ISSN 2347 - 3983
Volume 8. No. 9, September 2020
International Journal of Emerging Trends in Engineering Research
Available Online at http://www.warse.org/IJETER/static/pdf/file/ijeter64892020.pdf
https://doi.org/10.30534/ijeter/2020/64892020

Analysis of the Various Properties of an Antenna Array's Radiation

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ABSTRACT

As technological innovations improve over time, antennas have become an inherent piece of our everyday lives and it is essential for individuals to understand how data is moved through these devices. There are different methods of deciding how energy can be transmitted by antennas in an efficient manner, and not all things are seen on the antennas themselves, as there are a few issues that may emerge from the transmission cables that they are associated with too. A common method of deciding how an antenna can transmit signals of energy is through the analysis of its radiation pattern. The radiation pattern of an antenna is able to determine how energy is radiated or data is propagated by a particular antenna. This analysis will focus on understanding the graphs of radiation patterns, beam scanning, patterns of arrays, and other types of graphs. Understanding all of these concepts are important in order to have the ability to effectively utilize antennas such as being able to maximize the amount of distance possible when correctly positioned and also having the ability to boost signals from other devices.

Key words: Azimuth, Directivity, Radiation Pattern, Antenna Systems.

1. INTRODUCTION

One of the greatest inventions known to man is the antenna as it was able to vastly improve the manner in which we transmit and receive data every day. However, as engineers, we should be asking the question of how does one know whether the antenna is working the manner in which it should, or to be more specific how can one make it effectively radiate energy and how far it can communicate it from? These questions can actually be answered by having a better understanding of radiation patterns and other graphs related.

The calculations on how to properly design an antenna are based on a source where it has the ability to equally transmit energy on all directions which is more commonly known as an isotropic source. However, in real-life scenarios, this is a long way from being accurate as there are different parameters that can influence an antenna's performance and transmission. Antenna signal transmission would also rely upon where the receiving antenna is found and what encompasses it [1, 2, 3]. With this in mind, an isotropic source can be utilized as a basis as it can be useful when it comes to closely emulating what is expected when designing an antenna.

As engineers it is significant to understand the operation of an antenna as transmitting and receiving data through the use of electronic devices is currently playing a huge role in this day and age [4]. The manner in which we utilize the web would likewise require properly working antennas and satellites as this is the premise of how transmission of data happens around the world. Additionally, it can be said that we would most likely not come as far as we have today if we are without the proper understanding of the proper designing and operations of an antenna.

Despite the fact that these ideas or concepts are already existing and developed, there are still possible developments that can be made such as designing and producing a more efficient system or possibly providing improvements on the way we are able to communicate with one another around the world.

2. BACKGROUND OF THE STUDY

As the world improves over time, antennas have had a tremendous impact on our everyday lives. With this in mind, there is great importance when it comes to understanding how an antenna performs. To further discuss, understanding antennas can aid when it comes to comprehending signal reception and how a certain area's reception could be affected. For instance, for antennas that are being used by vessels, it is conceivable that the vessel antenna receiver may get information from more than one way which may include either a useful or damaging interference from the received signal [5, 6].

Antennas usually come in various styles and sizes which rely upon what it is to be used for such as basic dipoles like the "Yagi Uda Antenna", collapsed dipole, etc. There is also something called the "Antenna Array" which is an antenna

that transmits and receives radio waves however it is made out of multiple different antennas that acts as a single antenna. Antenna arrays are also very significant as it has the ability to provide a high amount of gain and directivity when alongside beam scanning [7]. Additionally, antenna array's are also used when it comes to producing high-resolution images or videos as this would normally require tremendously high frequencies such as the terahertz range to have the option to appreciate having these resolutions [8, 9, 10].

As expressed earlier, antennas have played a vital role when it comes to the progressions of our generation, some of which include the manner in which we transmit and receive information. With this in mind, antennas are not just for the purpose of communication but also for our personal pleasure such as the different features it could provide for our entertainment. Additionally, it can be said that it is important to understand antennas and its different parameters as without the understanding of these an antenna would not function properly and none of these would be possible.

3. STATEMENT OF THE PROBLEM

When it comes to learning and understanding an antenna one of the biggest problems being encountered by future engineers is how the lecture lessons only tackle the theory and not the actual data from a practical application. This research aims to help researchers learn about the different properties of an antenna and how to understand these properties.

A portion of the properties that will be discussed and will appear in this research are topics that are not really elaborated on in lessons from lecture classes, yet it very well may be comprehended with the help of prior knowledge obtained from previous electronics and communication lecture classes. As mentioned earlier in the paper, this paper aims to aid in improving the learning and understanding of radiation patterns, beam scanning, patterns of arrays, etc.

It should also be noted that the study will not be dealing with the mathematical theories of the topic which is already being taught in the lecture class, however, it will focus more on being able to learn and understand the graphs presented and what each of them would mean or represent. With this in mind, the graphs presented will hopefully aid researchers and future engineers in a way that would make them better appreciate and understand the theories being learned in a lecture course and also appreciate how antennas operate and are being implemented in real-world situations.

4. SIGNIFICANCE OF THE STUDY

The importance of the study being conducted is to provide researchers a better understanding of the graphs of different antenna properties. To further discuss, an antenna's radiation pattern is one of the most significant properties to understand as it provides knowledge on how much energy is being directed by an antenna in a certain direction and also the propagation's wideness or narrowness at a specific direction. Additionally, this is very significant to understand as engineers in the real world would use this to decide the most proficient direction for an antenna to work at its maximum capability. Array patterns on the other hand are used in order to determine the directivity of an antenna when it is directed at a specific direction and angle. In addition, is also used for enhancing the antenna's performance by determining the required spacing between the arrays and the wavelengths' factor.

To support the validity of the study being conducted numerous theories and concepts were used and applied by the researchers to the antenna array. Additionally, it also has a fairly similar idea to the Yagi Uda Antenna, whereas the antenna array's number of elements is directly proportional to the system's power. Moreover, this relationship is due to the fact that in order to improve power in a specific direction the power being radiated by each element of the antenna array is summed up and focused on that specific direction, however, it should also be noted that this in return drops or cancels out the power in undesired directions.

5. DESCRIPTION OF THE SYSTEM

The researchers designed a system that investigates the properties of an antenna array, whereas the length and spacing of each element are determined. With this in mind, other different parameters or properties of an antenna are produced by making use of the computer programming language MATLAB. The code produced to simulate the system was done in this specific application as it already provides a specific set of commands and functions that can produce the results needed to better understand an antenna. Additionally, to determine how certain properties that would affect the system the values of the variables placed were varied in order to determine the behavior of the system.

6. METHODOLOGY

In this project, an antenna array is implemented in MATLAB by clearly determining the following properties: the length of the antenna element and space between the elements. Since MATLAB can perform calculations with very minimal loading time, MATLAB is used for this project. Additionally, due to the availability of the antenna array analysis toolbox, MATLAB is used, for it is easy to use, implement, and modify an antenna array to what the researchers see fit. In the code, the “dipole_tuner.m” and “phaseshift.m” function from the antenna array analysis examples of MATLAB is used in this project.

7. REVIEW OF RELATED LITERATURE

In the study of Alibakhshikenari and Virdee [11], due to the requirement of very high frequencies that would reach terahertz or would mostly operate in the terahertz region, a conceptual 34x34 antenna array is developed for 8K

resolution video transfer and streaming. To deal with this frequency range of 125-300GHz, a 34x34 antenna array is designed where a technique that deals with the isolation of antennas with metallic via-holes and then in the periphery of the patch antennas embed a circular dielectric slot is proposed. This technique is believed to have better gain and efficiency. Using the method of moments and finite element method to base the full-wave electromagnetic solvers, Alibakhshikenari, and Virdee have optimized the design of a 34x34 antenna array [12].

The study of Castro, Dopazo, Alvarez, et al is about developing a method of evaluating accurately the antennas on ships, for scattering by the factors on a ship prevents the ship to receive signal from a certain angle of the radiation pattern of the antenna installed. Since the multipath effect could occur, there are problems needed to be accounted for when measurements are to be done on ships. Although doing the suggested way of solving the multipath effect is long and tiresome, the study of Castro, Dopazo, Alvarez, et al proposed a two-ray model. The two-ray model describes the scenario at hand, then validate the created model using data acquired through different frequencies that the model is tested upon, and study the data to see if it could provide knowledge to the researchers as to the effect of reflection of signals from the waves with respect to what is measured on the data of the antenna [13, 14, 15].

Since antennas that are large and fixed in a certain position are difficult to implement a test field and practically impossible due to other factors, the study of characteristics of antenna radiation by using small unmanned aerial vehicles (UAV) is proposed by Zhang, Shuang, Chen, et al. The use of UAV is proposed, for the researchers believe technological development in UAV is developed enough to a point that UAV can be applied in their study. In their study, UAV is applied through understanding radiation patterns using a drone with a connected RF transmitter and test antenna. The important parameter in their study is getting the position of the UAV and having a synchronous signal. Using a synchronized GPS receiver that is placed on the ground, the important parameters are tackled where the GPS receiver would be able to track where the UAV is in real-time. In order to get accurate data on their studies, the antenna radiation properties are determined to get an accurate representation of the data which will establish whether the proposed UAV system is accurate [16, 17, 18, 19, 20].

Similarly, to the previous study, the study of Naghdehforushha and Moradi [21] is about wireless terahertz technology where higher transfer rates are needed to be considered successful. To execute these types of operations on this frequency, the device is suggested to be made of graphene. Due to its ability to alter and tuning its conductivity complex, graphene can be applied in nanoantennas and other different applications. Since graphene antennas have low gain and radiation inefficiencies, the researchers assume that the graphene sheet is not exposed to any external magnetic field and has an isotropic conductivity [22, 23, 24, 25, 26].

Due to the numerous number of paths wherein the data is able to pass through, as well as the relationship between them, the study of Abril-García, Tapia-Rodríguez, García-Juárez, et al [27] is about finding the direction of arrival and time delays of a certain system. This study is important in multipath measurements, the accuracy of these directions of arrival, and time delays specifically for an environment where it is a non-line of sight. To identify these parameters, the azimuth angle of arrival and the elevation angle of arrival is used with their proposed algorithm and their yielded estimation of the parameters to accurately estimate the bad channel conditions such as low signal to noise ratio and harsh multi-path channels. By reducing the computational complexity of the algorithm, the algorithm can be used for applications that do not require accurate estimations for bad channel conditions [28, 29, 30].

8. THEORETICAL CONSIDERATIONS

Because the experiment aims to find a further understanding of radiation patterns and how they can be interpreted when encountered in various applications, the main theoretical consideration is that no hindrances are present in the antenna array's path that could interfere with it. Because of the absence of obstructions, it can be said that the simulations are done in ideal conditions. This is done to find the best possible patterns of antenna array radiation for specific frequencies. In terms of considerations for the use of MATLAB [31] in simulating a dipole system, the code includes graphical outputs to produce a visual representation of the simulation data in order to easily identify the peaks in the radiation strength, as well as other important observations about the antenna's radiation.

9. DATA AND RESULTS

Figures 1 to 8 shows the different simulation models. MATLAB was used as a simulation tool.

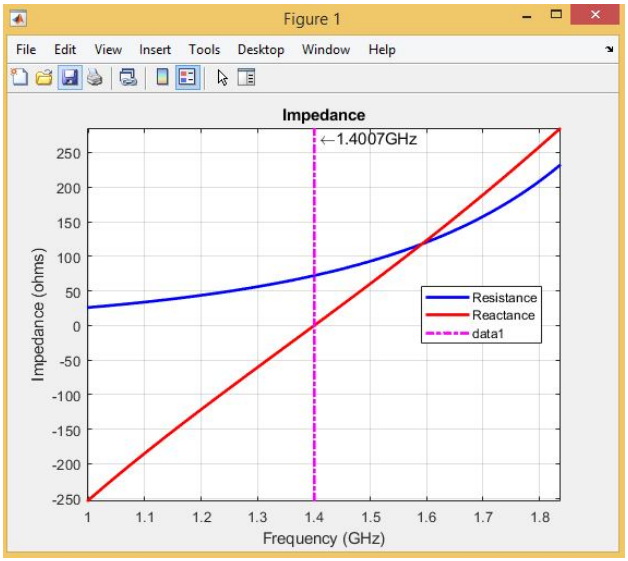

Figure 1: Impedance vs Frequency Graph

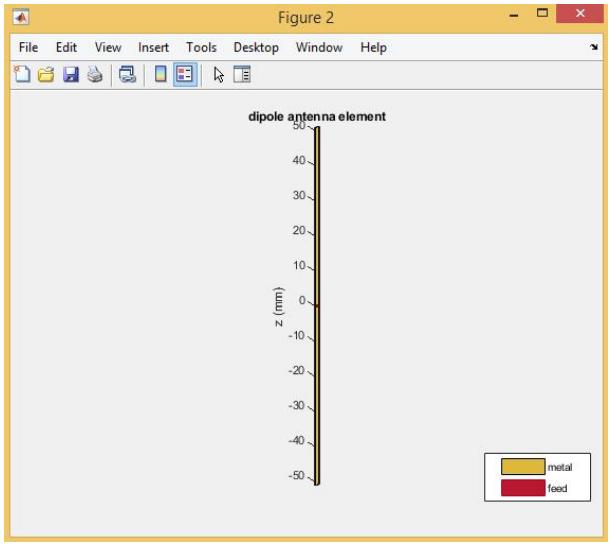

Figure 2: Dipole Antenna Element

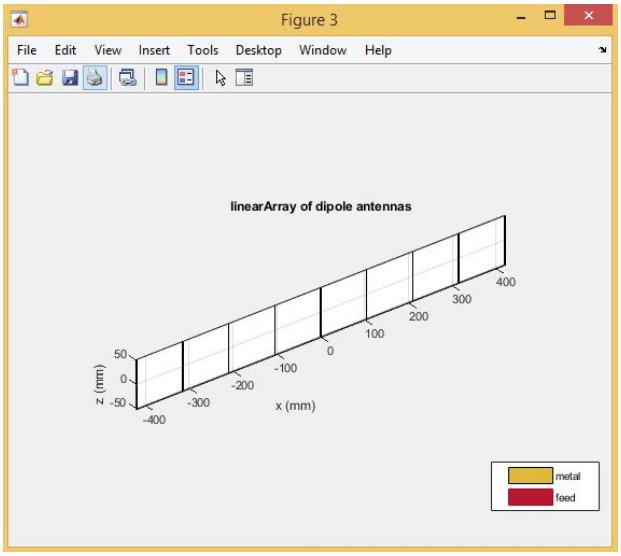

Figure 3: Linear Array of Dipole Antennas

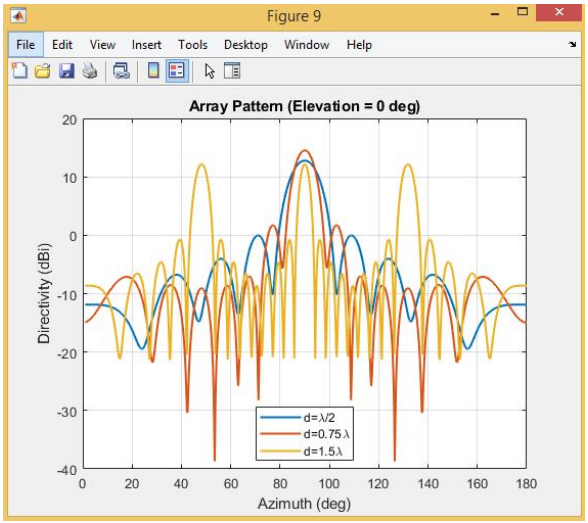

Figure 4: Pattern of the Array

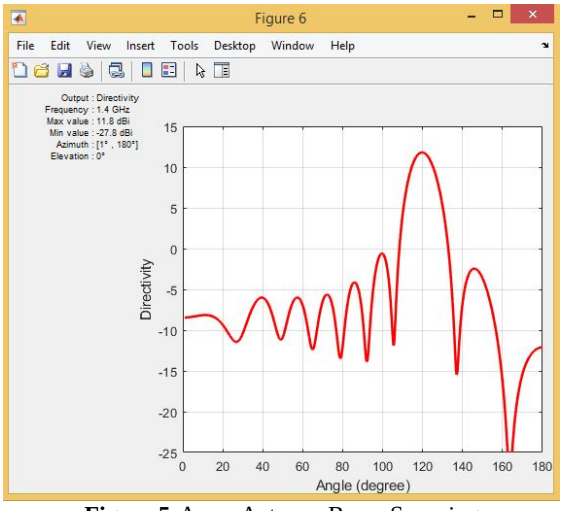

Figure 5: Array Antenna Beam Scanning

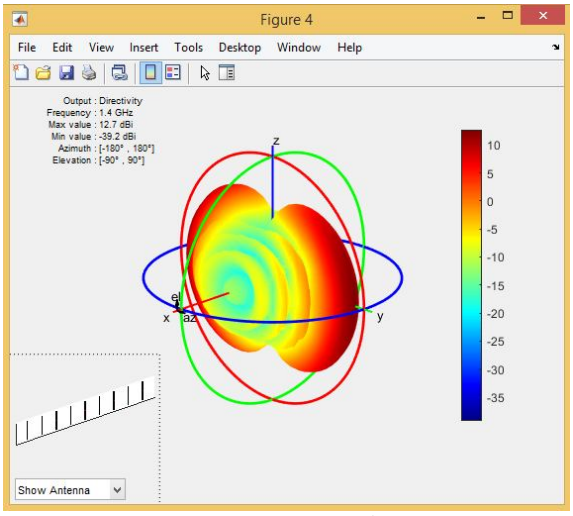

Figure 6: Antenna Pattern of Radiation

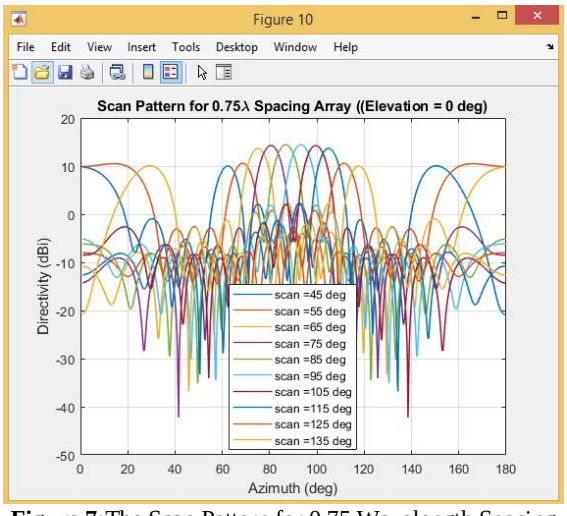

Figure 7: The Scan Pattern for 0.75 Wavelength Spacing

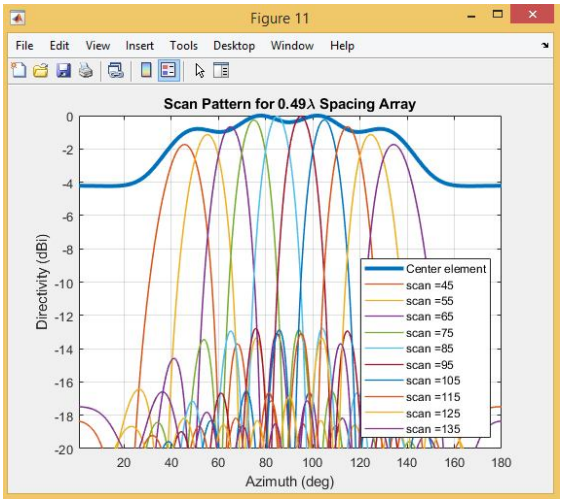

Figure 8: The Scan Pattern for 0.49 Wavelength Spacing

10. ANALYSIS OF DATA

Based on the results, it can be easily observed where the peak of the antenna's radiation strength is present in the resulting radiation patterns. Given a specific wavelength factor and distance from an antenna array, the directivity power can also be seen. It can also be observed that there is a peak directivity produced by the antenna arrays with respect to an azimuth angle for a given distance. Given the information from these results, it can be found where antenna arrays perform the best when it comes to signal transmission. Furthermore, the impedance chart shows that resonance occurs at 1.6GHz, meaning the system's resistance and reactance converge or meet at approximately the same frequency.

Based on the scan pattern charts, the optimal spacing or distance between antennas was obtained in order to result in better directivity. Antennas that are spaced from one another and have a factor of 0.75 produced better directivity gain than those with 0.49 wavelength factors which only exhibit unity gain.

Additionally, based on the results obtained, it can be seen that varying the frequency does not significantly affect the system's output as most of the data and outputs will remain the same despite frequency changes.

11. CONCLUSION

The researchers have therefore concluded that learning about the properties of antennas and their behavior plays a huge role in learning and working with communication systems. This is because antennas are widely used nowadays, especially with the dawn of wireless systems that transmit data. Furthermore, the study of antennas will greatly help in the further development of 5G technology, which requires innovation and upgrades to the current wireless systems that many countries have.

While the results and data obtained from the simulations performed are not as innovative and crucial in modern wireless technologies, they still serve as a great foundation for understanding wireless systems and the concepts involved may lead towards the development of better and more advanced wireless systems involving antennas - thus resulting in better, faster, and more efficient data transmission.

As many new technologies arise in the field of wireless communication such as 5G and high quality or high fidelity data transfer, developments are needed on the transmission systems as well. With the understanding and further study of the basics and fundamentals of antennas, students may be led to innovations to support the global demand for data transmission and new technologies that provide better transmission at the cost of being too taxing for current or obsolete systems to support.

12. RECOMMENDATIONS

It is highly recommended for future works or experiments related to or involving the topic tackled in this paper to focus on non-ideal simulations. This may be done by introducing interferences or hindrances to signal transmission in the simulations in order to obtain more realistic results, those closer to real-life behaviors of wireless communication systems involving antennas. It may also tackle possible diffraction experienced by the antenna and the signal being transmitted, as well as the energy sent through the diffracted signal's direction.

In terms of simulation considerations, extra spacing may be implemented in order to observe if there are better spacing for better directivity gains or to simply observe how the gain varies with respect to distance. Changing some parameters may also be done in order to observe their relationship with the overall radiation pattern, and to prove any equations or concepts that may result from these found relationships between the varied parameters and results.

Another recommended objective would be to compare antenna arrays for specific frequencies to possibly conclude which arrays are best for a given frequency range. This can be done by comparing simulation results regarding performance and efficiency, with varied trials and parameter changes for further observation leading to a reliable comparison.

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