of the magnetic field can be observed by the fact that most arrows are in the direction parallel to the wall representing the width of the waveguide. This is again expected due to the TE classification of all modes.

3.2 Results and Discussion of Task 1b

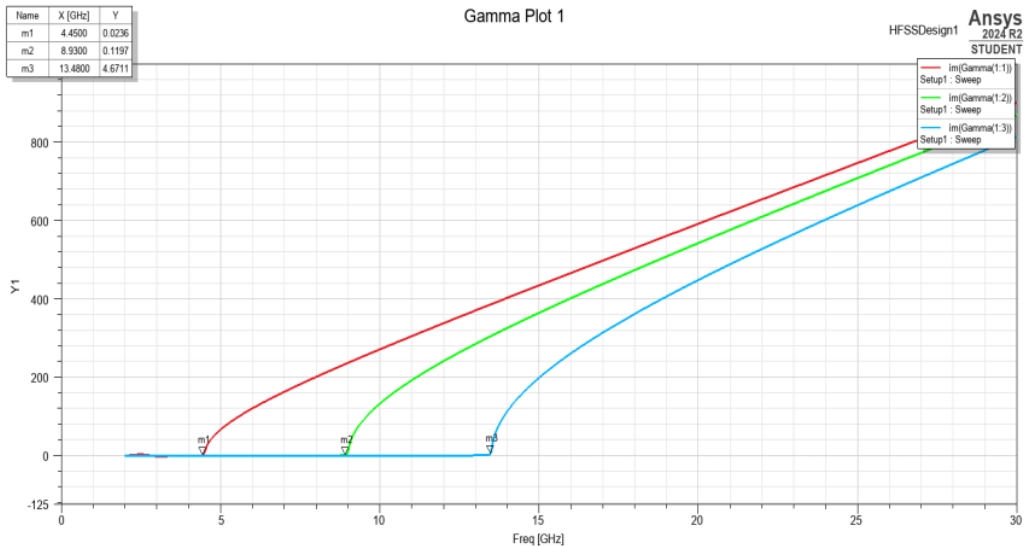


Figure 4 - A Graph Showing the Cut-off Frequencies of the Rectangular Teflon Waveguide Obtained During the Frequency Sweep Simulation.

From the graph shown in Figure 4, the cutoff frequency of modes 1, 2 and 3 respectively were determined as 4.45GHz, 8.93GHz and 13.48GHz. The theoretical formulas used in Section 2.4 determined the cutoff frequency for each respective mode to be 4.5GHz, 9GHz and 13.5GHz. The frequencies obtained in the Teflon simulation were further from the theoretically calculated values when compared to the Vacuum simulation due to the inability to accurately place the marker on the intercept with the x axis.

The cutoff frequencies of the Teflon waveguide are lower than the Vacuum waveguide due to Teflon's higher permittivity, reducing the speed of propagation and subsequently the frequency [15].

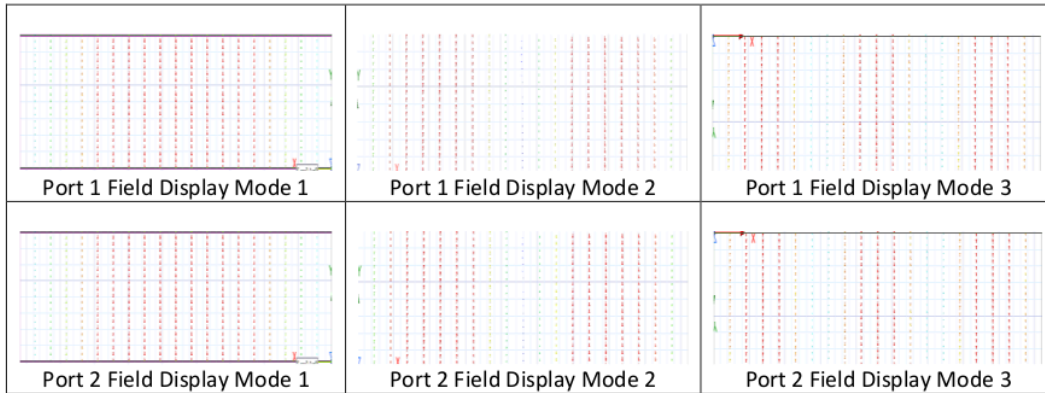


Table 6 - A Table Comparing the Different Field Displays of Each Port and Subsequent Mode Obtained from the Frequency Sweep Simulation.

The modes shown in Table 6 are identical to those generated by the rectangular vacuum waveguide with the dominant mode (mode 1) being TE_{10} , mode 2 being TE_{20} and mode 3 being TE_{30} . This is because despite Teflon having a higher relative permittivity than a vacuum, the difference is not significant enough to cause a substantial change to the waveguide's supported modes [15]. When combined with the identical geometries used by both the vacuum and Teflon waveguides, this results in the same modes being supported.

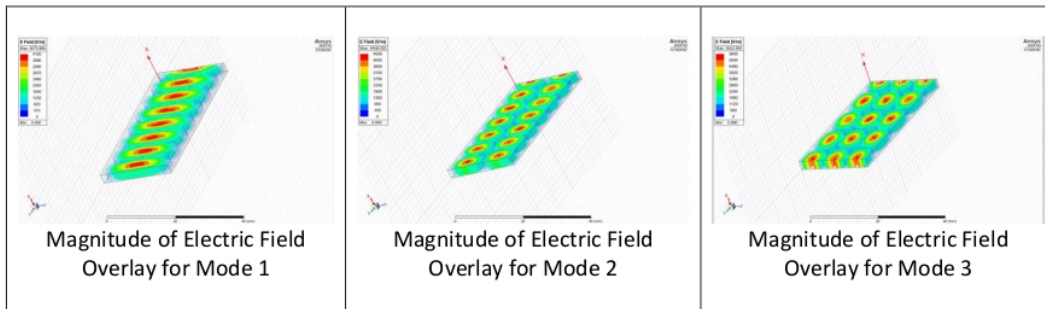


Table 7 - A Table Comparing the Magnitude of Electric Field Overlays for Each Mode Obtained from the Frequency Sweep Simulation.

Due to Teflon being a dielectric medium with a relative permittivity (dielectric constant) greater than air, the material causes greater interference with the propagation of electromagnetic waves [16]. This results in a weaker propagation of signal through the waveguide, causing the lower values of electric field strength when compared to a vacuum, shown in Table 7.

Having a greater relative permittivity also results in the increased attenuation of signal observed on the boundaries of the waveguide, further reducing the strength of the signal transmitted and resulting in possible signal distortion. A signal of the same frequency will propagate with lower velocity through the Teflon waveguide than the vacuum waveguide for the same reason.

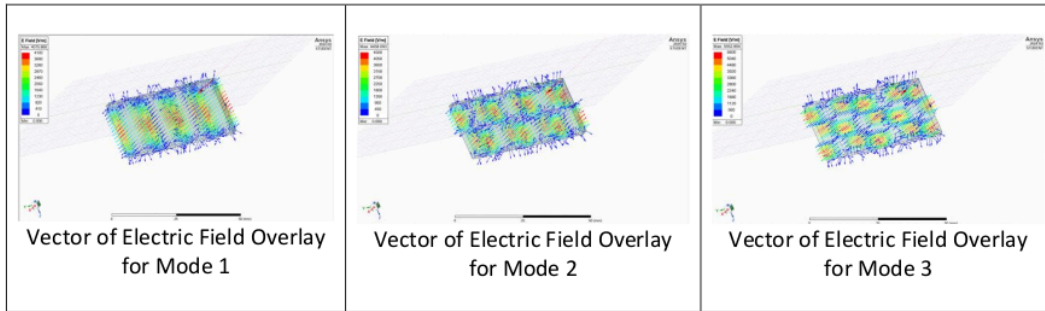


Table 8 - A Table Comparing the Vector of Electric Field Overlays between Each Mode Obtained from the Frequency Sweep Simulation.

As seen in the vacuum waveguide, Table 8 demonstrates the transverse direction of the electric field when compared to the direction of signal propagation. This pattern was again expected due to the transverse electric classification of all modes within the waveguide.

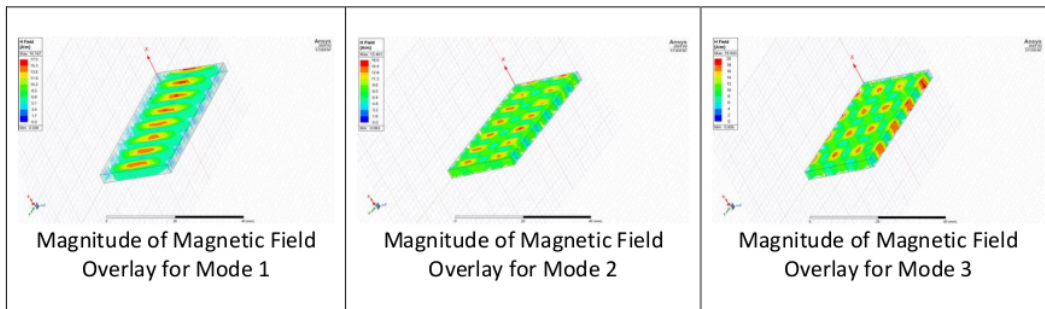


Table 9 - A Table Comparing the Magnitude of Magnetic Field Overlays for Each Mode Obtained from the Frequency Sweep Simulation.

Like the vacuum waveguide, the propagation of magnetic fields within the Teflon waveguide (shown in Table 9) is less efficient than electric fields. This is due to the same reasoning as stated for the vacuum waveguide.

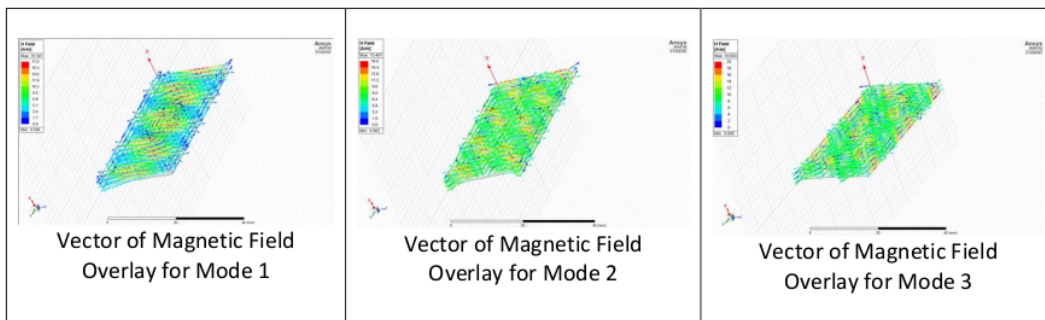


Table 10 - A Table Comparing the Vector of Magnetic Field Overlays between Each Mode Obtained from the Frequency Sweep Simulation.

Table 10 shows the longitudinal component of the magnetic field, travelling parallel to the walls of the waveguide rather than transverse to the direction of propagation. This is the expected direction of travel for the magnetic field given the TE classification of all modes.

3.3 Results and Discussion of Task 2

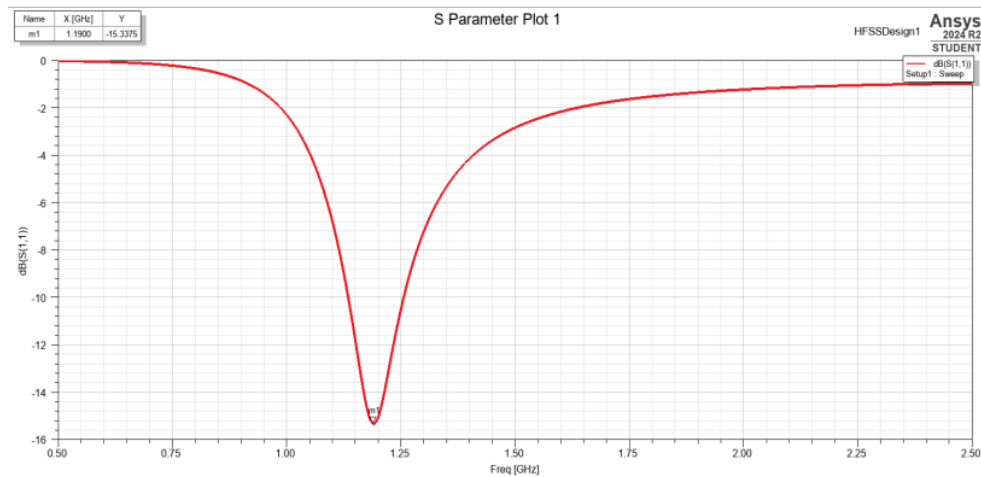


Figure 5 - A Graph Showing the Operating Frequency of the Halfwave Dipole Antenna Obtained from the Simulation.

In order to represent the electromagnetic network characteristics of the antenna, an S Parameter Plot was created in the results tab of Ansys. This describes the proportion of signal that is reflected or transmitted by ports in a network [17]. The S parameter shown in Figure 5 is S_{11} meaning that the signal is both transmitted and received at port 1. It represents the reflection coefficient – a ratio of the transmitted power compared to the power reflected through the system [18].

From looking at Figure 5, the frequency at which the most efficient transmission will occur is 1.19 GHz. This is the frequency at which the antenna will transmit the most signal and have the least number of reflections. This differs from the calculated theoretical operating frequency of 1.3GHz due to lack of impedance matching within the system. This is because a port impedance of 50 ohms was applied rather than the 73 ohms normally required for a halfwave dipole antenna, resulting in increased signal reflections and inefficient power transfer [18].

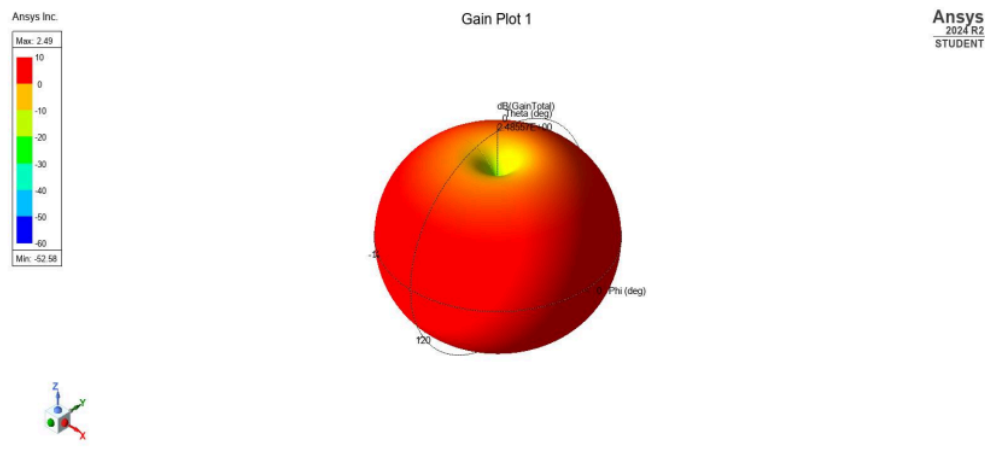


Figure 6 - A Graph Showing the Emissions Pattern of the Electromagnetic Waves Generated by the Antenna During the Simulation.

Figure 6 shows the emission pattern created by the halfwave dipole antenna. This pattern is omnidirectional, demonstrating that the antenna designed using the researcher's student number functions as intended.

The graph also shows that the maximum output of the antenna was 2.49dB which could have been increased if the port impedance applied to the simulation was matched to that of the antenna.

4 Conclusion

When simulating propagation and emission patterns of waveguides and antennas, the cutoff and operating frequencies produced in Ansys Electronics High Frequency Simulation Software were a minimum of 99.64% accurate in comparison to values calculated using theoretical formulas. This demonstrates that Ansys Electronics is a reliable programme for obtaining theoretically accurate cutoff frequencies of waveguides and operating frequencies of antennas.

Errors observed between theoretical calculations, simulated results and real-world behaviours in propagation and emission patterns are due to non-ideal component behaviours not accounted for in both theoretical and simulated environments.

The propagation of electromagnetic waves through a vacuum rectangular waveguide was more efficient than through a Teflon rectangular waveguide of the same geometry. This is due to Teflon's higher relative permittivity causing an increase in material interference leading to lower propagation velocities of signals at the same frequency, reduced electric and magnetic field strengths throughout the material as well as increased signal attenuation at the boundaries of the waveguide. Overall, this results in a signal with higher distortion and lower clarity being propagated through Teflon than a vacuum.

All modes of the vacuum and Teflon waveguide were classified as Transverse Electric which was expected due to the rectangular dimensions of the waveguide as well as the similarities between properties of a vacuum and Teflon.

The HFSS simulation software produced an omnidirectional emission pattern typical of a halfwave dipole, as expected given the design parameters. Power emitted would have increased if the port impedance was matched to that of the antenna. Impedance matching would also have increased the accuracy of the simulated operating frequency in comparison to theoretical calculations.

5 References

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EMR Assignment - Emma Biggs

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

74/100

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Comment 1

It is better to have it in a fresh page

PAGE 3

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Comment 2

Introduction should include several key elements to ensure that the reader understands the purpose, scope, and structure of the report

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GRADING FORM: EMR-MAY 2025 OME

EMMA BIGGS

73.90

ENGAGEMENT WITH LITERATURE

Marks will be awarded based on the extent of research and/or own reading, selection of credible sources, application of appropriate referencing conventions. You MUST include evidence of sources that you have discovered yourself during the course of your own student centred work.



Demonstrates engagement with an extensive range of relevant and credible literature, with

consistently accurate application of referencing. Broad range of credible sources, including textbooks, academic journals, and manufacturer datasheets. In-text referencing is consistently applied and relevant to the context. However, the inclusion of more peer-reviewed journal sources would have strengthened the work.

7.3

KNOWLEDGE AND UNDERSTANDING

Marks will be awarded for the accuracy of your description of the concepts and principles of EMW and how this relates to the design used.



Demonstrates excellent, detailed knowledge and highly critical understanding of well-established antenna and waveguide principles. Shows deep understanding of electromagnetic theory, including Maxwell's equations and TE modes. Clearly explains how waveguide dimensions influence cutoff frequencies and mode propagation. This could be further improved by expanding on the real-world implications and including a brief discussion on why higher-order modes are generally undesirable in communication systems.

19.5

COGNITIVE AND INTELLECTUAL

Marks will be awarded for the quality and validity of your interpretation of the experimental results gathered. You should consider the differences between the simulated and theoretical and explain possible causes for them.



Excellent critical evaluation of antenna and waveguide principles. The comparison between calculated and simulated results is systematic and mathematically supported, with a good explanation of observed differences. A more detailed discussion on mode cutoffs and evanescent modes would enhance the analysis.

17.5

PRACTICAL SKILLS

Marks will be awarded for the use of the available tools, models and techniques to explain your results and their relationship to the theory of the concepts.



Demonstrates advanced application of a range of established methods, materials, tools, and techniques. Shows excellent use of HFSS to simulate both waveguide and antenna behaviour. Effectively applies gamma plots, vector/magnitude overlays, and port field displays. Consistently applies theory to practice in an accurate and logical manner, with well-developed links between the two.

15.6

TRANSFERABLE SKILLS FOR LIFE

This section will be assessed based on the employability skills gained, written and presentational quality of the report. Style, structure, grammar, spelling etc..



Communicates professionally and consistently using a medium appropriate for the intended audience. The work is coherent, highly fluent, and presented proficiently. The report has a clear

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structure with effective use of figures, tables, and headings. Report is well structured with logical flow. Clear and professional tone throughout. Writing is technically good, and explanations are mostly professional and focused. Alignment should be improved, and a thorough proofread is recommended to address minor grammatical and formality issues.