

Robert Webb 2308625 EMR Assignment

by Bobby Webb

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Electromagnetic Radiation

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Abstract

This report presents a comprehensive simulation study of two types of rectangular waveguides and a half-wave dipole antenna, conducted using ANSYS HFSS and CST Studio Suite. The waveguides were designed based on specific dimensional parameters derived from the author's student number, with one modelled using vacuum as the dielectric material and the other using Teflon. Electromagnetic performance, including field distributions and cut-off frequencies for TE modes, was analysed and compared against theoretical predictions. Simulation results demonstrated good agreement, with TE₁₀ mode confirmed as the dominant propagation mode and minimal variation between simulated and theoretical cut-off frequencies.

Additionally, a half-wave dipole antenna was designed to resonate at approximately 1.306 GHz. The antenna exhibited an impedance close to 73 ohms, a broadside radiation pattern, and a return loss below -20 dB at resonance, validating its suitability for practical communication applications. Overall, the simulations effectively confirmed theoretical expectations and highlighted the influence of material properties on waveguide behaviour, as well as the importance of precise dimensional design in antenna performance.

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Waveguides and Halfwave Dipole Antenna Simulations

1.1. Introduction

Within this report, the author was tasked to create, simulate and validate data on two types of waveguides and a half-wave dipole Antenna. These simulations were done in Ansys and CST, dedicated simulation software for testing antennas and waveguides, to name but a few. The author had to design the waveguide around their student number to decide the width of the waveguide. This was then done again for the second waveguide, with the only difference being the material change from Vacuum to Teflon.

1.1.1. Waveguide Theory:

Waveguides are used to channel EM (Electromagnetic) signals within a structure, they are used to prevent losses and spreading of waves during transmission from one end to the other. For a rectangular waveguide, as used in this report, they are a hollow metallic conducting tube with a rectangular cross section, they are usually constructed with a length $a > b$, where b is the breadth of the waveguide. Waves are transmitted longitudinally through the waveguide, the waves are then reflected off the conducting walls, and depending on the total reflection inside, which would result in either the magnetic field or the electric field in the direction of wave propagation [1].

1.1.2. Half wave Dipole Theory:

This design makes the half-wave dipole most efficient at its resonant frequency, where the total length of the antenna is equal to half the wavelength of the signal. [2]

When driven with an alternating current (AC) at the resonant frequency, the antenna produces oscillating electric and magnetic fields along its length. These oscillations radiate outward into an area as electromagnetic waves. The resulting radiation pattern is toroidal or doughnut also known as omnidirectional, with the strongest signal emitted perpendicular to the axis of the antenna and minimal radiation along the antenna's ends. At resonance, a centre-fed half-wave dipole typically presents an input impedance of approximately 73 ohms (Ω) [3]. This value allows for relatively straightforward matching with common transmission lines, such as coaxial cables, minimising signal reflection and power loss.

1.2. Methodology

In tasks 1 and 2, the author had to design and create a Waveguide from 2 different materials; these materials were a vacuum and Teflon, they were both designed and developed using Ansys software.

1.2.1. Waveguides Methodology

The rectangular waveguide was modelled and simulated using ANSYS software to simulate its electromagnetic performance. The waveguide was designed using the author's student number with a width (a) of 23 mm, a height (b) of 4 mm, and a total length (L) of 50 mm. The interior region was assigned as air, and the walls were treated as perfect electric conductors (PEC) to represent an

idealised metallic structure. This was repeated for the other waveguide, but the only difference is the material of Teflon.

Wave ports were applied to both ends of the waveguide to excite and receive the dominant TE₁₀ mode. Each port was defined to match the cross-sectional dimensions of the waveguide, with appropriate integration lines placed to ensure accurate mode excitation. A frequency sweep around the expected operational band was implemented to observe the behaviour of the waveguide across the spectrum.

Simulation outputs included S-parameters, specifically S₁₁ and S₂₁, to characterise the reflection and transmission properties. Additionally, electric field distribution plots were analysed to verify proper excitation of the TE₁₀ mode. The observed cut-off frequency and field patterns were compared against theoretical numbers to validate the accuracy of the simulation model.

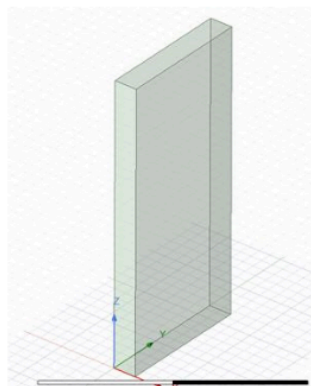


Figure 1: PEC Waveguide

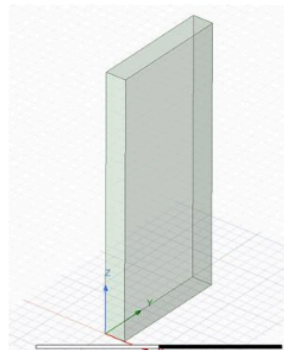


Figure 2: Teflon Waveguide

1.2.2. Half-Wave Dipole Antenna Methodology:

When constructing the waveguide, the author had to use their student number to aid the sizing/measurements, with the Length being 230mm, due to the author's student number, the length would be 115mm on each side with an excitation in the middle (1mm gap) this can be known as a 50 Ω lumped port which is used to allow the dipole to radiate as current and voltage is distributed up and down the antenna also known as a feeding gap. The length of the conductive elements is half of the maximum possible wavelength, $\lambda/2$ [4]. The dipole was placed in a rectangular radiating surface environment.

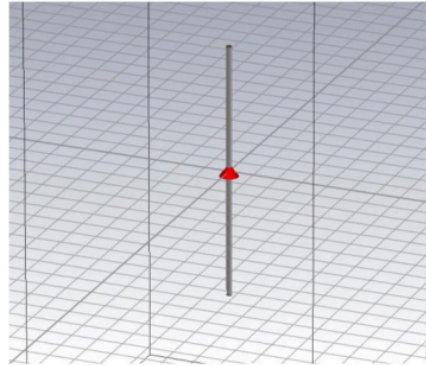


Figure 3: Halfwave Dipole Antenna

1.3. Results

This section shows all of the results for the waveguides and the Dipole Antenna

1.3.1 PEC Waveguide Port Field Displays

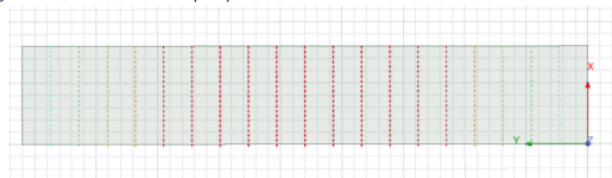


Figure 4: Port Field Display 1 Mode 1 – Vacuum

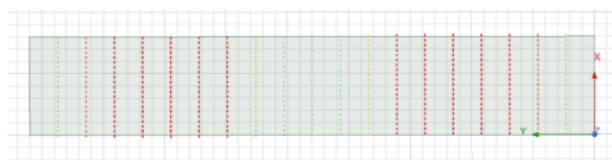


Figure 5: Port Field Display 1 Mode 2 - Vacuum

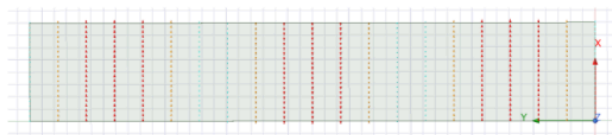


Figure 6: Port Field Display 1 Mode 3 - Vacuum

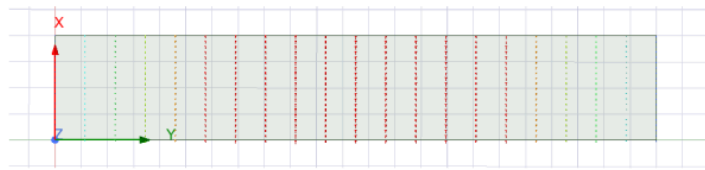


Figure 7: Port Field Display 2 Mode 1 - Vacuum

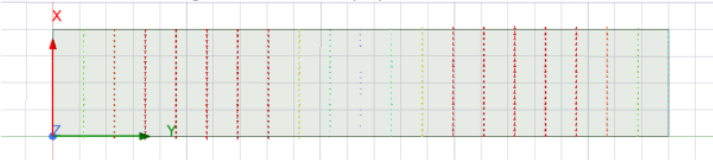


Figure 8: Port Field Display 2 Mode 2 - Vacuum

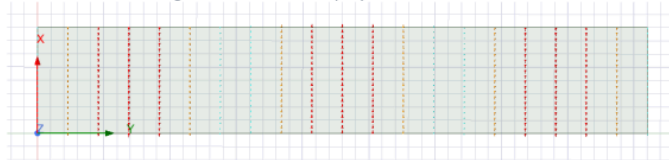


Figure 9: Port Field Display 2 Mode 3 - Vacuum

1.3.2. PEC Waveguide E & H Magnitude and Vector Plots

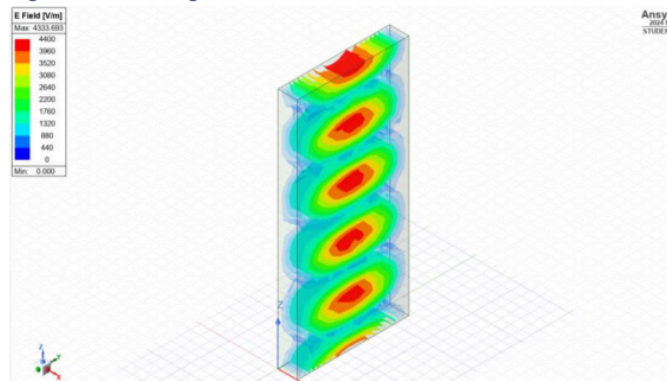


Figure 10: Mode 1 E Field Magnitude Plot

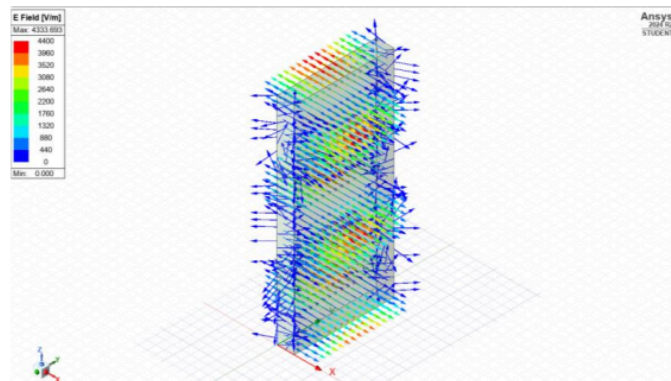


Figure 11: Mode 1 E Field Vector Plot

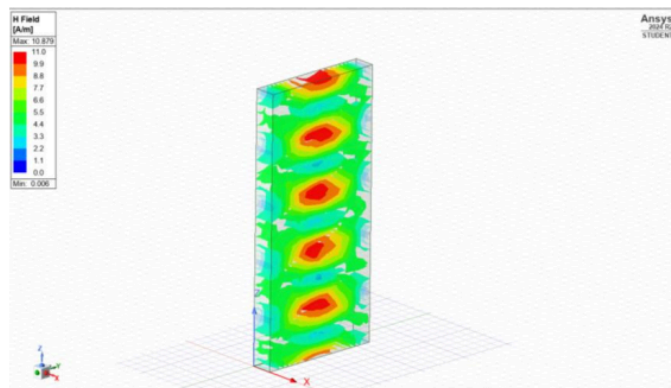


Figure 12: Mode 1 H Field Magnitude Plot

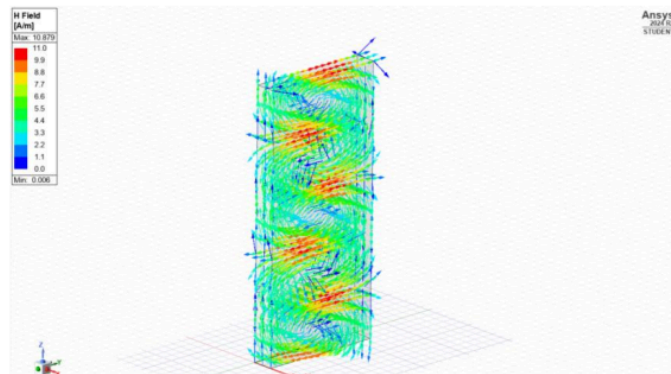


Figure 13: Mode 1 H Field Vector Plot

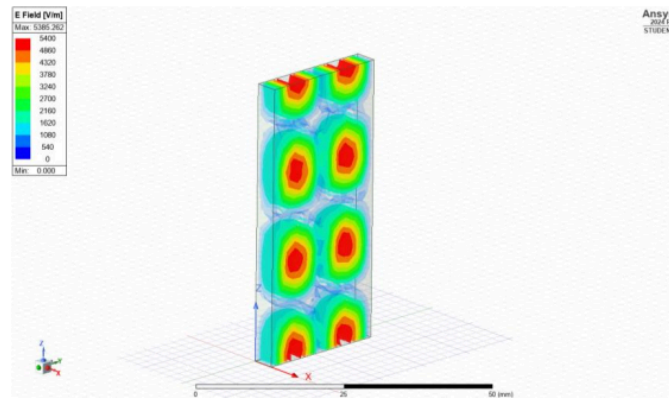


Figure 14: Mode 2 E Field Magnitude Plot

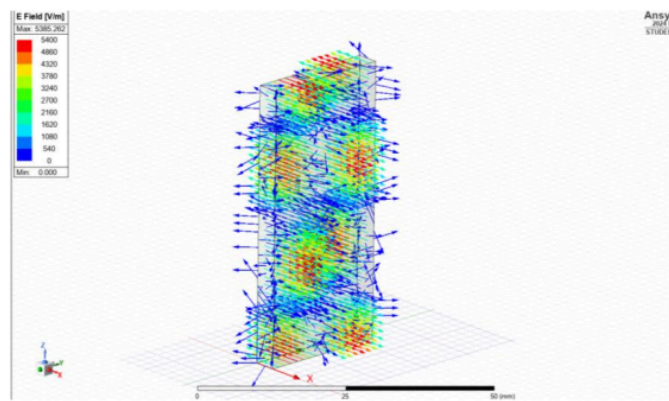


Figure 15: Mode 2 E Field Vector Plot

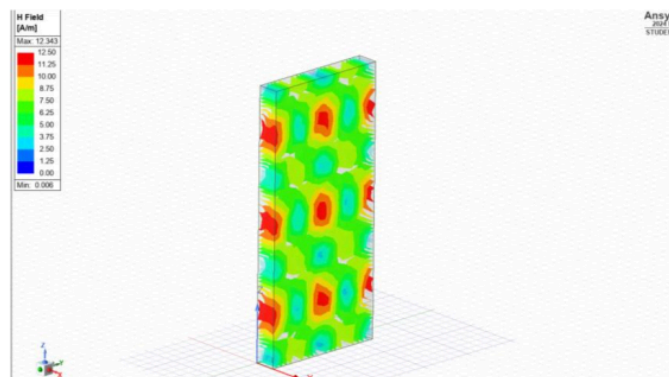


Figure 16: Mode 2 H Field Magnitude Plot

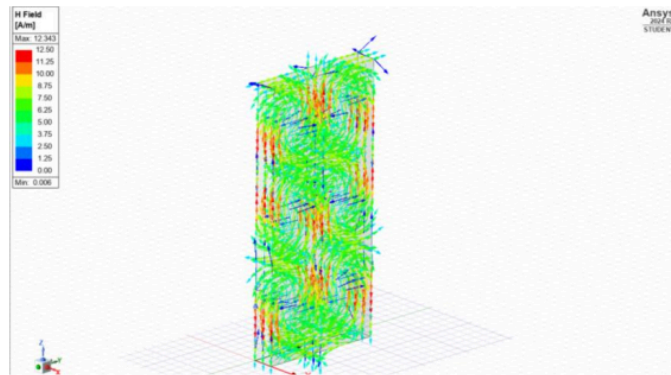


Figure 17: Mode 2 H Field Vector Plot

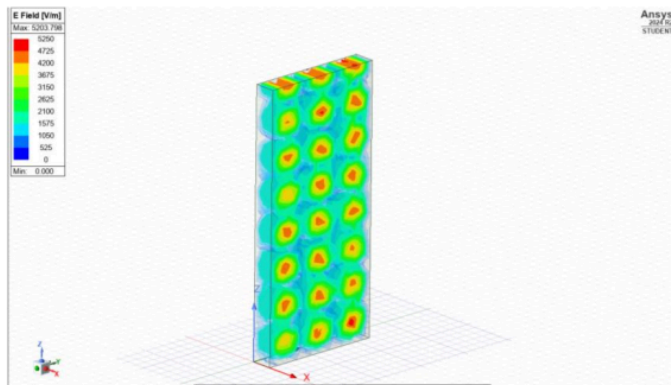


Figure 18: Mode 3 E Field Magnitude Plot

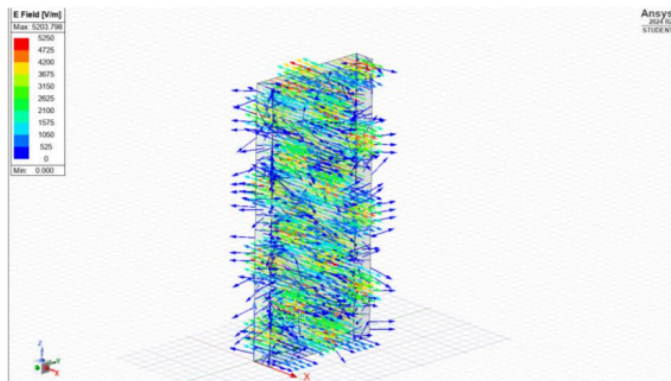


Figure 19: Mode 3 E Field Vector Plot

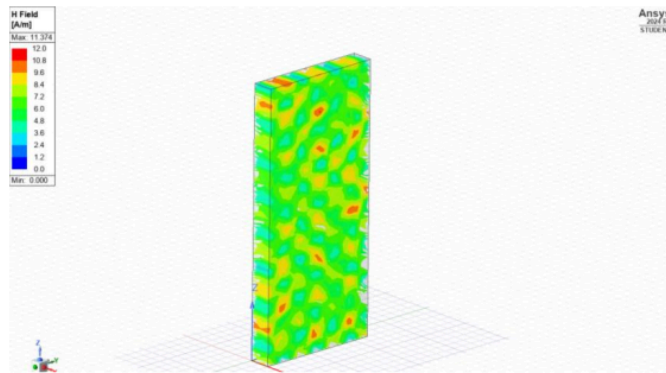


Figure 20: Mode 3 H Field Magnitude Plot

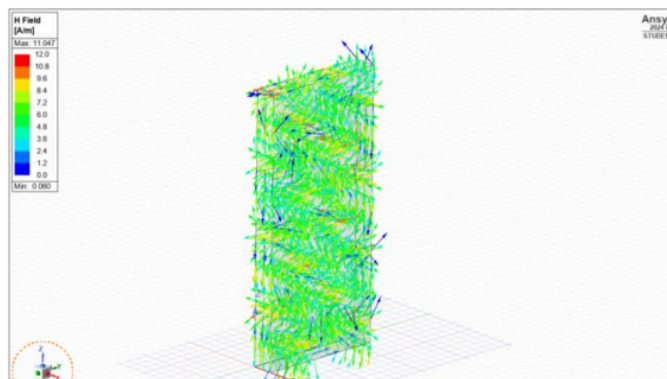


Figure 21: Mode 3 H Field Vector Plot

1.3.3. Teflon Waveguide Port Field Displays

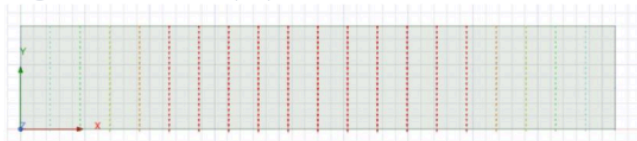


Figure 22: Port Field Display 1 Mode 1 – Teflon

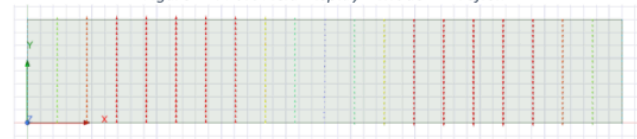


Figure 23: Port Field Display 1 Mode 2 – Teflon

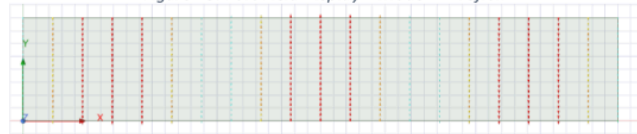


Figure 24: Port Field Display 1 Mode 3 – Teflon

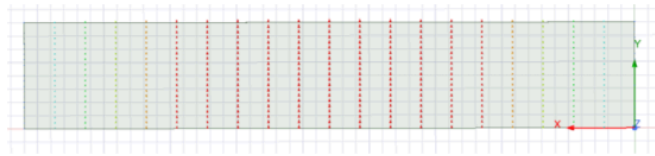


Figure 25: Port Field Display 2 Mode 1 – Teflon

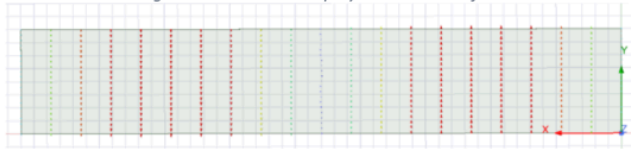


Figure 26: Port Field Display 2 Mode 2 – Teflon



Figure 27: Port Field Display 2 Mode 3 – Teflon

1.3.4. PEC Waveguide E & H Magnitude and Vector Plots

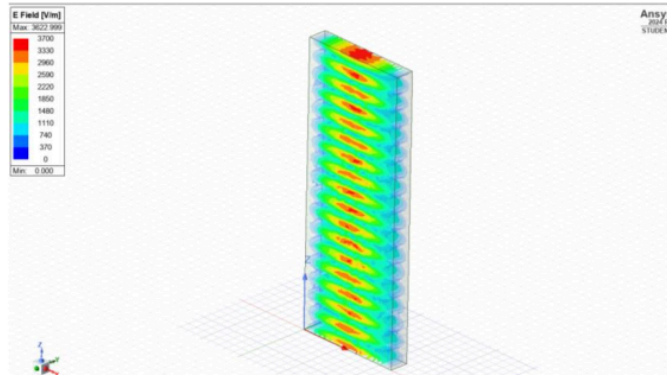


Figure 28: Mode 1 E Field Magnitude Plot Teflon

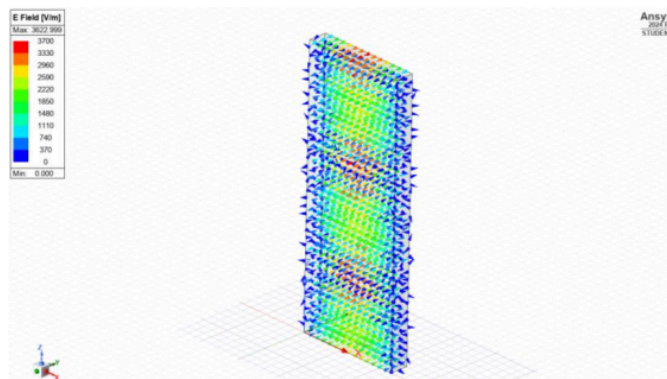


Figure 29: Mode 1 E Field Vector Plot Teflon

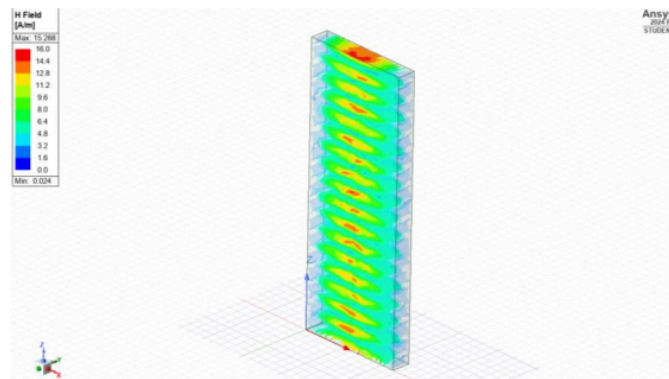


Figure 30: Mode 1 H Field Magnitude Plot Teflon

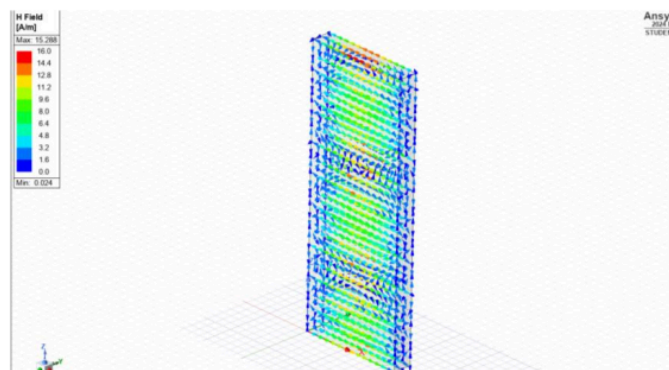


Figure 31: Mode 1 H Field Vector Plot Teflon

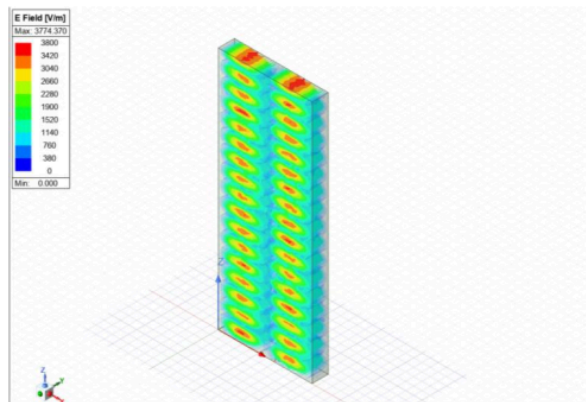


Figure 32: Mode 2 E Field Magnitude Plot Teflon

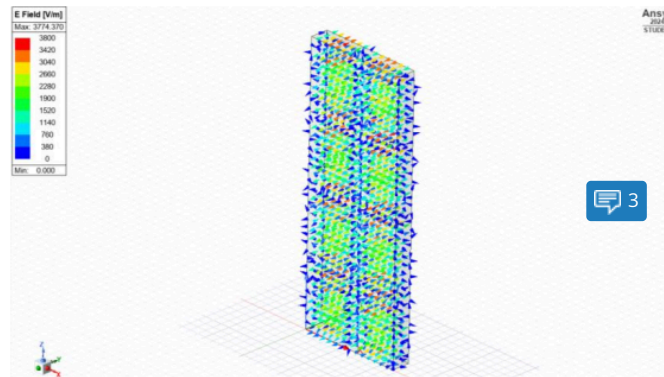


Figure 33: Mode 2 E Field Vector Plot Teflon

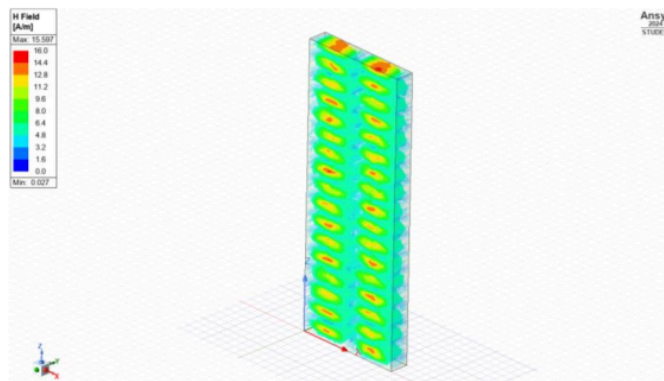


Figure 34: Mode 2 H Field Magnitude Plot Teflon

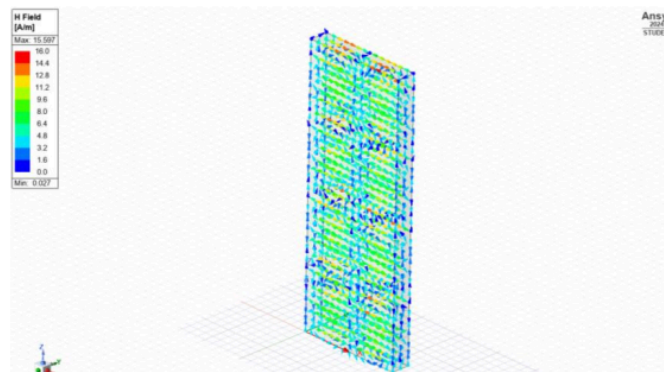


Figure 35: Mode 2 H Field Vector Plot Teflon

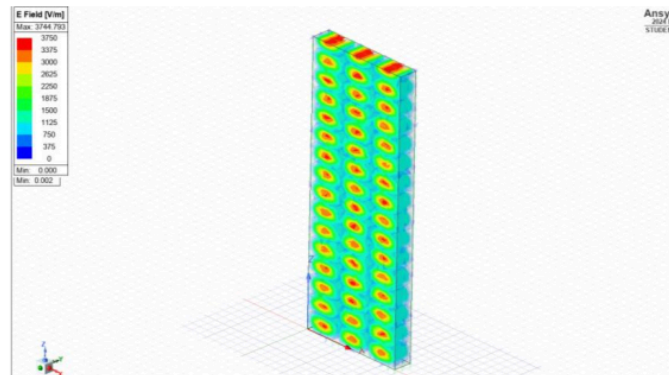


Figure 36: Mode 3 E Field Magnitude Plot Teflon

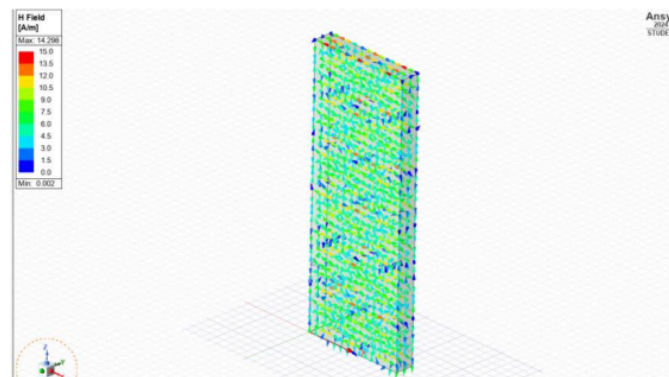


Figure 37: Mode 3 E Field Vector Plot Teflon

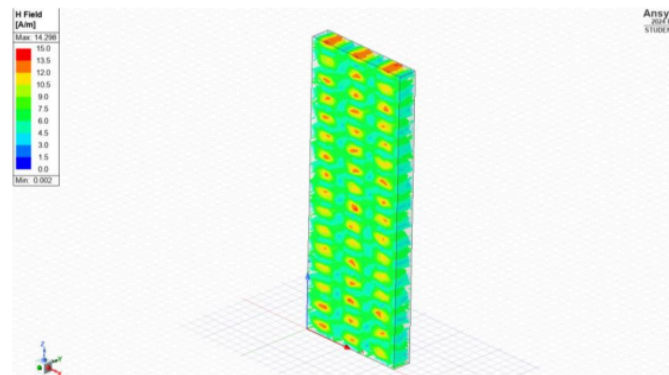


Figure 38: Mode 3 H Field Magnitude Plot Teflon

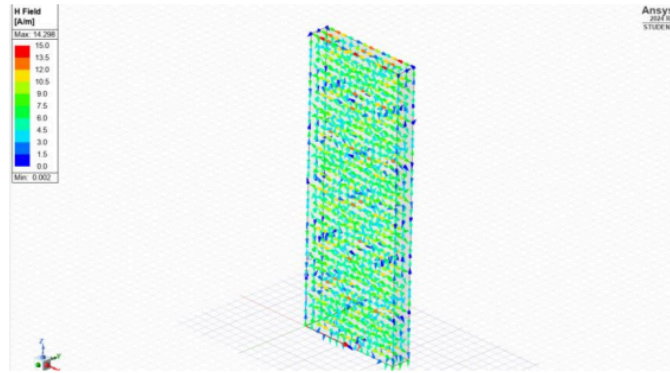


Figure 39: Mode 3 H Field Vector Plot Teflon

After simulating the 2 waveguides, PEC and Teflon, the author then plotted two graphs which can be used to help visualise the cut-off frequencies for the modes. The graphs in Figures 40 and 41 show the cut-off frequencies for each mode when simulating the waveguide. These then show that Mode 1 (TE₁₀) is the dominant mode due to it having the smallest cut-off frequency, allowing it to propagate with the least loss. This is the same across both materials; the difference between the two cut-off frequencies is 1.98 GHz.

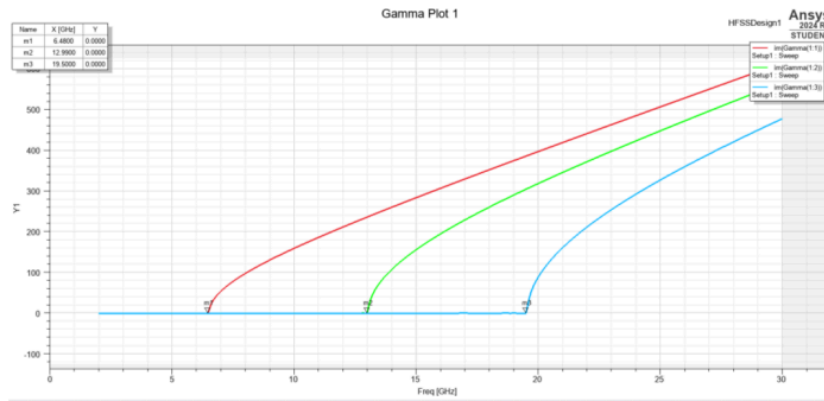


Figure 40: Vacuum Waveguide Gamma Plot

$$c = \frac{1}{\sqrt{\epsilon\mu}} = 3 \times 10^8 \text{ m/s}$$

$$TE_{1:0} = f_c = \frac{c}{2} \sqrt{\left(\frac{1}{0.023}\right)^2 + \left(\frac{0\pi}{0.004}\right)^2} = 6.52 \times 10^9 \text{ Hz} = 6.5 \text{ GHz}$$

$$TE_{2:0} = f_c = \frac{c}{2} \sqrt{\left(\frac{2}{0.023}\right)^2 + \left(\frac{0\pi}{0.004}\right)^2} = 1.30 \times 10^{10} \text{ Hz} = 13 \text{ GHz}$$

$$TE_{3:0} = f_c = \frac{c}{2} \sqrt{\left(\frac{3}{0.023}\right)^2 + \left(\frac{0\pi}{0.004}\right)^2} = 1.97 \times 10^9 \text{ Hz} = 19.7 \text{ GHz}$$

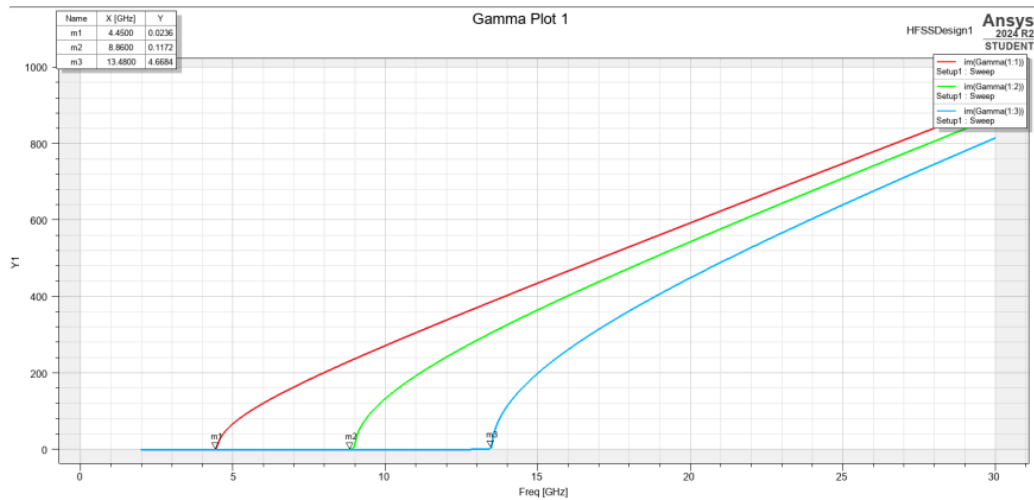


Figure 41: Teflon Waveguide Gamma Plot

$$c = \frac{1}{\sqrt{\epsilon\mu}} = \frac{(3 \times 10^8)}{\sqrt{1 \times 2.1}} = 2.07 \times 10^8$$

$$TE\ 1:0 = f_c = \frac{c}{2} \sqrt{\left(\frac{1}{0.023}\right)^2 + \left(\frac{0\pi}{0.004}\right)^2} = 4.5\ \text{GHz}$$

$$TE\ 2:0 = f_c = \frac{c}{2} \sqrt{\left(\frac{2}{0.023}\right)^2 + \left(\frac{0\pi}{0.004}\right)^2} = 9\ \text{GHz}$$

$$TE\ 3:0 = f_c = \frac{c}{2} \sqrt{\left(\frac{3}{0.023}\right)^2 + \left(\frac{0\pi}{0.004}\right)^2} = 13.5\ \text{GHz}$$

After completing the calculations for the cut-off frequencies, there was a bigger difference between the two different materials the higher the frequency became during the simulation. This is due to the materials changing the magnetic field, enabling the transmission to be different through the waveguide.

Halfwave Dipole Antenna

$$\text{Length of the halfwave dipole} = \frac{230\text{mm}}{2} = 115\text{mm}$$

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

$$\text{Operating Frequency, } f = \frac{230\text{mm}}{3 \times 10^8 \text{m/s}} = 1.306\ \text{GHz}$$

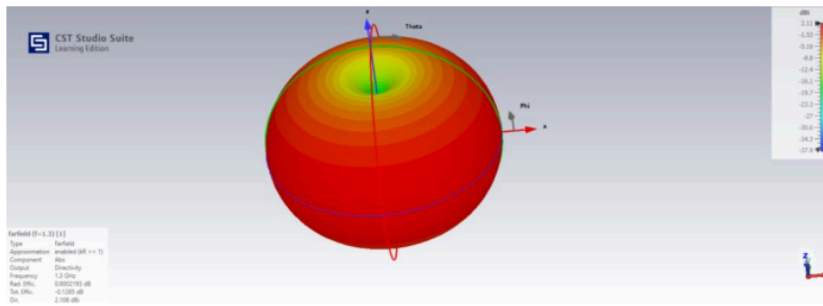


Figure 42: Halfwave Dipole Antenna Radiation Pattern

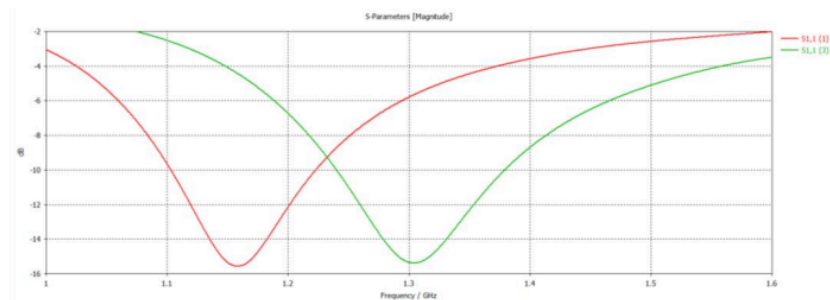


Figure 43: S1.1 against Frequency Plot for Dipole Antenna

The red plot shown in Fig. 43 is the original from the simulation, whilst this is correct, it is just the wavelength divided by 2, the green plot is the scaled frequency /frequency shift from having to increase the dipole length slightly to push the operating frequency up to a more precise frequency, the increase in the length of a dipole increases the frequency in which is outputted. Figures 44 and 45 show the directivity on two different planes, Phi and Theta, phi being a 'side view', which shows the radiation outwards and the nulls at the top and bottom where it has a weaker field of radiation. Whereas Theta directivity is a 'top-down' view which shows the strength of fields radiating out and direction, in this instance it displays that the dipole radiated at 360 degrees.

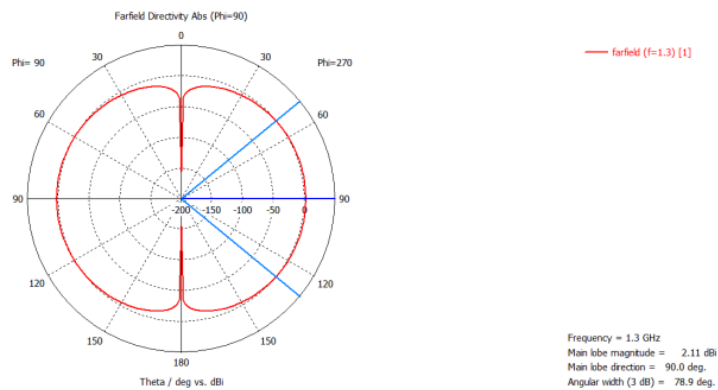


Figure 44: Dipole Antenna Phi Directivity

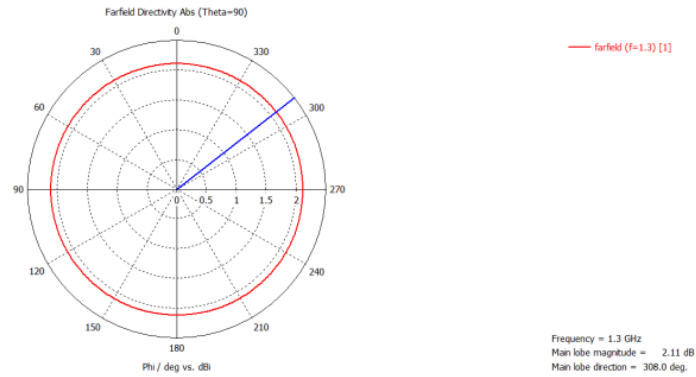


Figure 45: Dipole Antenna Theta Directivity

1.4. Discussion

1.4.1. Waveguides Results:

The simulation results showed differences between the PEC vacuum and Teflon rectangular waveguides. The PEC waveguide showed faster wave propagation due to the vacuum's permittivity ($\epsilon_r = 1$), which led to a higher cut-off frequency and reduced signal delay. However, the Teflon waveguide, with $\epsilon_r \approx 2.1$, showed a lower cut-off frequency, which was confirmed when the author used theoretical calculations, and more confined electromagnetic fields, which resulted in slower velocity. While both waveguides effectively guided the dominant TE_{10} mode, the Teflon dielectric increased the effective electrical length, which may be an advantage if used in compact designs. However, increased dielectric losses in Teflon could degrade performance in high-power or long-distance applications. Overall, the choice of dielectric material significantly impacts waveguide behaviour.

1.4.2. Halfwave Dipole Results:

The half-wave dipole antenna that had a total length of 230 mm (2 x 115mm) was analysed both theoretically and through simulation, using a theoretical formula the operating frequency of around 1.306 GHz was calculated after adjusting the length due to having a lesser frequency at 115mm because of fringing effect [5] this was counteracted by increasing the length slightly to increase its inductance. The simulation resonant frequency for the half-wave dipole of this length is approximately 1.304 GHz, confirming that the antenna is appropriately dimensioned for resonance at the intended frequency.

Theoretical research shows an input impedance of around 73 ohms [6], and a radiation pattern with a gain of approximately 2.15 dBi. These characteristics were confirmed through simulation using CST, where the half-wave dipole antenna demonstrated a resonant frequency closely matching 1.306 GHz. Simulated results showed an input impedance of 70–75 ohms, return loss (S_{11}) below -20 dB at resonance, and a gain of about 2.1–2.3 dBi. The radiation pattern maintained the expected doughnut shape the author expected.

Overall, the antenna exhibits high efficiency and excellent matching performance at the target frequency, making it well-suited for use in communication systems operating around 1.3 GHz.

1.5. Conclusion

Overall, the simulations confirmed that material properties significantly influence waveguide performance, with the PEC (vacuum) waveguide exhibiting higher cut-off frequencies and faster wave propagation compared to the Teflon-filled counterpart. Both supported the dominant TE_{10} mode effectively. The half-wave dipole antenna, designed with a total length of 230 mm, achieved resonance near the operating frequency of 1.306 GHz, showing good impedance matching and a typical 360-degree radiation pattern. Overall, the results align closely with theoretical expectations, demonstrating accurate modelling and reliable performance of both waveguides and the antenna.

2.0. Drone Radar Literature Review

2.1. Introduction

Within this literature review of the report, you will read about the reasons why radars, known for detecting and tracking aircraft within the airspace, fail to detect and track drones as well as some other UAS platforms. Drones are a fairly new and emerging technology which is advancing at an extremely fast pace, with market leaders such as DJI, Autel and Parrot to name but a few. Each specialises in different aspects of life in which a drone can be used. In this literature review, the author will evaluate the technological advancements to help detect drones and discuss the societal and environmental impacts of the systems.

Drones are an ever-increasing security threat not to just the UK but to the world in general, with incidents including things like Gatwick Airport back in 2018 causing significant disruption and grounding hundreds of flights and stopping about 110,000 passengers from traveling overnight [6], this caused significant issues and shone the light onto drones as being an upcoming security threat for years to come. During 2023 alone, there were over 6000 incidents involving drone use reported to the police, and a lot more which went unreported. These incidents pose a significant risk to the public and all modes of transport, predominantly air travel.

The use of drone radar from a societal point of view would be to allow the tracking and tracing of platforms which could cause disruption to things like UK airport by completely disregarding the no-fly zones, this is essential for things like airports and the consequences for an aircraft being in a collision with a drone could end up being catastrophic. This could also be used to help counter the use of drones to drop contraband into prisons for inmates. Due to them being small and quiet in a loud prison environment, they would be hard to detect by prison officers. 31% of the reports stated above were related to drones being suspected of delivering items within prisons. [7] [8]

2.2. Literature Review

Radar has been around since World War II, with the British developing the systems and then providing the US Armed Forces allowing for joined support within the Battle. With the word 'Radar' meaning Radio Detection and Ranging [9], the use of radar has become critical within the 20th century, with aircraft and ships being the leading users of radar systems.

New advancements in drone radar enable the use of radio energy to detect smaller objects such as drones, i.e. DJI platforms. These new advancements utilise the same idea as standard aircraft radar, which sends out signal waves that are then reflected from the platform. The radar then 'listens' for the echo, which is the waves being reflected from the platform back to the radar. Advancements in this field have seen a lot of drone detection kits using the Micro-Doppler effect technology [10], this effect is utilised in most drone radars as it allows the detection of drones rather than birds, etc to be traced and tracked.

2.2.1 Micro-Doppler Effect:

The 'Micro-Doppler' is generated due to the periodic movement of a main structural component of an item, device or object. This movement creates 'micro-motion' which created side bands about the bulk Doppler Frequency [11]. The phase of the signal that is returned to the radar from such an object will change depending on what that object could be. Drones have propellers which spin to keep them in flight whereas birds use their wings and flap; radar struggles to know the difference

between the two types of movement, due to them being about the same size (depending on what platform is being flown, DJI Mini-series etc), other methods of drone detection would include the modulation of the RCS (Radar Cross-Section) but the Micro Doppler radar overcomes most of these issues by primarily focusing on the signatures being emitted during its flight.

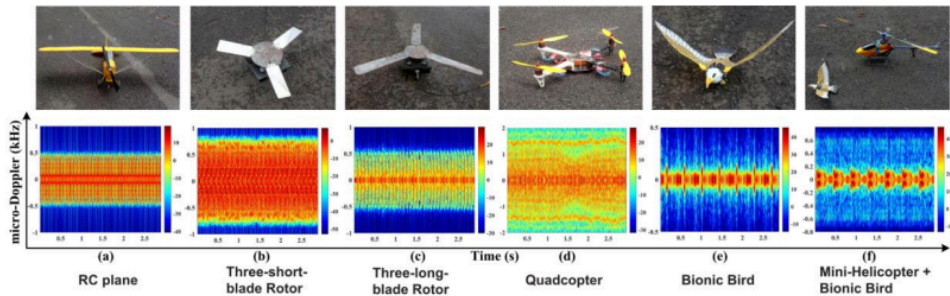


Figure 46: Micro-Doppler Signature Dataset of Small Unmanned Aerial Vehicle (SUAV) [12]

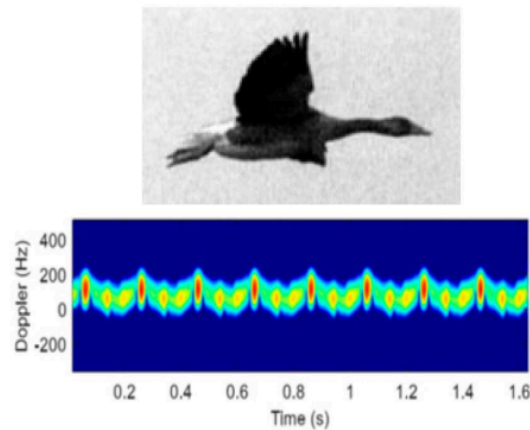


Figure 47: Doppler effect of a bird flapping its wings [13]

Figure 23 shows the Micro-Doppler signatures on a range of different UAS systems, this is what the radar uses to distinguish the differences between drones and birds, figure 24 shows the doppler effect of a bird flapping its wings, most drones are quadcopters so using image 'D' in fig23 you can see that there is a major difference in the effect being given off by the rotors compared to the wings of the bird. The radar looks into the modulation of the object rather than the speed as it is more straightforward to distinguish between the two instead of by speed.

2.2.2 Modulation of the RCS:

Another recent advancement in Drone radar technology has been the use of identifying the modulation of the RCS (Radar Cross Section). The cross section of a drone would be extremely small due to the small size of a drone and the materials used when manufacturing it. [14] When in flight, the RCS will be the same but will be hard to locate and track due to the constant and sudden movement in which drones can do, radar which track the RCS of the drone are new to the market and have proven themselves well and can differentiate between platforms and birds with significant accuracy which is a big selling point in the current market.

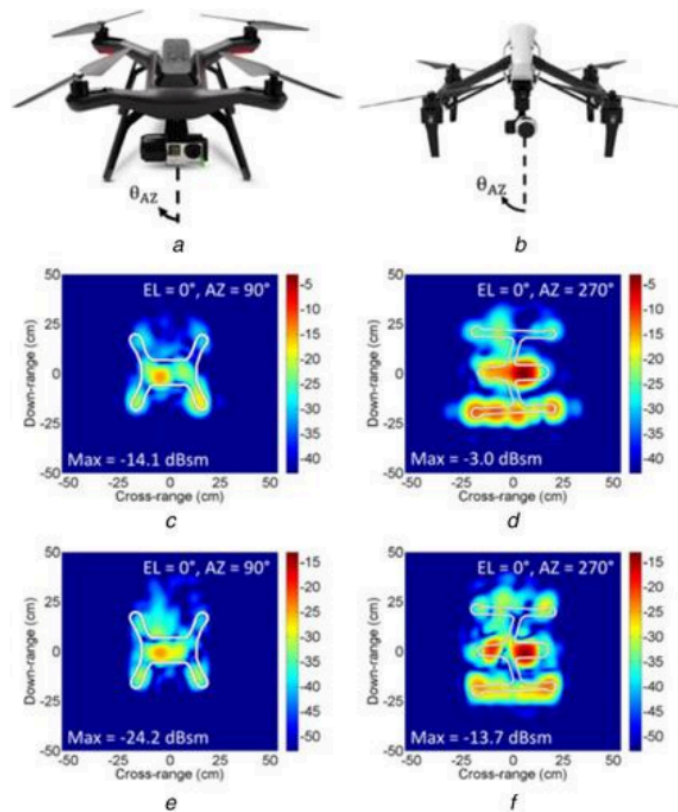


Figure 48: ISAR images [15]

The above images show what the modulation of an RCS looks like, visually you can just about work out it's a platform, but new radar with this technology can take this data and analyse it in seconds and decide whether it's a platform or a drone, this is market changing technology which will be used increasingly.

2.3. Discussion

The application of the radars to drones is the fact that they can locate and enable the tracking of drones right from small to large sizes without getting confused between birds and the platforms. These applications have allowed more incidents to be prevented or acted upon to reduce crime rates or disruption. The use of Micro-Doppler radars is a great technological advancement which should continue to be utilised and deployed in drone radar as it seems to be a very good system and makes good detection decisions between birds and drone platforms. With this, the modulation of the RCS would still be a great technology to continue to develop and improve, especially with different types of platforms being designed and manufactured, which could be even smaller in the future.

The application of both the micro-doppler and RCS modulation radars has seen great advancements in drone radar technology. Drones can now track more and smaller platforms, which poses good societal impacts. Due to the radar being over the air, effects on the environment are minimal, so this also poses a good look in the environment area due to negligible impacts being produced. Overall,

the applications of these radars are fantastic due to the fact that it is able to track at any time of the day, no matter the weather and can detect much further than VLOS (Visual Line of Sight), as well as in most cases they can detect multiple drones simultaneously.

2.3.1 Future Improvements:

AI-Assisted Drone Tracking Radar:

Improvements for the future could involve utilising AI (Artificial Intelligence) in a radar system, this could be trained to recognise all different types of signatures drones give off and be used to search and track. Once it matches the signatures, it could then track the location of the drone until it lands or gets turned off. With it being trained AI, it could be able to recognise the exact platform and provide all of its details to the user of the radar all of the details such as location, model, and ground speed, to name but a few. this would have good impacts due to it being able to potentially help the Police with searching and investigations when drone incidents occur. This would have no bad effect on the environment due to no waste being created, etc, only making the airspace safer for members of the public.

2.4. Conclusion

Overall, the current drone radars are doing an adequate job of identifying drones as well as determining the difference between a drone and birds. The societal impacts of the drone radars also leans very positive as it helps to reduce illegal drone use as the platforms can be tracked right from the start of their flight as well as keeps air travel safer. Using other methods like the modulation of the RCS is also a good style which is effective and can scan vast amounts of airspace, processing the differences of drones to birds and ground clutter amongst it. As more drones are purchased by consumers and no doubt more incidents occur, these forms of radars will be great to utilise and improve going forward to ensure they can be tracked and the new advancements have been market-changing with new technology being unlocked to help detect platforms.

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Robert Webb 2308625 EMR Assignment

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

77 /100

PAGE 1

PAGE 2

PAGE 3



Comment 1

Good work

PAGE 4

PAGE 5



Comment 2

It is better to include the citation before the full stop

PAGE 6

PAGE 7

PAGE 8

PAGE 9

PAGE 10

PAGE 11

PAGE 12

PAGE 13



Comment 3

You
have included a figure without mentioning it in the text. You should refer to
the figure in the text, otherwise it is not worth including as the reader will
not know what it relates to.



Comment 4

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have included a figure without mentioning it in the text. You should refer to
the figure in the text, otherwise it is not worth including as the reader will
not know what it relates to.

ENGAGEMENT WITH LITERATURE

The report should demonstrate the use of relevant, high-quality academic and professional sources. Comprehensive research incorporating recent journal articles, textbooks, and reliable sources should be evident. The credibility of each source should be evaluated, favouring peer-reviewed materials. All references must follow IEEE format, with consistent in-text citations.



Demonstrates engagement with a wide range of literature including independently sourced materials. Credible set of sources is used. References include textbooks, journal articles, and online resources. It is better to avoid reference from online blogs and Wikipedia. In-text referencing is consistently applied and relevant to the context. Referencing is consistent and correctly formatted using IEEE style. The number of peer-reviewed academic journal articles remains limited.

6**KNOWLEDGE AND UNDERSTANDING**

The report must exhibit sound knowledge of RF principles, waveguides, and antenna theories. Theoretical concepts such as wave modes and propagation should be clearly explained. Concepts should be related meaningfully to practical contexts. The report should demonstrate how this knowledge informed the design decisions.



Excellent and detailed understanding of waveguide behaviour, TE modes, cut-off frequency, antenna radiation, wave propagation, mode identification, and material impacts on cut-off frequency. Formulas are accurate and clearly explained. The dominance of TE_{10} is justified. The dipole antenna section is described correctly. Include more theoretical validation of field plots. Additionally, detailed discussion on data limitations or real-time constraints in embedded radar systems would have strengthened.

20.75

COGNITIVE AND INTELLECTUAL

The report should present a critical analysis of simulation results and theoretical data. Findings must be discussed with evidence, leading to logical and valid conclusions. Comparisons between theoretical and simulation results should be presented. Discussions should include implications, limitations, and alternative solutions.



Excellent critical analysis of antenna and waveguide concepts. Good comparison of theoretical vs. simulated results with quantified differences. Dipole antenna design shows excellent reasoning. Task 3 reflects advanced thinking and correctly identifies the factors causing small discrepancies. In Task 1, include a table comparing theoretical and simulated cutoff frequency (f_c) values with percentage error to strengthen your argument and highlight the accuracy of your results.

19

Designed effective solutions using industry-standard tools with a clear focus on performance and usability. Waveguide and antenna designs

demonstrate good understanding of material choices and commercial considerations. The radar section aligns well with societal, environmental, and user needs, and incorporates innovative technologies such as machine learning.

PRACTICAL SKILLS

Appropriate engineering software and methodologies should be applied to design waveguides and antennas. The simulation process and parameters should be documented clearly, with justifications for methods used. Results should be presented with neat plots and visuals. Problem-solving skills should be demonstrated through analysis and design refinements.



An advanced application of a range of established methods, materials, tools, and techniques. Excellent use of HFSS simulations, including the port field display, field magnitudes, vector plots, S-parameters, and radiation patterns. The application context is well considered and insightful. To improve further, specify the boundary conditions used (e.g., PEC, radiation boundary) and the solver settings.

16

TRANSFERABLE SKILLS FOR LIFE

The report should be clear and well-structured for technical and non-technical readers. Complex ideas must be communicated effectively, with appropriate terminology and visual aids. A logical flow from introduction to conclusion should be maintained. Professional presentation elements such as clear headings, subheadings, and a well-organised reference list should be included.



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 structure with effective use of figures, and headings. Report is well structured with logical flow. Writing is technically good, and explanations are mostly professional and focused. Alignment should be improved. Although figure numbers and captions are present, most figures are grouped together, with their descriptions appearing several pages later. Most of the figure included are not referred in the descriptive part. This disrupts the continuity and makes interpretation difficult. A thorough proofread is also recommended to enhance the overall quality of the report.

14.75