

EMR Report

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Abstract

This report details the simulation of a set of given RF components, the components are a Vacuum filled waveguide 23mm by 3mm a Teflon filled waveguide of the same dimensions and a PEC halfwave dipole antenna.

The results of which are, to the surprise of no one, almost exactly as would be expected, aside from the halfwave dipole being designed without considering the fringing effect, thus leading to a slightly reduced resonant frequency than would otherwise be expected.

Finally concluding that Ansys HFSS can simulate electromagnetic effects as would be expected.

Introduction

In this report the results of a simulation of a given waveguide and halfwave dipole is detailed.

It covers the methodology behind simulating the designs in question, a description and discussion of the results obtained and a conclusion

The task brief has requested a problem analysis in this section, however no problem to solve is detailed in said brief. As such what follows is a problem analysis of the problems resulting from an assignment brief asking a student to perform a problem analysis of a problem which does not exist.

Problem Analysis

The primary problem associated with asking a student to perform a problem analysis on a problem which has not described, defined, or even mentioned as existing is that it can lead to an extremely unpredictable result.

For instance, one student may see the directive to perform a problem analysis and assume they missed something in the brief. Then upon finding no problem defined in the brief, simply assume the directive was some form of typographic error. Ultimately producing nothing and potentially sacrificing marks and of course by extension class average.

Whereas, another student may pick a problem to perform an analysis on effectively at random. Inadvertently recontextualising their produced report around something completely different to the original intention of the writer of the assignment. This could be detrimental to the student as they could produce a report that does not discuss any of the required topics, thereby losing marks and class average.

It may also push students to concluding that the assignment brief was not written with an abundance of care or attention. Potentially encouraging the student to disengage from the assignment and apply very little to no effort into it.

An additional problem associated with the above described problem analysis is that by producing an assignment brief that includes such obvious logical errors as this. Is that it reflects rather poorly on the organisation that produced it, particularly on whomever reviewed the document in question. As the writer can somewhat be excused for assuming knowledge that perhaps should not be assumed known by the reader. However, the reviewer should be

expected to catch errors such as this because, upon reading the document for the first time, they will encounter the reference to non-existent elements of the document, and should recognise that they do not know what the document they are reading is discussing.

Methodology

Simulation Methods

The simulation method used was to create the specified design to be simulated in Ansys HFSS, then follow the step-by-step instructions provided by the lecturer on completing the assignment. (Modal network analysis in Ansys)

Theoretical Approach

No theoretical approach was employed because the task did not require or specify any design parameters.

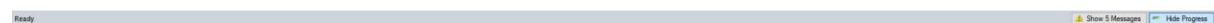
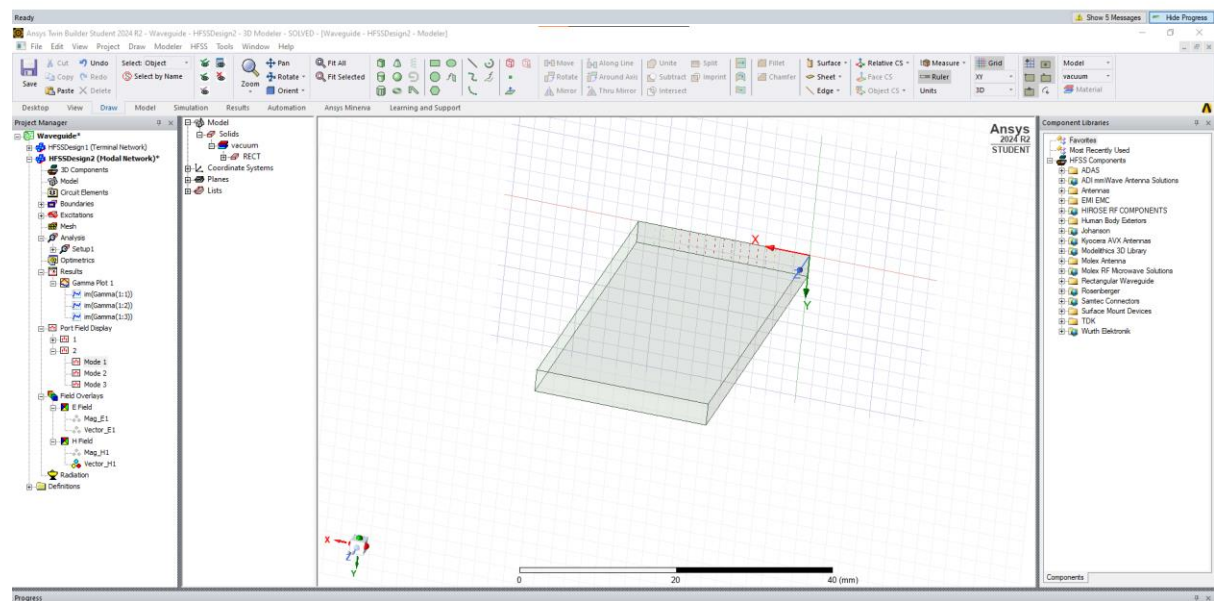
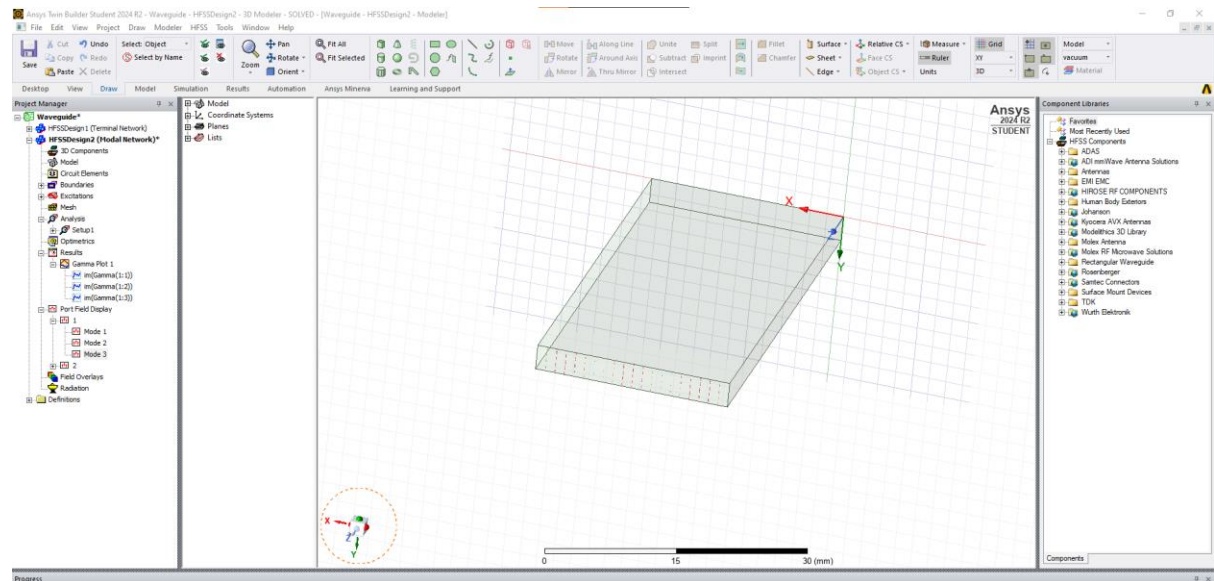
With a lack of any parameters of a goal of any description there is no way to judge the performance of a design and thus no way to make a design that performs better or worse.

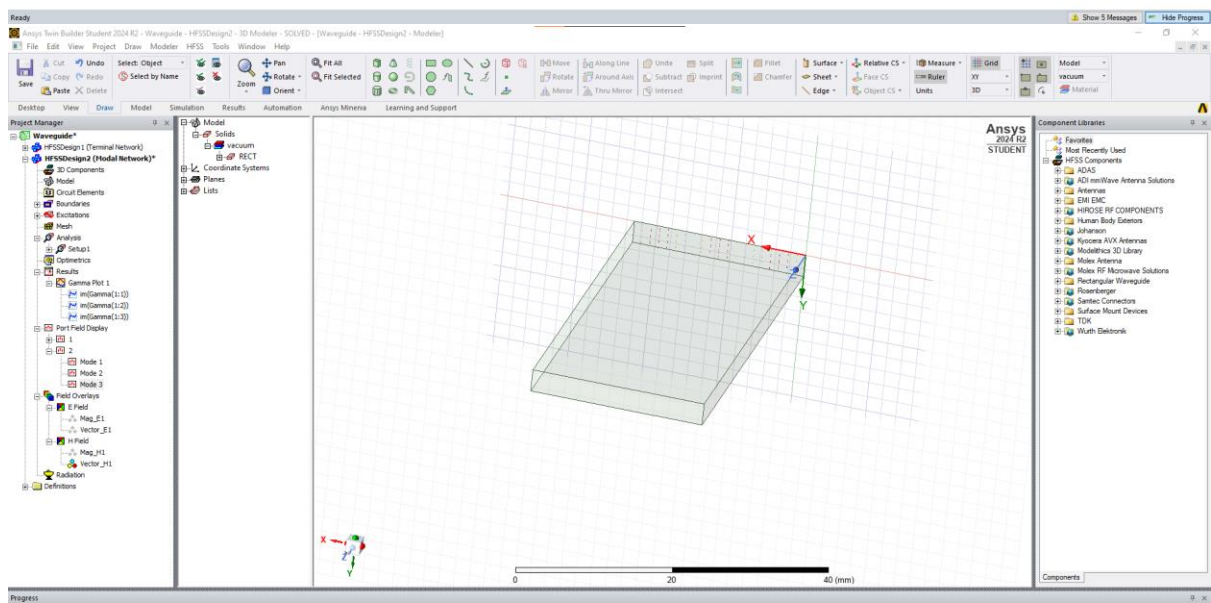
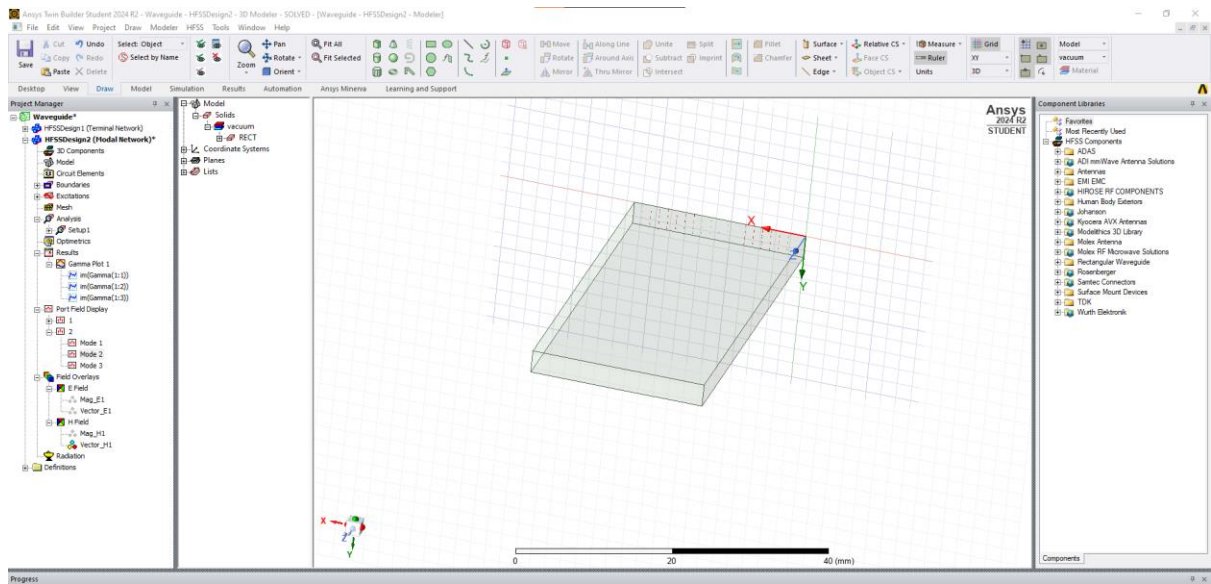
A design could be made to behave more conventionally, however the explicit specification of waveguide dimensions effectively forecloses this potential opportunity for independent thought.

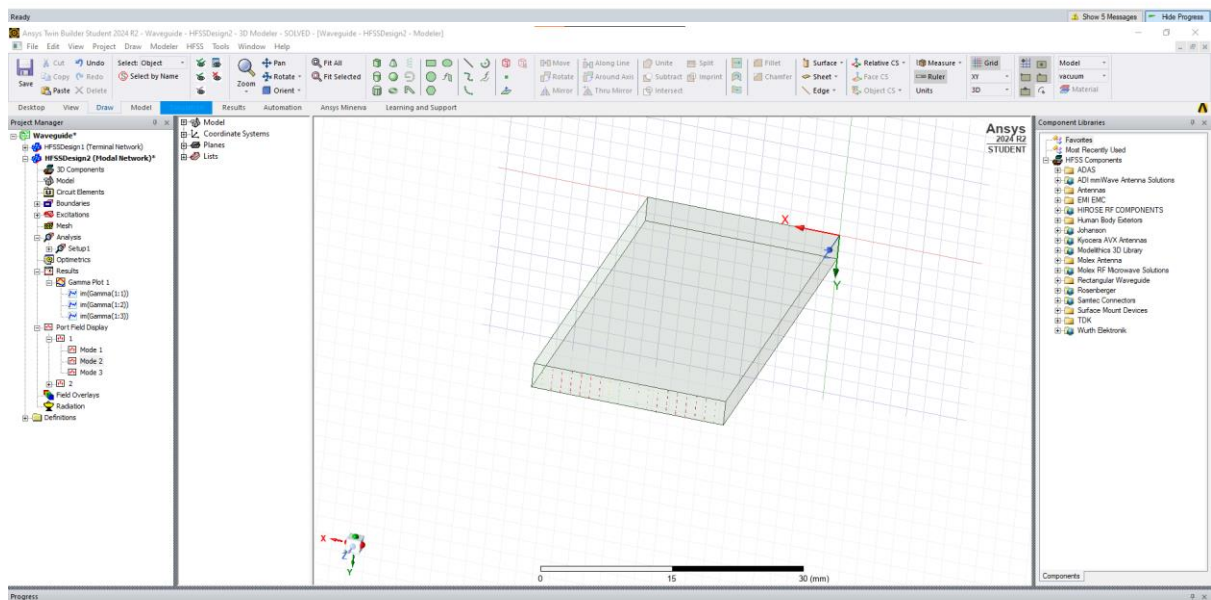
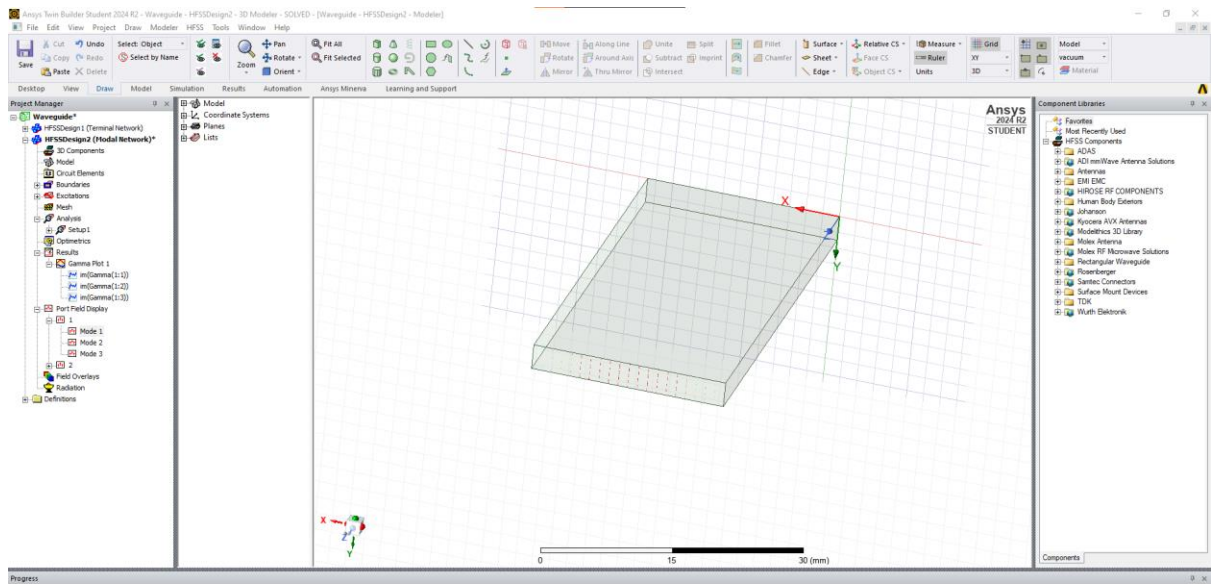
Results

Task 1a

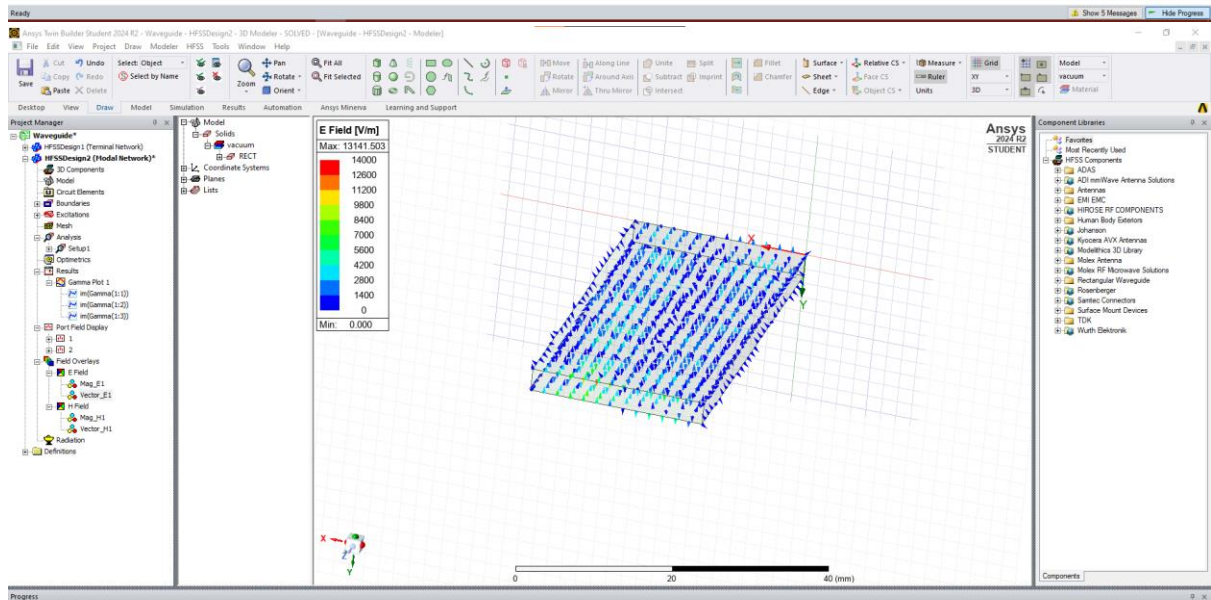
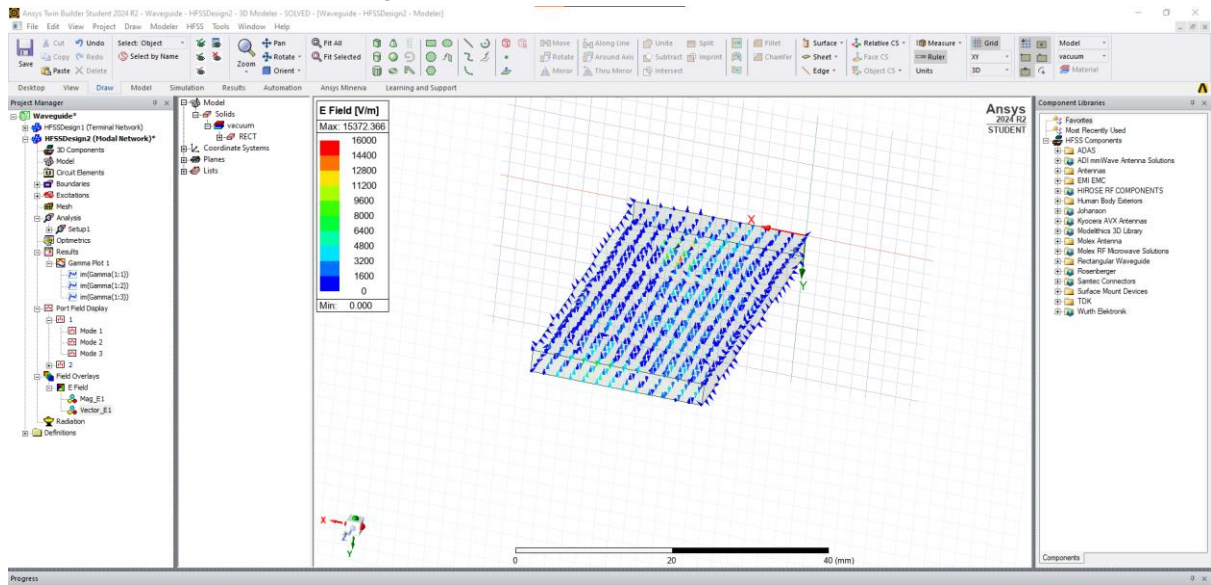
Port Field Display

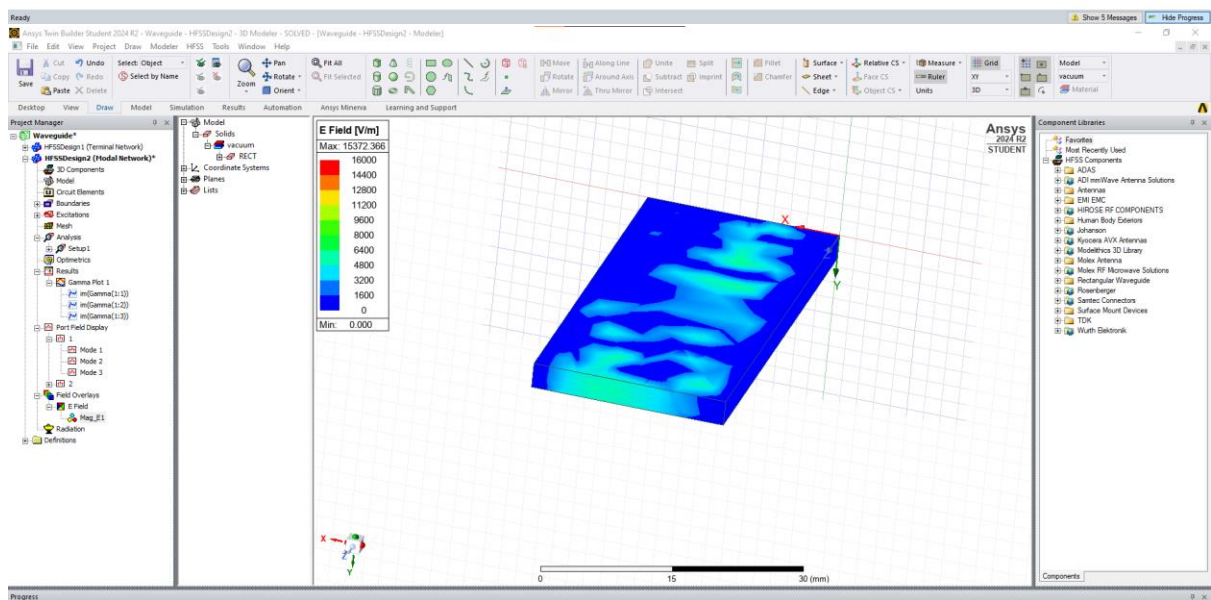
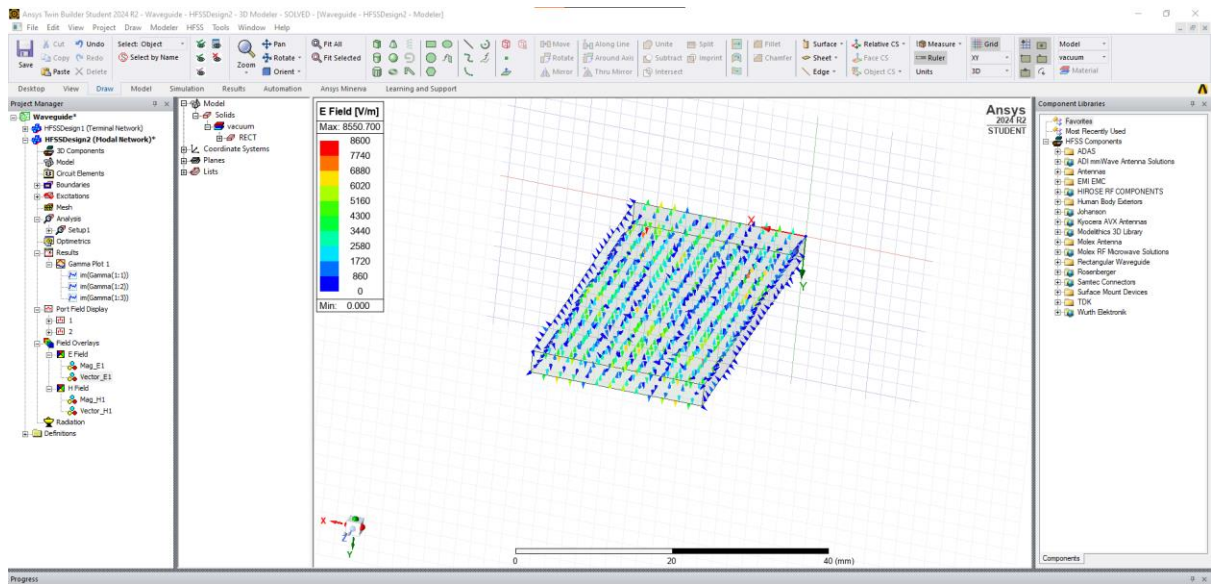


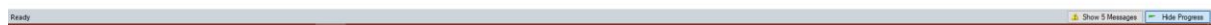
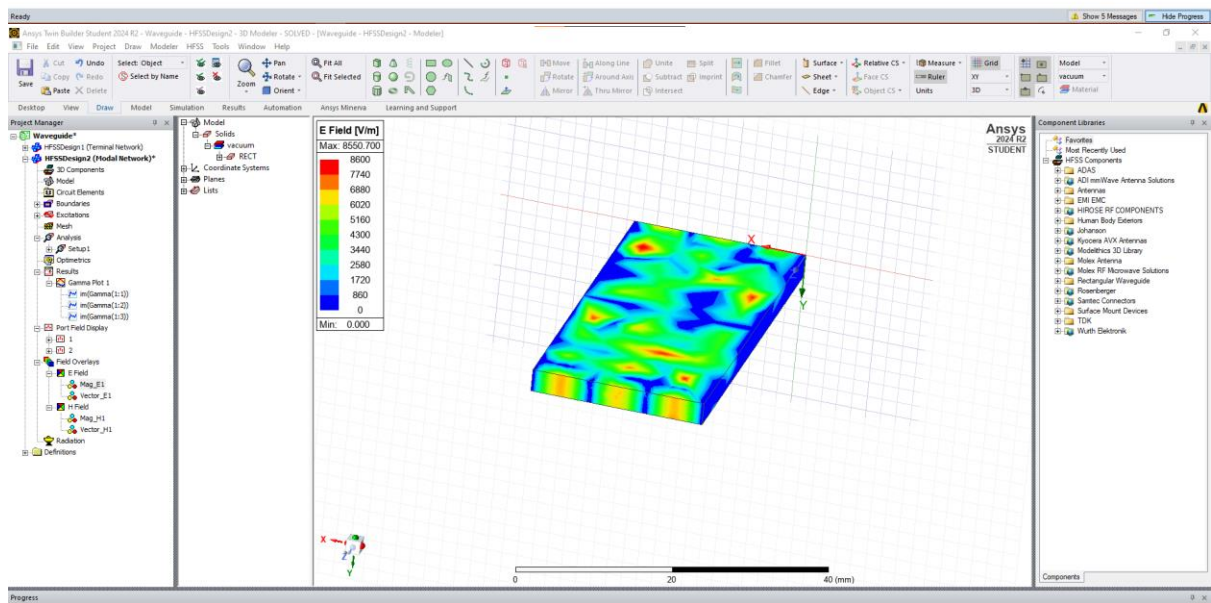
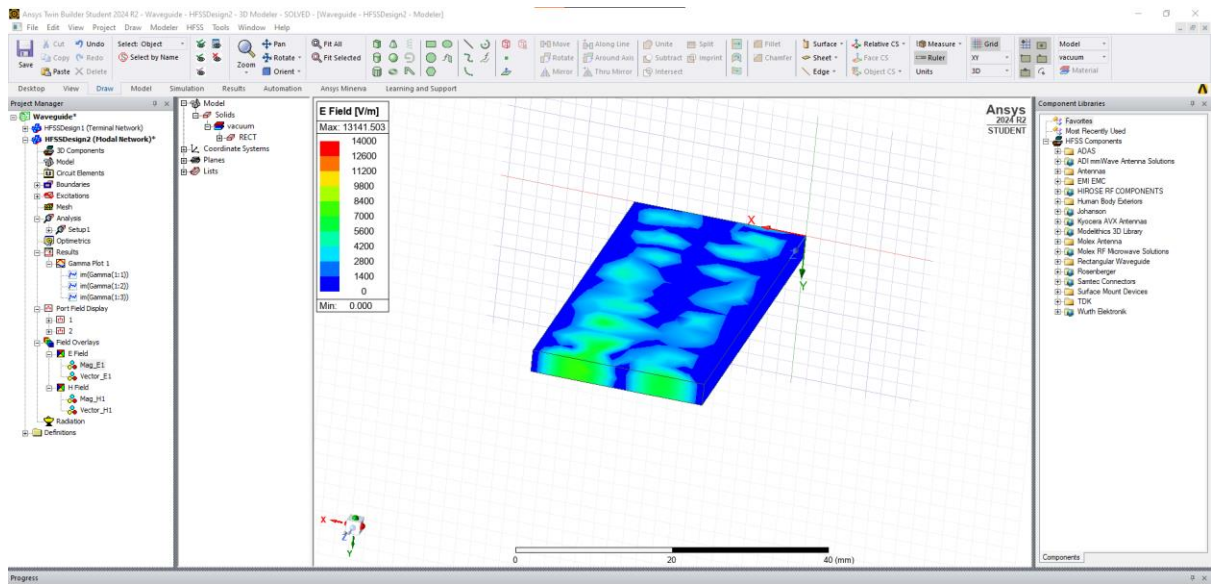




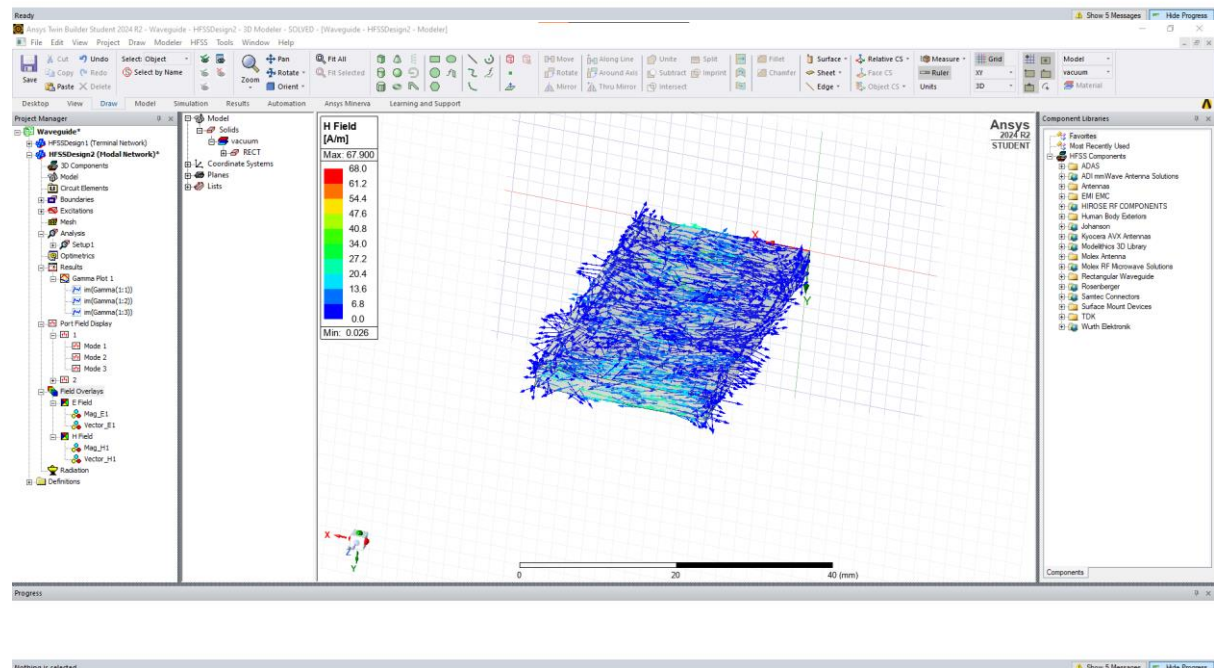
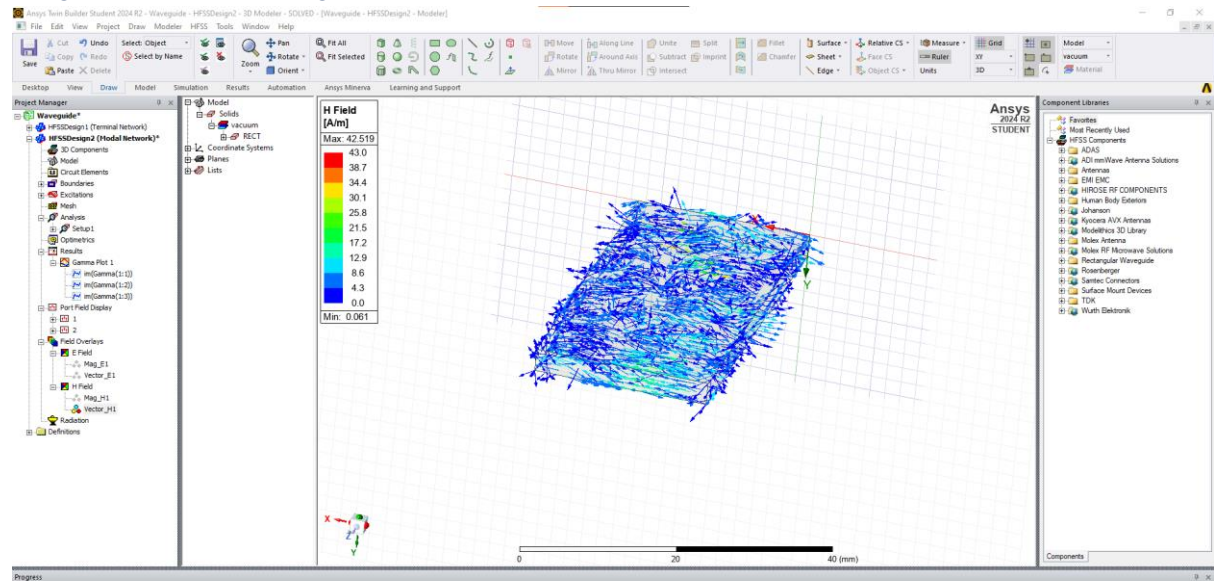
Electric Field propagation

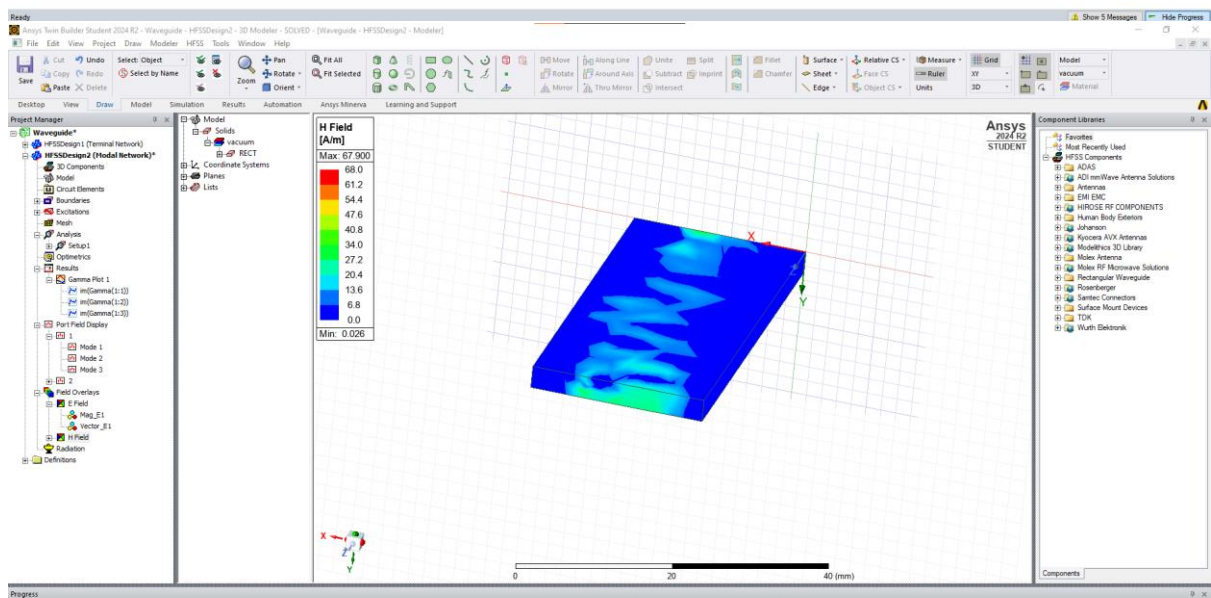
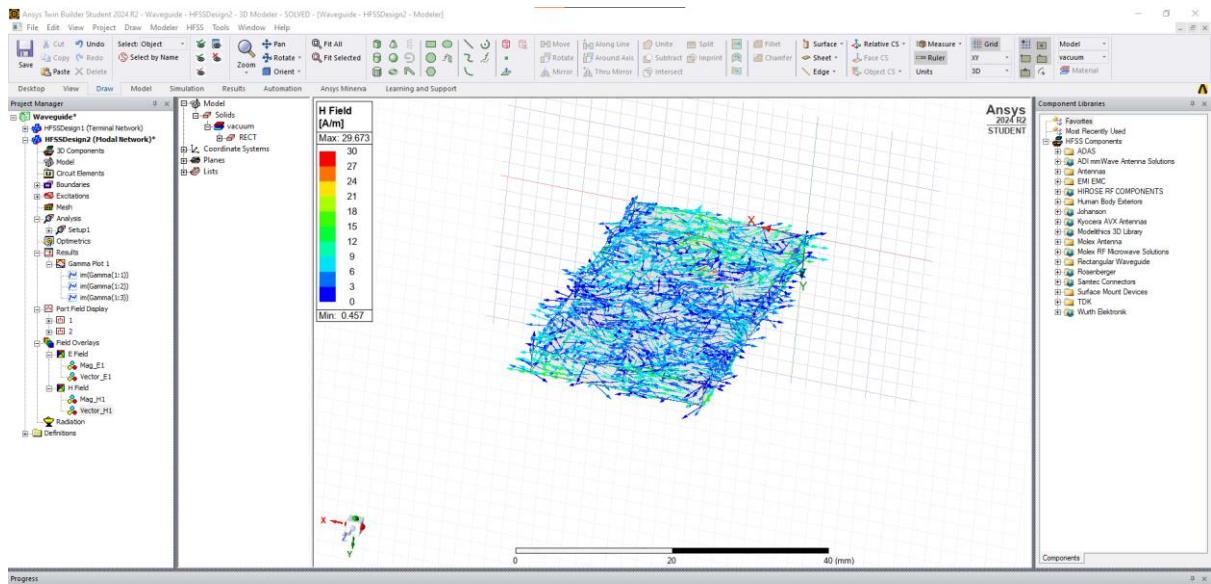




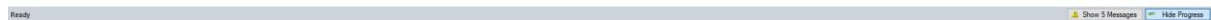
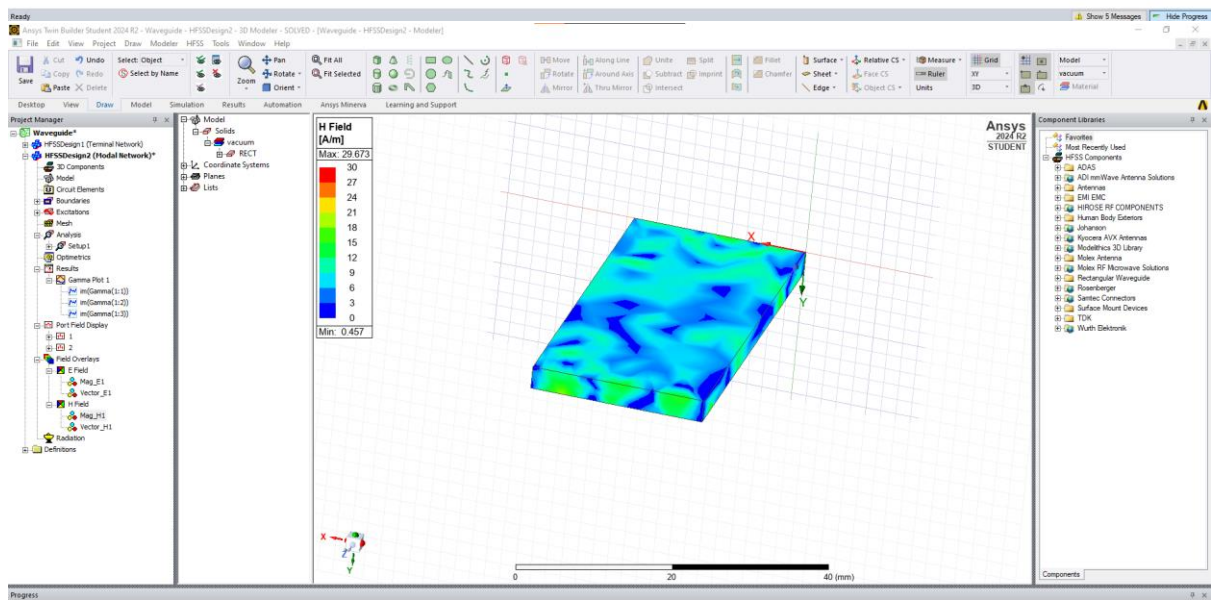
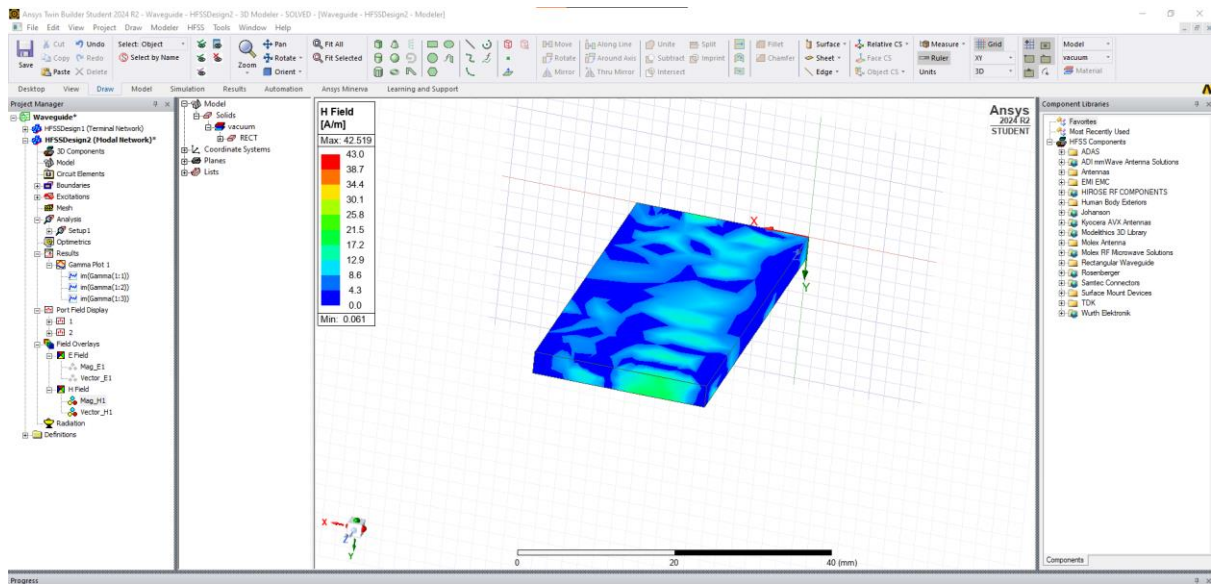


Magnetic Field Propagation

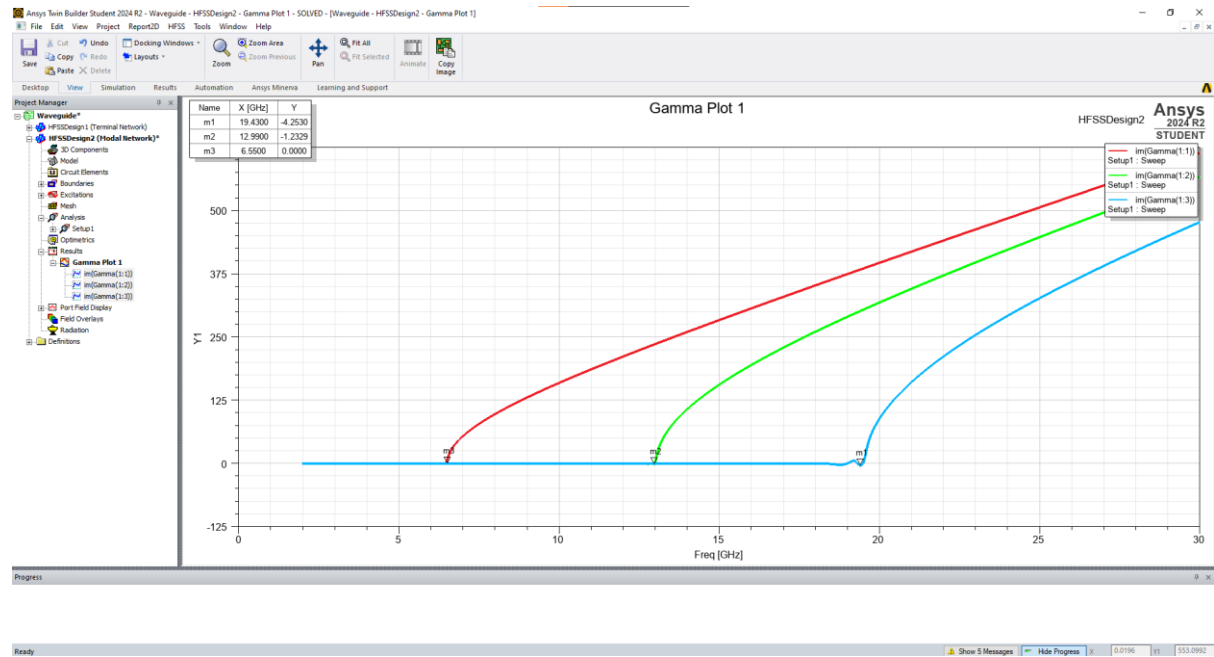




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Cut-off Frequencies



The calculated cut-off frequencies are:

The cut-off frequency for TE₁₀ is 6.55GHz

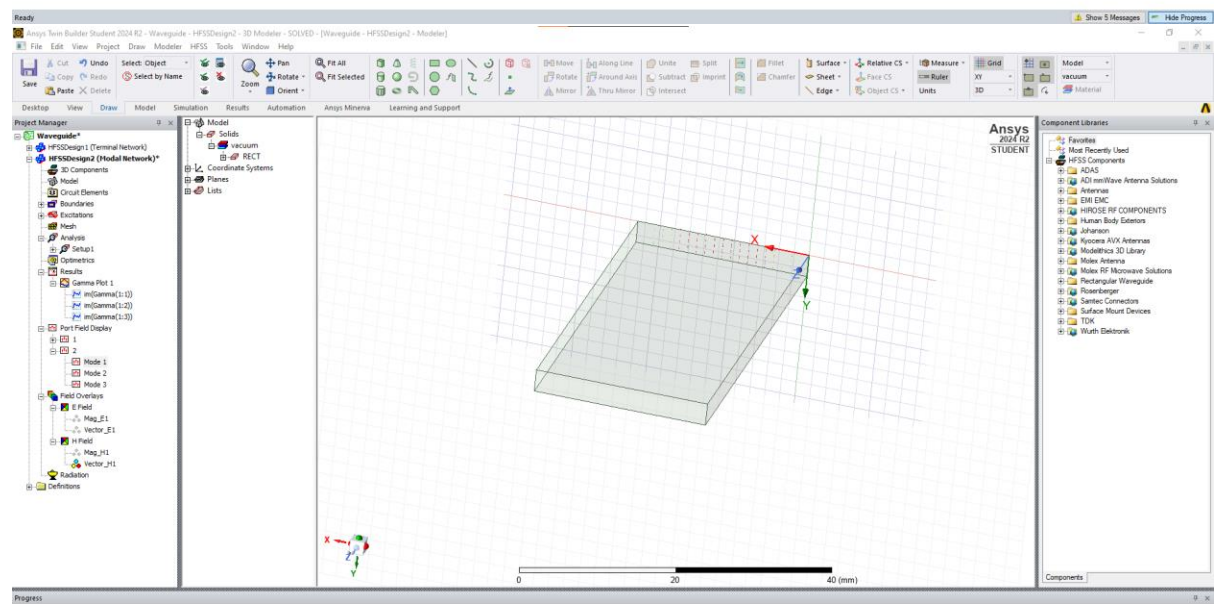
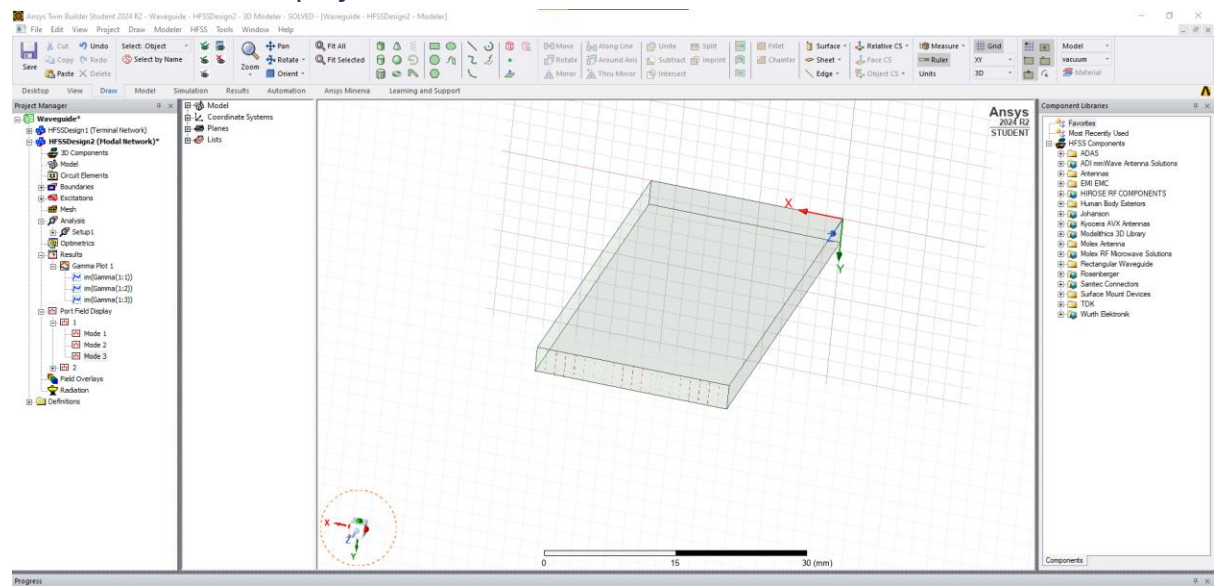
The cut-off frequency for TE₂₀ is 12.99GHz

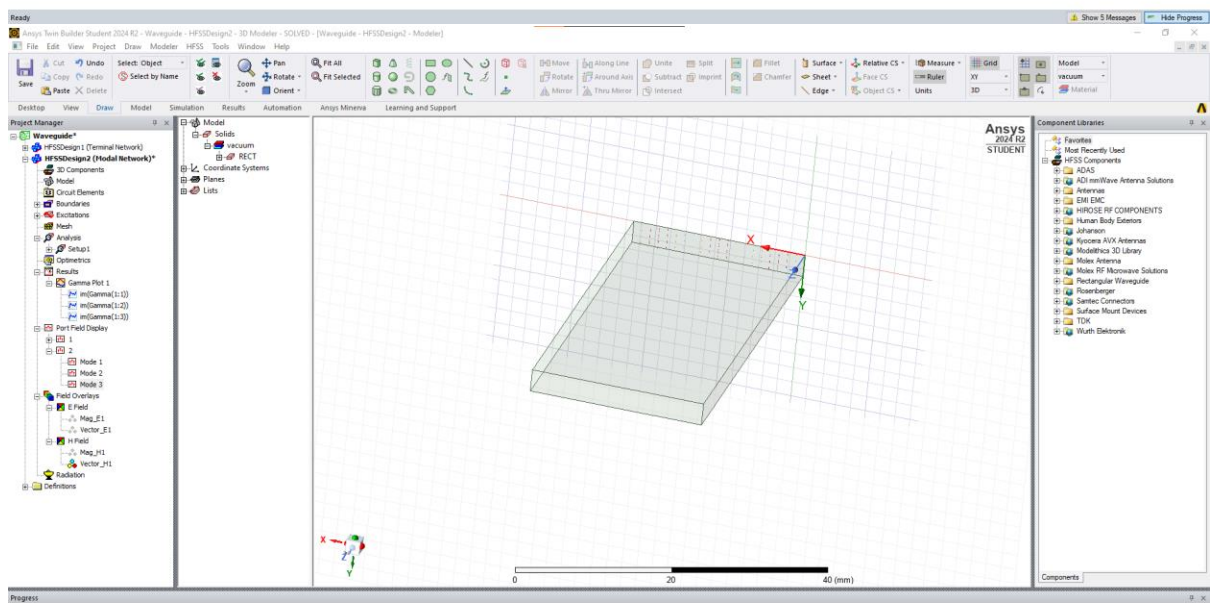
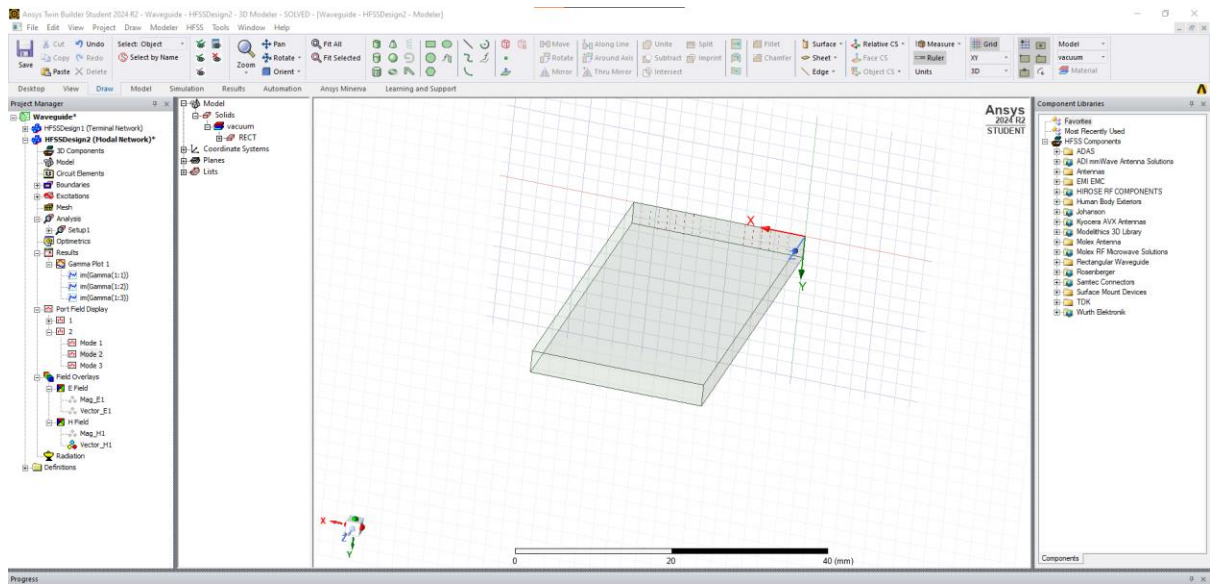
The cut-off frequency for TE₃₀ is 19.55GHz

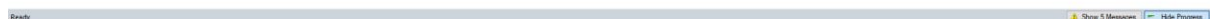
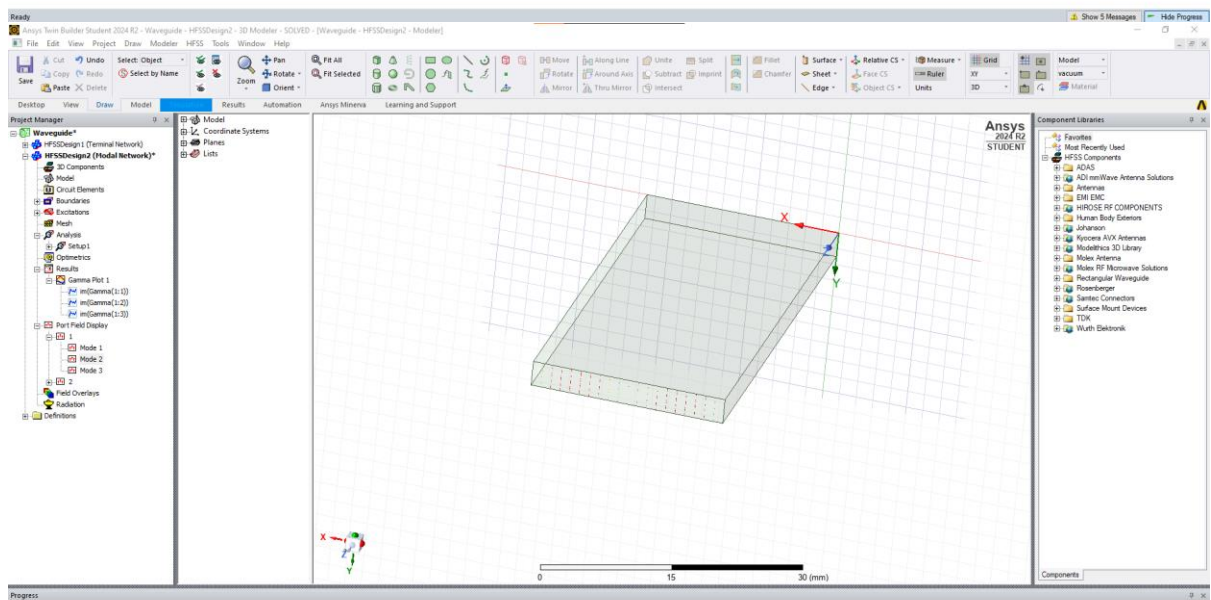
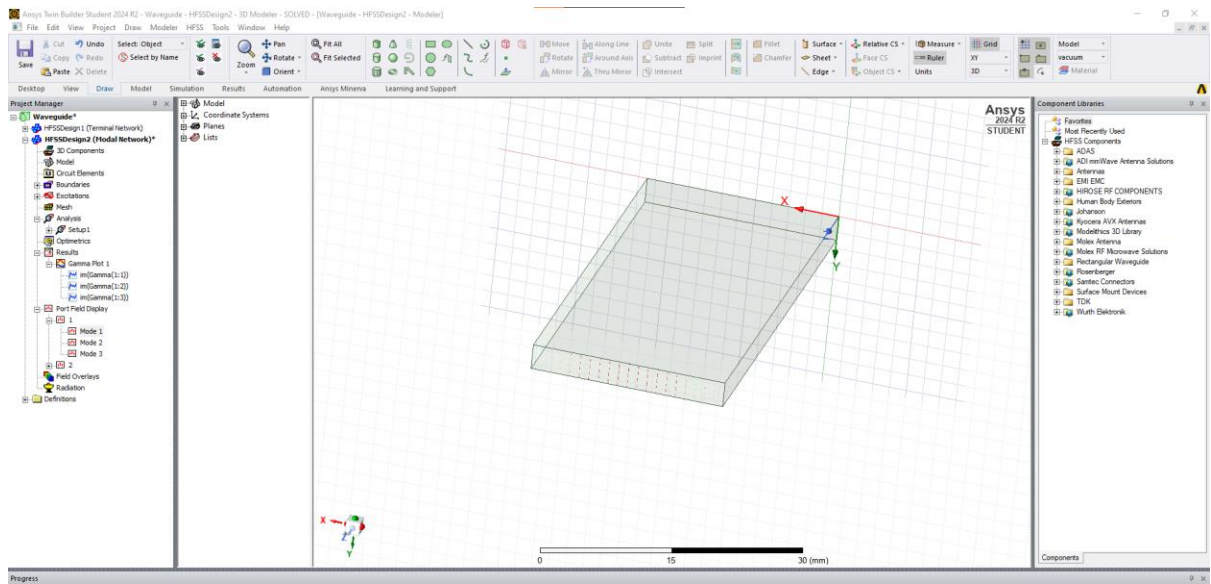
Task 1b

Port Field display

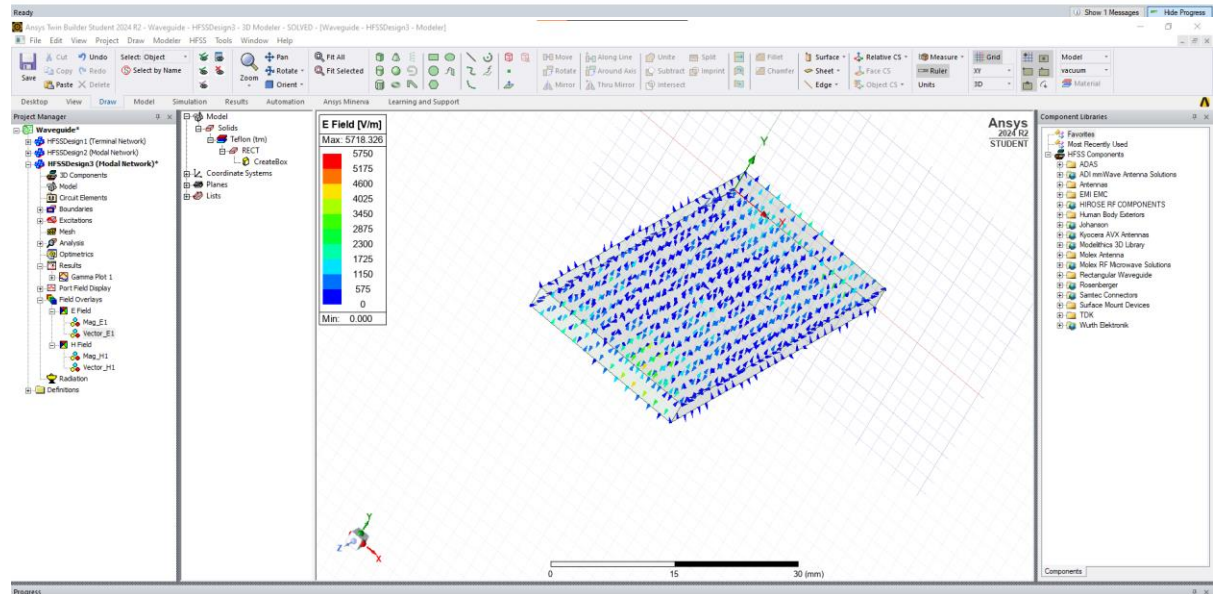
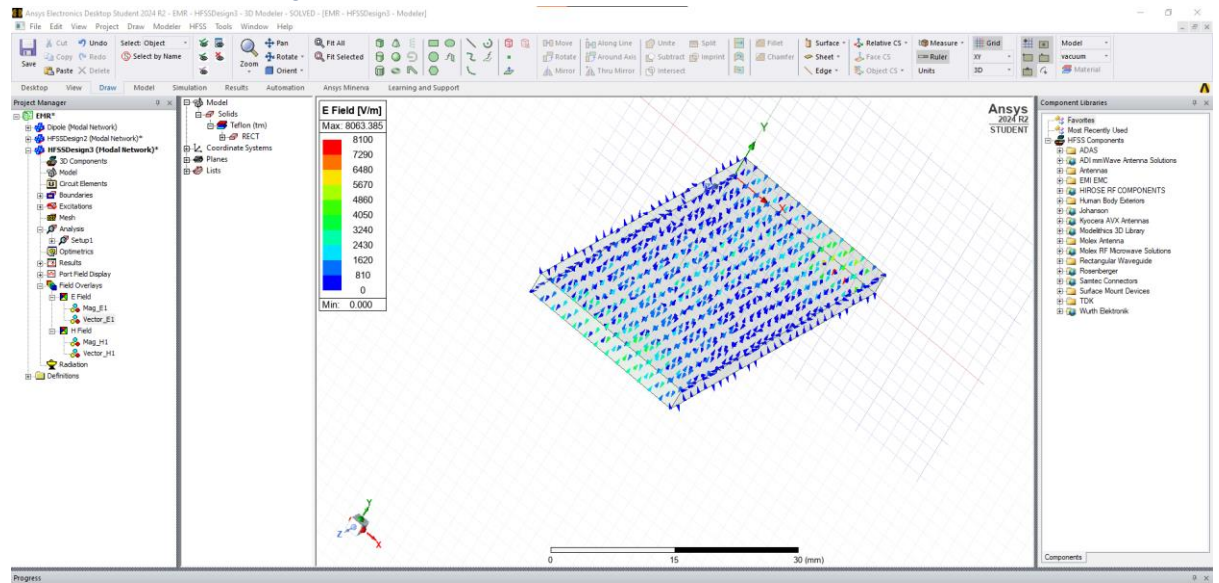
Port Field display

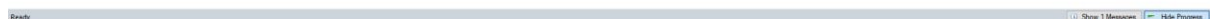
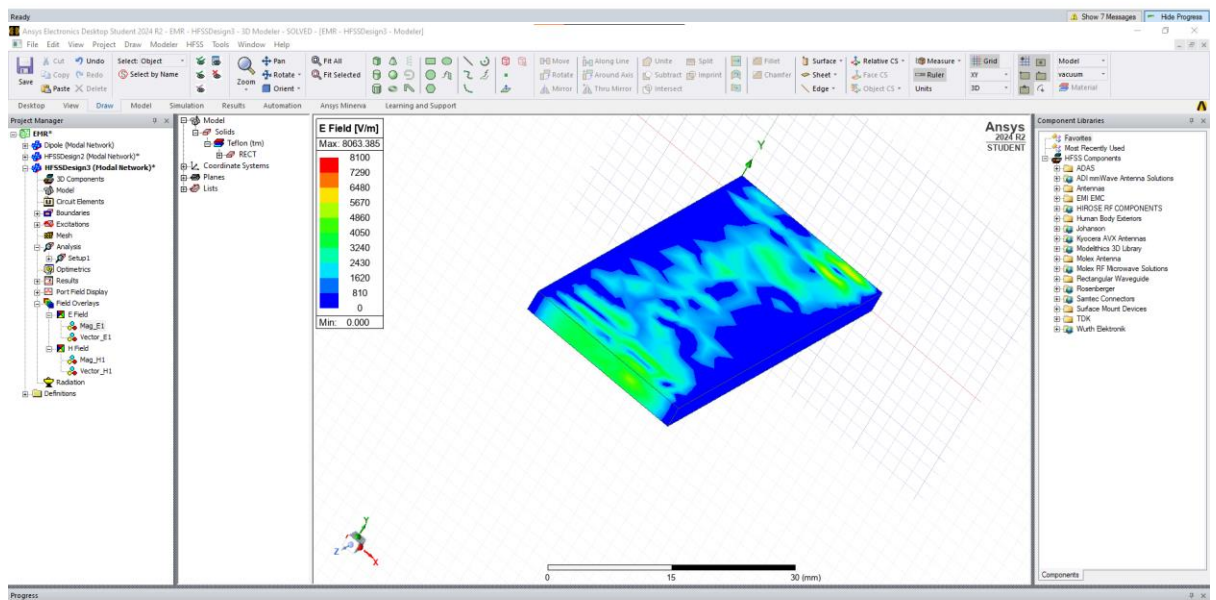
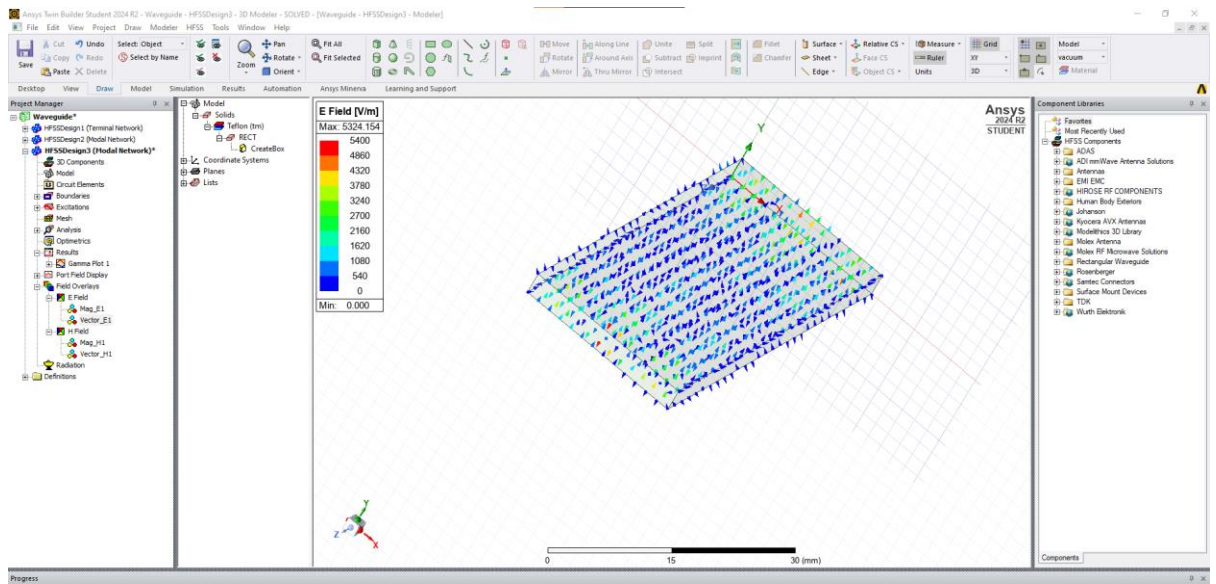


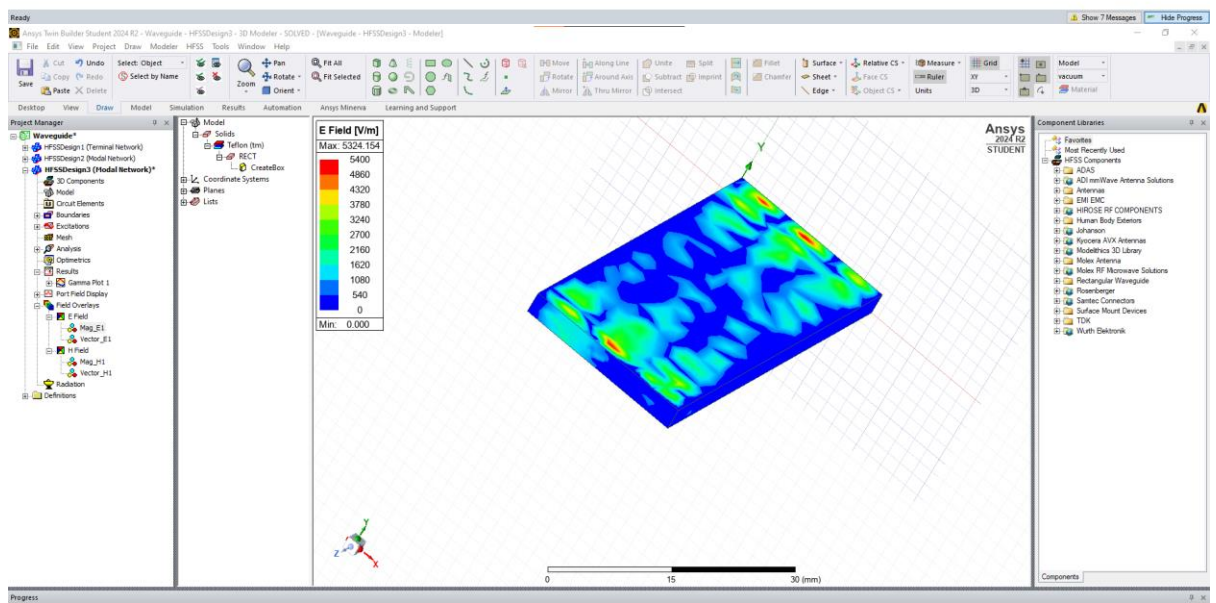
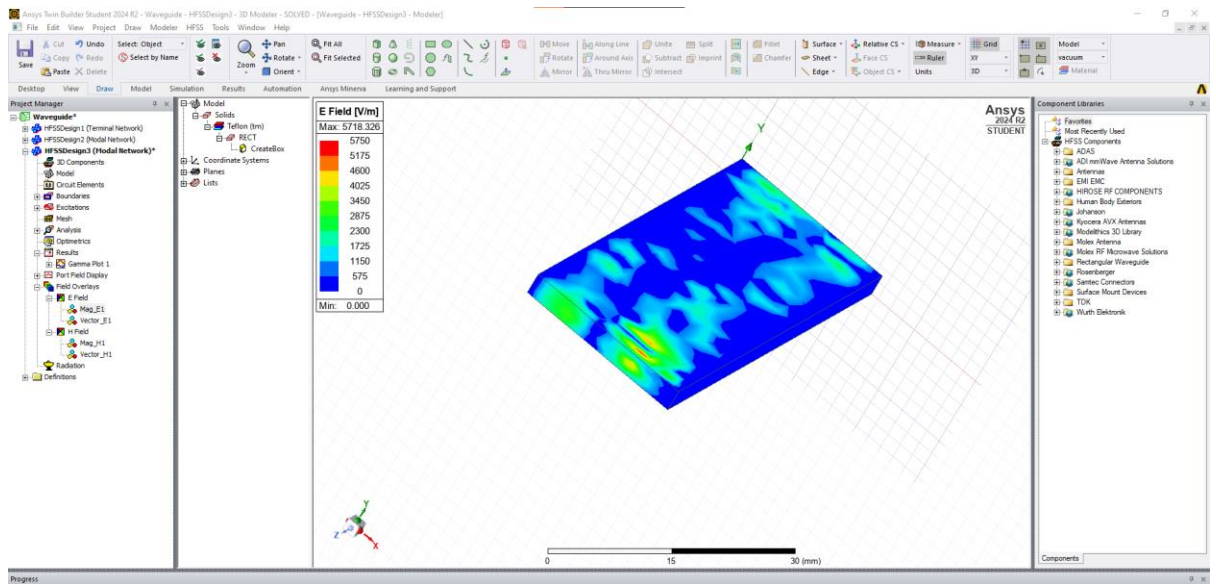


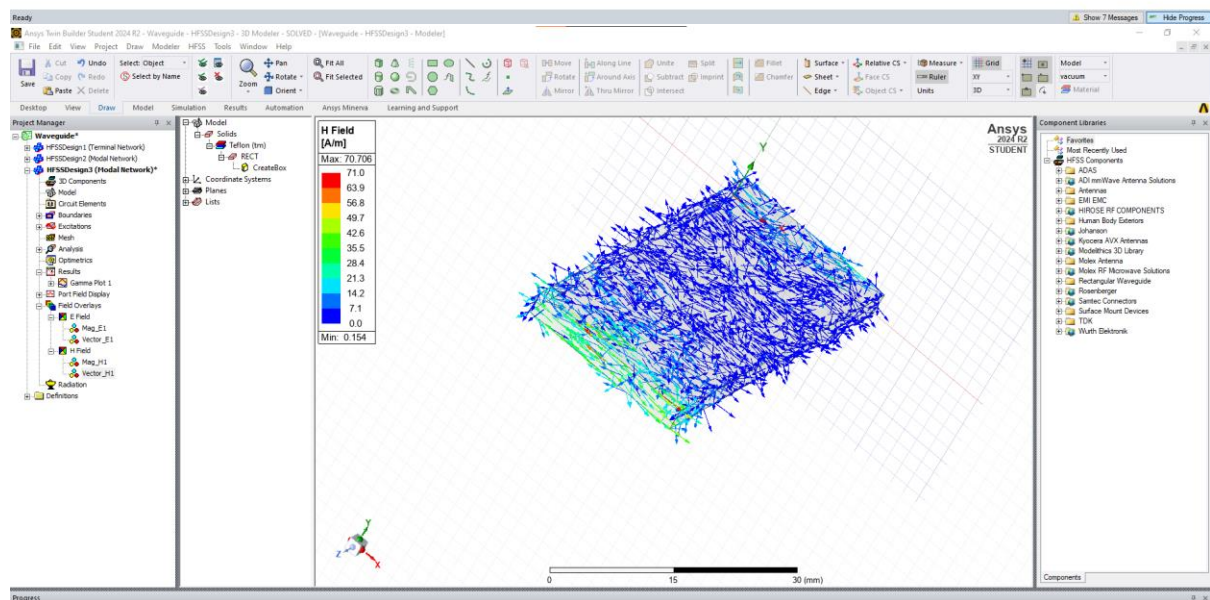


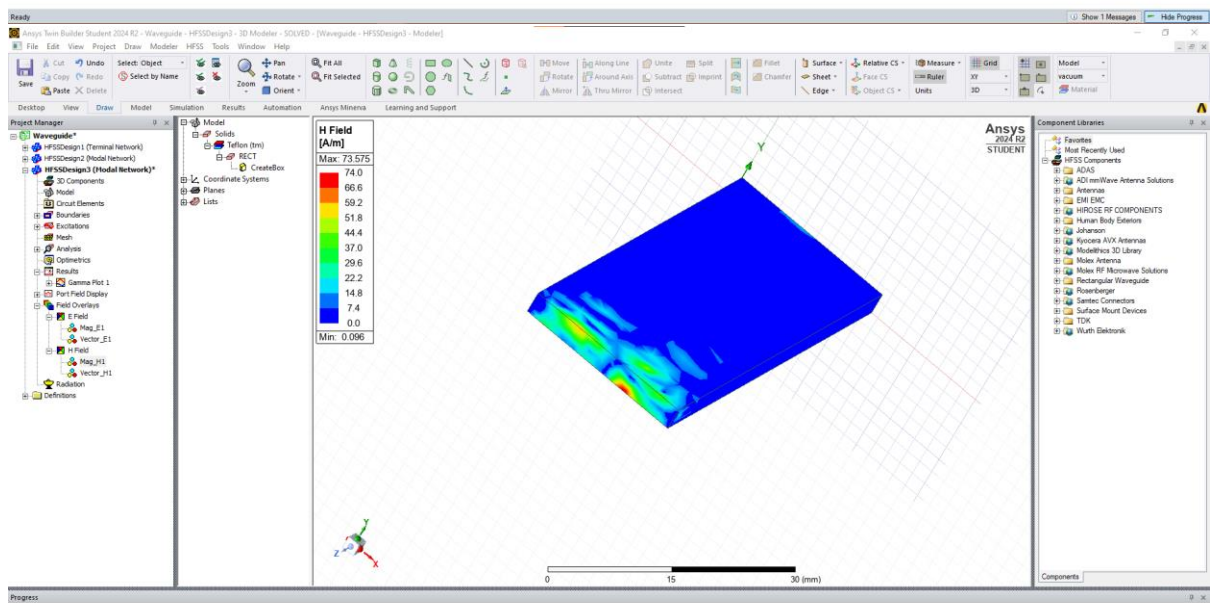
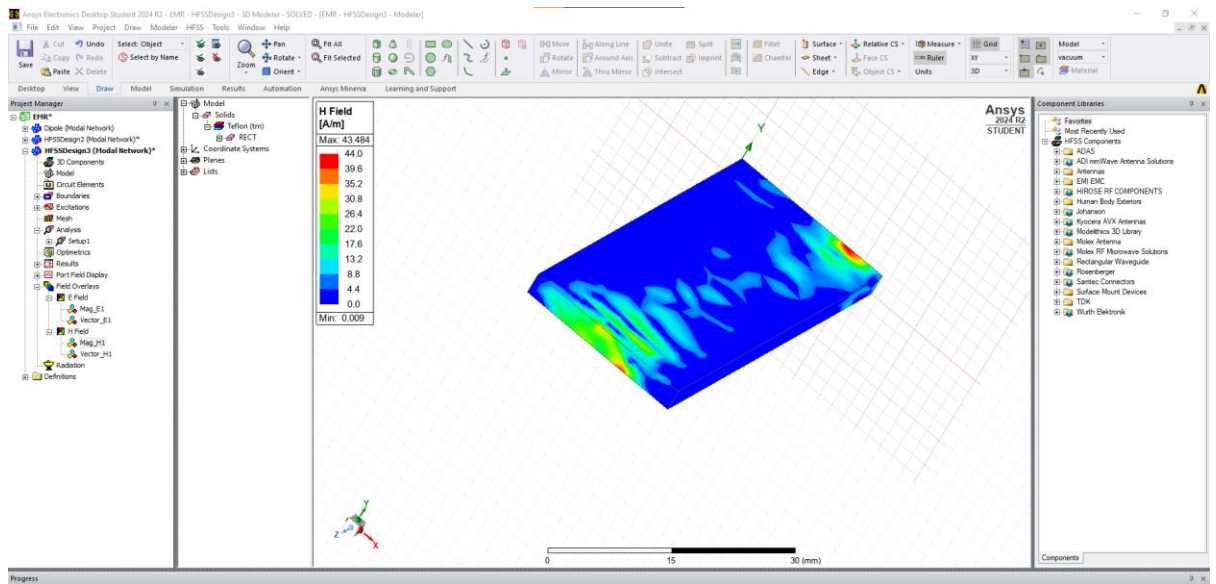
Electric Field Propagation

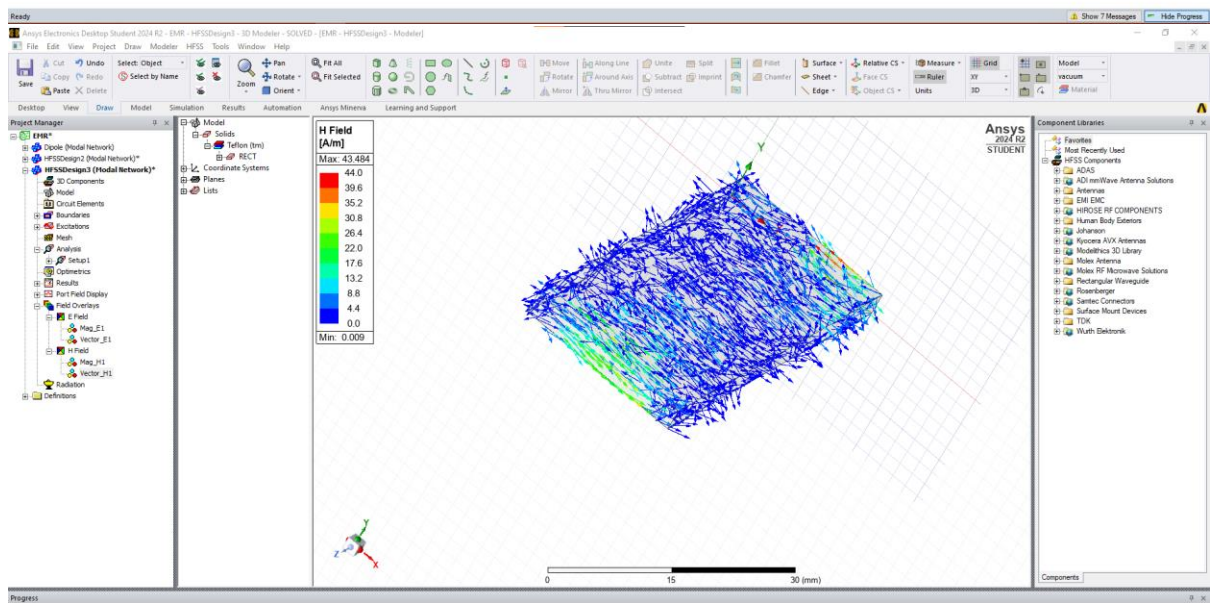
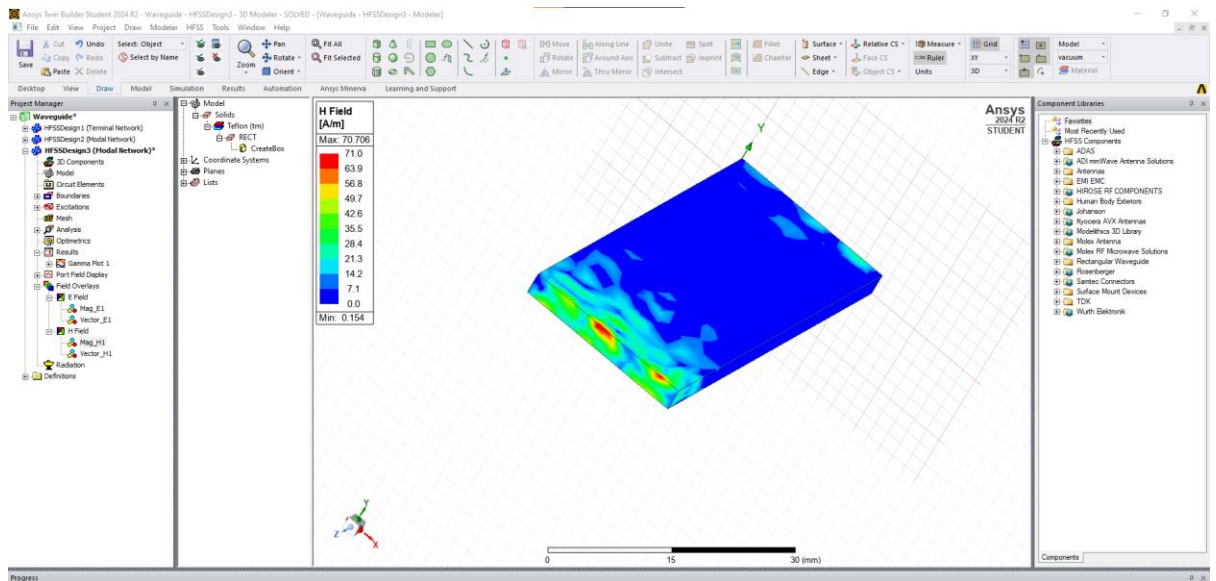




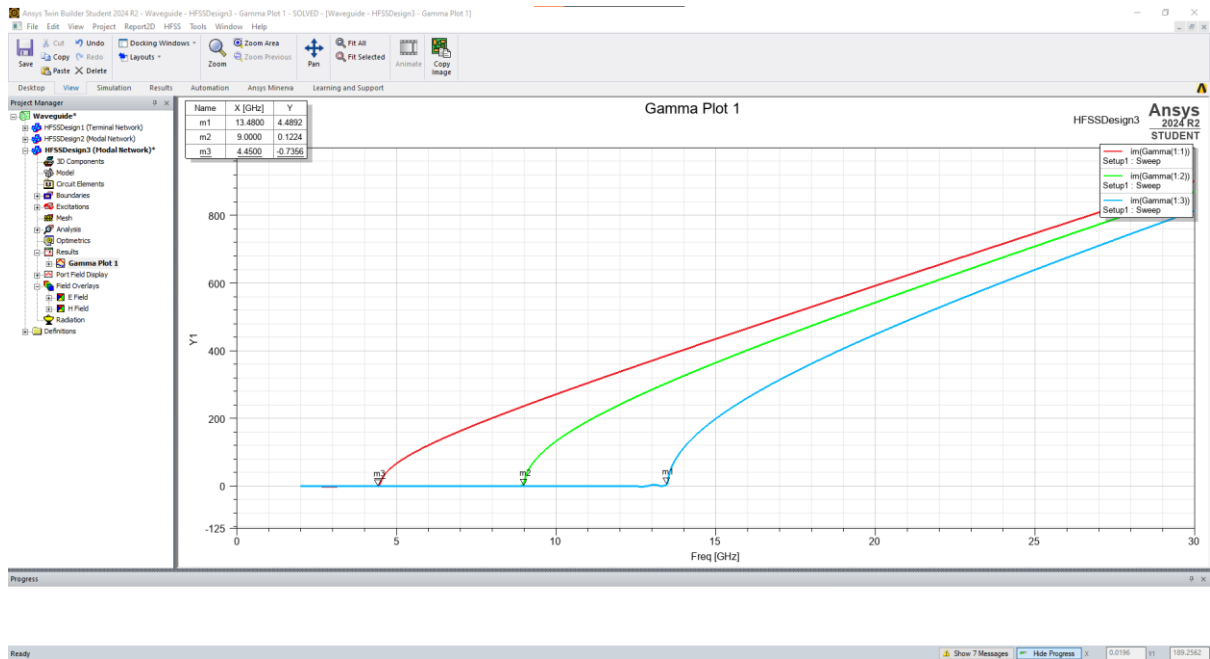








Cut-off Frequencies



TE10 – 4.45GHz

TE20 – 9.00GHz

TE30 – 13.48GHz

Task 2

Length

The defined Wavelength is 230mm (or 1303MHz), to make this a halfwave dipole the length is set to half the wavelength (115mm).

S-Parameters

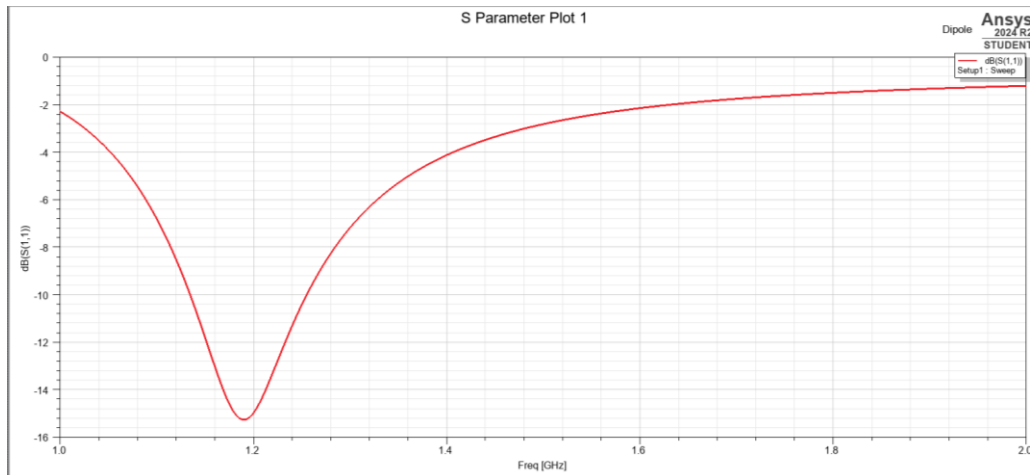


Figure 1

From the above graph it can be determined that the operating frequency of the simulated antenna is approximately 1.2GHz. This result is slightly lower than the designed frequency because of an affect known as fringing, whereby field disturbances caused by the abrupt end of the antenna cause its electrical length to be somewhat lengthened from what would otherwise be expected.

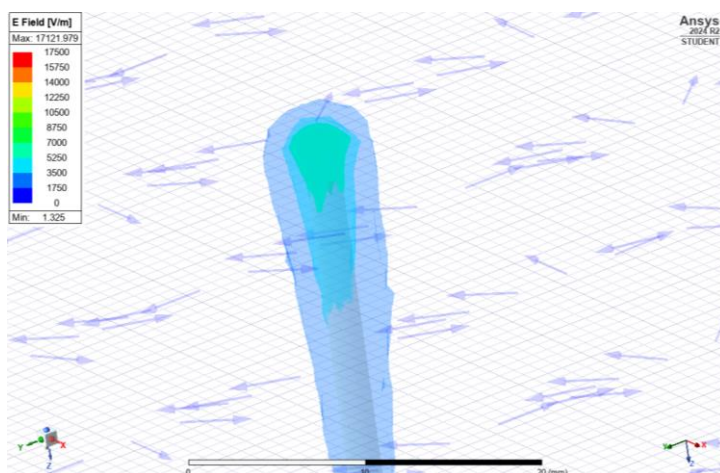


Figure 2

Radiation Pattern

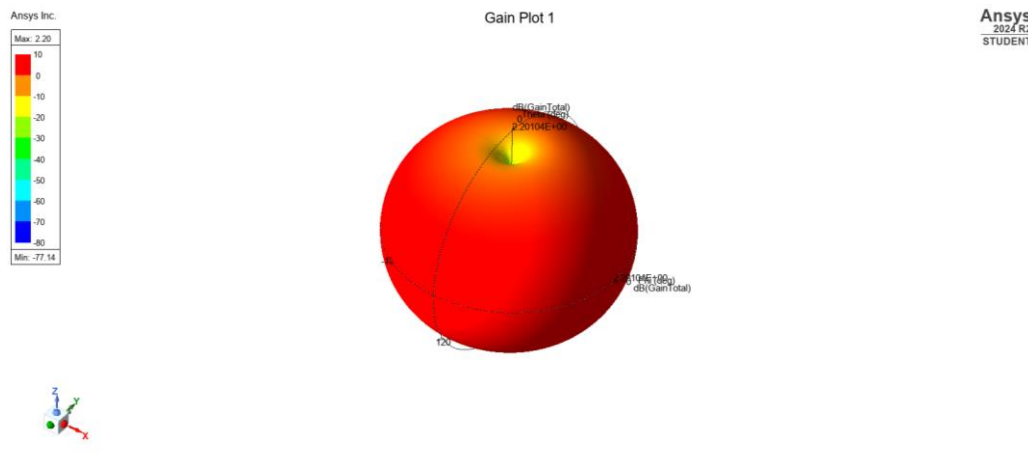


Figure 3

The radiation pattern simulated above appears exactly as expected a toroidal pattern with a gain around 2.15dBi, 2.20 is slightly higher than expected, however this is probably thanks to be constructed out of PEC which is much more performant than any real material.

Discussion

A discussion of these results is extremely challenging as no surrounding context nor purpose has been provided for the simulation. There is no experiment that has been performed to compare against and neither is there a purpose or design goal to evaluate performance or lack thereof against.

The only discussion that can reasonably be undertaken is in comparing the results to anticipated results, which is a pointless exercise. As the simulation software will have been extensively checked in this manner by the engineers who designed it.

The Vacuum waveguide exhibited the same cut-off frequencies the simulation predicted it would and as expected a waveguide with a width to height ratio of nearly 1:8 performed significantly worse than the more traditional 1:1.89, exhibiting significant field instabilities.

The Teflon waveguide did exactly the same as the vacuum, it exhibited the expected frequency response, being slightly lower from the slower propagation through its Teflon filling, and also was thoroughly unstable.

The dipole did have some small surprise in the fringing effects it exhibited, however the total effect of this fringing was less than 10%, in other words a negligible effect.

Conclusion

In conclusion, Ansys is some software which can be used to simulate antennas and waveguide.

Fringing is an effect which can slightly drop the resonant frequency of an antenna.

Designing a waveguide by picking completely random numbers doesn't produce very useful waveguide.

Problem analysis requires a problem to be defined to analyse.

RADAR UAV Discussion

Introduction

This section is a discussion on UAV detection with RADAR and the problems associated therein.

RADAR systems work by detecting Radio Frequency (RF) waves reflected off of objects then by measuring the power reflected and correlating with the time delay from the reflection the approximate size and distance of an object can be determined.

Unmanned Aerial Vehicles (UAV) are becoming an increasing concern for security and military forces around the world due to their low cost, high capacity for damage and ease of procurement.

Discussion

A RADARs ability to detect an object is dependent on the objects Radar Cross Section (RCS), and drones due to their small size and construction from generally low RCS material such as plastic [1] they tend to have a low RCS in the -10dBsm to -2dBsm range [2]

This low RCS does make them harder to detect, but far from impossible or even difficult.

For instance, the Soviet S-125 (NATO Reporting name: SA-3 Low Blow), can detect a target with an RCS of -10dBsm (0.1 square meters) out to a range of approximately 25 nautical miles (29 miles) [3]. With more modern systems such as the 92N2E (SA-21 Grave Stone) from 2007 being able to detect the same -10dBsm target out to 75 nautical miles (86 miles).

These ranges combined with typical UAV speeds of 124-220 mph, would give the SA-3 operator between 14.5 and 8 minutes to react and the SA-21 operator would have between 43 and 23.5 minutes to react.

Both of these reaction times are positively luxurious in comparison to the reaction times they would be afforded by a missile with a similarly low RCS, travelling at multiple times the speed of sound, which is after all the primary designed purpose of an air defence system.

The primary inherent issue with UAVs for RADAR is not *detection* it is *differentiation*. They can be difficult to distinguish from clutter, primarily birds in the case of UAVs. [4] [5]

This *is* due to their small RCS, but it is important to distinguish detection and differentiation. Detection with a RADAR is dependent on the receive sensitivity of the system, the transmitted power, the frequency it operates in and the range of the target. In a large number of modern systems drones fall well above these minimum parameters for detection.

The problem is introduced in differentiation, as most systems currently in use were designed before the modern UAVs battlefield debut, they were designed to deliberately filter out small low altitude target returns, as at the time the only thing producing such returns would be birds, which most military and commercial RADAR systems are uninterested in. However, as UAVs appear to RADAR extremely similar to a bird, this filtering will also remove most drones from the list of valid targets, thus making them hard to *differentiate*.

The reason UAVs are of great concern to military planners and security forces is not because they are some stealthy invisible threat. It is instead because they present a rather difficult dilemma in that the missile used to shoot a threatening drone out of the sky typically costs many times the cost of the drone.

This uneven cost ratio for attacking rather than defending encourages the attacker to simply overwhelm the defender with a massive swarm of UAVs.

Then for the defender they can either bankrupt themselves trying to fend off the attack, or let the attack succeed, both of which are a good outcome for the attacker and terrible for the defender.

No proposals for new methods of UAV detection with RADAR will be made in this report. This is because asking an EW practitioner in training for the Ministry of Defence to propose new methods of detecting a UAV with a drone, something with obvious military applications, is extraordinarily inappropriate. It is a request in an assignment that could very easily be interpreted as trying to manufacture a situation whereby the persons being assigned such a task may accidentally reveal classified material.

So, in light of the above I will not be proposing any new methods of UAV detection with RADAR, as it is a thoroughly inappropriate question to ask someone in my position.

Conclusion

The actual problems associated with UAVs are that they can be difficult to distinguish from clutter on a RADAR scope, if they aren't rejected by the systems clutter filtering and the cost dilemma that they inflict upon any defender.

References

- [1] H. S. a. R. M. Jha, "Theory and Applications," in *Active Radar Cross Section Reduction*, Cambridge University Press, 2015.
- [2] M. Ezuma, C. K. Anjnappa and V. Semkin, "Comparative Analysis of Radar-Cross-Section-Based UAV Recognition Techniques," *IEEE Sensors Journal*, vol. 1, no. 22, 2022.
- [3] D. C. Kopp, "Engagement and Fire Control Radars," January 2009. [Online]. Available: Dr Carlo Kopp. [Accessed 27 April 2025].
- [4] N. V. L. P. V. T. a. P. D. T. Tran VU HOP, "A Discrete Clutter Reduction Method for Drone Detection with High Resolution Radars," IOS Press, 2022.
- [5] H. J. M. C. Woosung Hwang, "Clutter Cancellation Methods for Small Target Detection Using High-Resolution W-band Radar," 2023.