ISSN 2347 - 3983
Volume 7, No. 8 August 2019
International Journal of Emerging Trends in Engineering Research
Available Online at http://www.warse.org/IJETER/static/pdf/file/ijeter11782019.pdf
https://doi.org/10.30534/ijeter/2019/11782019

Effect of Dielectric Substrate on Dipole Antenna Directivity

Aaron Don M. Africa, Antonio Miguel Sarmiento Alejo, Grant Lewis Milan Bulaong, Samantha Maxine Ronquillo Santos, Jerrick Spencer Kehyeng Uy

Department of Electronics and Communications Engineering
De La Salle University, Manila
2401 Taft Ave., Malate, Manila 1004,
Philippines, aaron.africa@dlsu.edu.ph

ABSTRACT

This paper aimed to determine how the directivity was affected by the dielectric substrate in the dipole antenna. The researchers had to choose different substrates and specific property of antennas in order to produce this study. Given all these substrates, the study focused on which of these would produce the best results that would be beneficial to antennas of a certain function. For this case, it is the directivity of the antenna that is being researched on. Through the use of the Matrix Laboratory (MATLAB) software, the researchers were able to conduct a comparative study on these different substrates to obtain their directivities. After the researchers conducted the simulation, the dielectric substrate, Fused Quartz was found to have the least value in directivity while Air had the highest directivity. Additionally, the researchers were able to deduce that the lower the constant of the material, the higher the directivity of the material. This showed that the relationship between the two variables was inversely proportional.

Key words: Dielectric Substrate, Dipole Antenna, Directivity, Substrates, Fused Quartz.

1. INTRODUCTION

In recent years wireless communication systems have increased the number of devices that would connect to wireless networks. From modern house appliances to cellular gadgets, the connection of those devices all relied on one common component; the antenna. Although there were several factors that affect the antenna propagation like geometric shape, material type, and length and width; dielectric substrates could have greatly impacted the propagation of the antenna without drastic changes on the geometric aspect of the antenna. Different substrate materials could have had an effect on the performance and characteristics of the antenna [1]. Some of these characteristics improve on the antenna use, some examples are flexibility, robustness, compact nature and retain excellent performance. High dielectric- constants affect the antenna by decreasing the efficiency and suffers from a very narrow bandwidth [2]. That suggested however that the material for dielectric-substrates affect the efficiency of the wave emitted by the antenna. Some common dielectric substances included bakelite,R04003,

Taconic TLC FR4 Glass Epoxy, and RT duriod. Those different dielectric substrate types differ in multiple properties like return loss, antenna gain, directivity, and bandwidth. However, for the study, the only directivity was prioritized.

The researchers intended to observe the effect of different dielectric substrates on a simple dipole antenna; specifically, the directivity of the wave polarization. That was due to the nature of dipole antennas to polarize greater in a specific direction. That magnitude could then have been computed and compared to different types of dielectric substrates. That would have been done by simulation in a matrix laboratory application (MATLAB). With the help of different toolboxes, a simulation of the antenna would have been made. Since a dipole antenna was the simplest antenna type, as well as the most common type of antenna this class of antenna would have been used to analyze the results to see if the directivity of the antenna was affected.

2. BACKGROUND OF THE STUDY

The dipole antenna was considered one of the most basic types of antenna and was used because of its practicality. There were different types of substrates that would be used as a layer that would support the antenna. The different substrates that were used were applied given that they were available on the matrix laboratory (MATLAB) software. Five substrates were used to produce different figures and different values for directivity. These substrates were: Air, Teflon, Foam, Polystyrene and Fused Quartz. The relative permittivity of the five substrates was found as follows: 1 for Air, 2.1 for Teflon, 1.03 for Foam, 2.55 for Polystyrene, and 3.78 for Fused Quartz. All of the values of which were obtained from MATLAB. For this paper, the dipole antenna was used because it closely resembles the input impedance. The researchers decided to choose one property that could be further studied in order to see if the dielectric substrate in a dipole antenna would affect the directivity. Directivity was a parameter that was used to quantize the directional flow of the antenna's pattern. So, for example, if the antenna has radiation that was symmetrically equal all around, then that means that it has a directivity of one. Additionally, if the directivity was equal to one, then the directionality would be zero. The directivity of an antenna relies heavily on its function. The greater the directivity, then the more pivoted or focused the signal would be. An example of an antenna that required a high directivity would be satellite dish antennas. This was because these antennas transmit and receive signals at a fixed location. An example of antennas that require low directivity would be walkie-talkies or cellphones. The reason for this was because it required to be able to receive signals in all directions. If the directivity were high, then people would only be able to receive calls from a certain point or angle.

3. STATEMENT OF THE PROBLEM

The latest trends in the field of signal transmission suggest that antennas with higher directivity and relatively higher gain are become increasingly necessary this field especially in large-scale, unidirectional communication systems for them to operate more efficiently. For example, antennas for consumer cell phones must be designed to have a low directivity because the signal can come from any direction, and the cell phone antenna should be able to receive it. In contrast, satellite dish antennas, which are much larger, must be designed to have very high directivity, because they are to receive signals from a fixed direction [3]. It has been shown that when the performance of antennas with a substrate having higher relative permittivity is compared with that of antennas with a substrate having a low value of relative permittivity, the difference in permittivity is considerable [4]. Also, directivity can be increased by using a multilayer dielectric-covered layer structure.

4. SIGNIFICANCE OF THE STUDY

The study proved to be significant due to the increase in wireless communication systems found in both household devices as well as handheld devices. dielectric substrates on antennas, specifically on soldered on antennas make use of this form factor for several reasons. Primarily on its easy and cheap application, the antennas that would be installed on devices allowed the use of wireless communication between devices as well as the internet. This alone allowed the manufacturers to expand the features found commonly used devices. In addition, another advantage this form factor offers is the flexibility of the antenna allows different use cases when applying this technology to the device. With the design of the circuit however, a dielectric substrate allows a better circuit to be made. Different dielectric substrates, however, are available to manufacturers hence a better understanding of the directivity and the characteristics of these dielectrics are important in designing these circuits. With the analysis of the directivity of the dielectric substrates, the directivity of the dielectric could be highlighted. The use of a dipole antenna makes sure that only the dielectric properties would affect the directivity of the propagation.

5. DESCRIPTION OF THE SYSTEM

A simulation comparing the resulting directivity of a dipole antenna after using five different types of mounting dielectrics (air, Teflon, foam, polystyrene, fused quartz) is introduced in this paper. The simulated antenna was tested over each dielectric material using a 4-meter band wave (70 MHz). The dipole was configured to support frequencies within the VHF band in order to accommodate the said wave.

6. METHODOLOGY

The researchers formulated the following MATLAB script in order to test a theoretical dipole antenna against the five dielectrics. The script required the use of the 'Antenna Toolbox' from MathWorks.

```
clc
clear
d = dipole('Length',0.15,'Width',0.015, 'Tilt',90,'TiltAxis',[0 1
0]);

t1 = [dielectric('Air')];
rf1 = reflector('Exciter',d,'Spacing',7.5e-3,'Substrate',t1);
rf1.GroundPlaneLength = inf;
show(rf1)
pattern(rf1,70e6)
dAir = pattern(rf1,70e6,0,90)

t2 = [dielectric('Teflon')];
rf2 = reflector('Exciter',d,'Spacing',7.5e-3,'Substrate',t2);
rf2.GroundPlaneLength = inf;
show(rf2)
pattern(rf2,70e6)
dTeflon = pattern(rf2,70e6,0,90)

t3 = [dielectric('Foam')];
rf3 = reflector('Exciter',d,'Spacing',7.5e-3,'Substrate',t3);
rf3.GroundPlaneLength = inf;
show(rf3)
pattern(rf3,70e6)
dFoam = pattern(rf3,70e6,0,90)

t4 = [dielectric('Polystyrene')];
rf4 = reflector('Exciter',d,'Spacing',7.5e-3,'Substrate',t4);
rf4.GroundPlaneLength = inf;
show(rf4)
pattern(rf4,70e6);
dPoly = pattern(rf4,70e6,0,90)

t5 = dielectric('Fused quartz');
rf5 = reflector('Exciter',d,'Spacing',7.5e-3,'Substrate',t5);
rf5.GroundPlaneLength = inf;
show(rf5)
pattern(rf5,70e6)
dFusedq = pattern(rf5,70e6,0,90)
```

The dipole antenna was specified to have a length of 0.15 meters, which results in a maximum acceptable frequency of 200 MHz. This is within the VHF band. Additionally, the width of the antenna is 0.015 meters, which is a typical antenna dimension [5]. The antenna is mounted parallel to the dielectric base by setting its tilt to 90.
Once the results of the experiment were obtained, a comparative analysis of the dielectric constants of the materials vs. dipole antenna directivity took place.

7. REVIEW OF RELATED LITERATURE

7.1. Dielectric Substrate

Quality of communication was seen to be highly dependent on antennas [6]. Antennas always stood as the very core and means for wireless communication systems [7]. Even so, they have also hindered any efforts towards making those systems smaller. With that in mind, they utilized the microstrip antenna carrying a metallic radiation patch to be applied onto the dielectric substrate. The shape of the patch could have been selected from a wide array of choices to fit better in terms of improving performance and analysis. Moreover, the microstrip antenna's dielectric constant was low to improve the edge radiation field intensity. Consequently, the constant of the substrate needed to be above 5 to work well with the formerly mentioned antenna.

In order to function at 2.4 GHz, they needed to analyze the nonradiating edges of each of the array's corresponding contents [8]. On the edges, there were the optimized rectangular microstrip antenna arrays with tabs in the shape of a semi-circle and four elements, corporate-fed, respectively [9]. They created antenna formations with the 1.6 millimetre thick FR4 dielectric substrate at a 4.4 permittivity. They tested the antenna's output and performance in terms of bandwidth, return loss, radiation patterns, and gain and then consequently determined the difference between those rectangular microstrip arrays with the conventional single-element versus semicircular tabs at the specified frequency.

Chemical and biochemical sensing was made easier and more efficient through the use of surface-enhanced Raman spectroscopy [10]. Surface-enhanced Raman spectroscopy was found to be more intense in the presence of an optical interference substrate with a dielectric spacer. In support of the initial substrate and spacer, a reflector was used as a back-up. The researchers, therefore, developed highly sensitive surface-enhanced Raman spectroscopy substrates with their own core-satellite nano-structures and silica-covered silicon interference layers. Due to the specific thickness and reflectivity of the silica spacer and silicon substrate respectively, the surface-enhanced Raman spectroscopy was seen to work better because of opposing signs in reflected coefficients. Moreover, in order to maximize the intensity of the nanogaps in the middle of the nanoparticles, all they had to do was vary the silica thickness [11]. To accomplish the latter, interference of reflected light should have been defined to add hot spots.

Power electronics have proven to be hindered in their durability and capability to perform by their very own packaging [12]. Regardless of how unique the device is, the problem was seen to still hold true [13]. With that in mind, the researchers created an integrated package assembly with layers of a copper circuit on the aluminum nitride dielectric used with the aluminum-silicon carbide substrate. Due to their modified packaging, its properties for thermal cycling has increased to become more reliable compared to the conventional direct bonded copper assembly. Above the factor of 18, the researchers were able to increase the thermal resistance in contrast to heat spreaders made out of thick copper. To further remedy the thermal performance situation, they integrated the single-phase liquid cooling into their layer to match the heat spreaders and cause a balance.

In the frequency range of infrared and visible, the researchers were able to create a multi-circular ring for perfectly absorbing metamaterials [14]. Similar experiments have already been conducted to prove the possibility [15]. Those were made possible due to the unity solar energy absorption method which was dependent on quite a number of factors. Those factors included the size, substrate thickness and composition, polarization effects in the transverse electric and magnetic modes, and even resonator effects. Their creation was able to perfectly absorb due to the patterns of low conductivity in aluminum metals and gallium arsenide dielectric substrates all in the ring. Moreover, the used the CST microwave studio and high-frequency structural simulator to determine the parameters for absorption in both frequencies. The reason behind its presence in both frequencies was the various electric and magnetic modes. Their results allowed them to conclude that their absorber was unaffected by polarization angles and was specifically perfect in the mentioned frequency ranges. Finally, they realized that their creation could have been utilized in sensing, imaging, stealth technology, and renewable solar energy.

7.2. Dipole Antennas

In order to detect real-time small fluctuations, a direct sampling method was utilized [16]. It was functional in various dynamic parameters due to the fact that it made use of a few dipole antennas. Their direct sampling method was proven theoretically with its indicator function depicted infinitely by Bessel functions of integer order, antenna configurations, and order zero of the Hankel function [17].

The researchers were able to remove membrane generated curl in the folding pattern of orbital mission devices to improve directionality with a strip material [18]. The strip material had a shape recovery function. Shape memory alloys were utilized in order to distinguish the wrinkles from the shape recovery [19]. Moreover, as they used the the alloy materials for the radiating area of the antenna, they were able to determine the method to monitor shapes through the evaluation of antenna gain changes after being affected by the alloys. Through the use of a dipole antenna, with the alloy material, and a circuit board, the researchers were able to pinpoint the change in power receive from the shape change of the alloy.

One of the biggest problems that needed a solution was the receiving performance of human head transceiver arrays without affecting the transmission [20]. It was with that in mind that they created a 16 element phased array with 8 Rx short folded dipole antennas and 8 TxRx surface loops all in a row and circumscribing a head [21]. The dipoles were along the middle axis of all transceiver loops perpendicular to the surface. They discovered that their new array improved central and peripheral signal to noise ratio. Finally, they were able to present the excellent performance of the dipoles at the ultra high frequency field.

They were able to create a multiband which had a high insolation input and output, which were both multiple in nature, for their antenna [22]. Their antenna specifically utilized a balanced mode and coupled neutralization line. In terms of the balanced modes of the antennas for both dipole and loop, they were utilized for the 8 by 8 multiple input and output in the LTE and 42 Chinese 5G bands [23]. The balanced modes were also causing really remarkable isolation. Moreover, for those that were unbalanced, they were utilized by decoupling structures. Through their results, they realized that they were able to perform really well in terms of radiation and also produce a low envelope correlation coefficient. Finally, their 8 antenna array was created with the 4 dipole and loop elements respectively.

They were able to create a dipole antenna capable of switching planar beams [24]. Their dipole was relatively small in size with folded slots and two parasitic elements with two positive intrinsic negative diodes. By utilizing a differential signal, they were able to excite the microstrip line needed for their feeding structure. Moreover, the ability to reconfigure their patterns was made possible by the varying states of the positive intrinsic negative diodes as seen in the Yagi-Uda antenna [25]. Finally, their dipole antenna was seen to perform remarkably well, therefore, making it enough for 5G communication system usage.

7.3. Directivity

The researchers were able to create a more general way to deal with antenna directivity by putting together the infinitesimal dipole model and cross-correlation Green’s function in a new formula [26]. Similar computations were also proven to be true [27]. They aimed to pursue their focus due to the fact that it would allow for better analysis and synthesis of antenna systems. In order for that improvement to occur, their combination method had to be utilized after being intertwined with optimization algorithms all over the world. Moreover, their combination opened doors for antenna gain applications, multiple inputs and outputs, and wireless power transfer, and more.

They were able to create a half-wave dipole antenna made through electromagnetic bandgap structures [28]. They wanted their work to be utilized mainly for wireless communication systems. The reason behind their utilization of the electromagnetic bandgap was due to the fact that it was a way to improve gain and directivity, reduce the size, and create a new frequency down the half-wave dipole antenna [29]. Moreover, their creation was functional in two frequency bands which were really good for mobile communication applications.

The researchers created a Huygens source antenna which was extremely thin and small yet electrical [30]. Moreover, their source antenna also came with an entire radiation characteristic. Mainly, their creation was made up of planar electric and magnetic dipoles all brought in together through one feed line at the same time. Their source antenna was able to present a directivity very close to the value from a magnetoelectric dipole antenna configuration but with efficiency in terms of radiation at 71.1% [31].

An electromagnetic bandgap structure, in the shape of a mushroom, to be utilized for antenna parameter enhancement was created [32]. The researchers aimed for their work to enhance low profile antennas within the 5-15 GHz range. Moreover, in terms of their operation band, they utilized three various antennas including a monopole, dipole, and loop antenna [33]. Afterward, their electromagnetic bandgap structure was designed to notice and work with new behaviors for the betterment of antenna parameters. Finally, they were able to record directivity, bandwidth, side, and main lobe level and gain respectively, angular width per antenna, and front to back ratio of their structure.

For faster and more efficient evaluation and analysis of the super directive performance of meta-atoms that were coupled, a new technique was created [34]. Normally, small antenna directivity could have been taken from measurements of a far distance of radiated power on a sphere. Through the new technique, they were able to provide a faster alternative in finding the directivity by utilizing a polar scan over a circular path all by using their new planar directivity for dipole arrays. They were able to show the analytical expressions for maximum values of recordable directivity, relate them to one another, and list their conversion parameters for super directive dimers [35].

8. THEORETICAL CONSIDERATIONS

Typically, a dipole antenna is mounted vertically, i.e. normal to its substrate so that it can transmit maximum power [36]. However, the simulation was developed so that the dipole antenna is mounted parallel to the dielectric, which is assumed to extend in all horizontal directions. This allows for the maximum absorption or reflection of the wave within the dielectric before radiating in the medium. An additional test may be added where the dipole is mounted vertically.

9. DATA AND RESULTS

Figure. 1 showcased the result of running the MATLAB code which produced the different values of directivity with respect to the different dielectric substrates. Figure 2 illustrated the antenna radiation of Air. The frequency was found to be 70Mhz and the maximum value was 8.72 dBi with a minimum value of -95.6dBi. Figure 3 illustrated the antenna radiation of

Teflon. It produced values of 70Mhz for its frequency, a maximum value of 4.74dBi, and a minimum value of -82dBi. Figure 4 illustrated the antenna radiation of Foam. It produced values of 70Mhz for its frequency, a maximum value of 4.74dBi, and a minimum value of -107dBi. Figure 5 illustrated the antenna radiation of Polystyrene. It produced values of 70Mhz for its frequency, a maximum value of 4.74dBi, and a minimum value of -76.7dBi. Figure 6 illustrated the antenna radiation of Fused Quartz. It produced values of 70Mhz for its frequency, a maximum value of 4.74dBi, and a minimum value of -69dBi.

```
dAir =

    8.7201

dTeflon =

    4.7425

dFoam =

    4.7431

dPoly =

    4.7422

dFusedq =

    4.7415
```

Figure 1: Results A

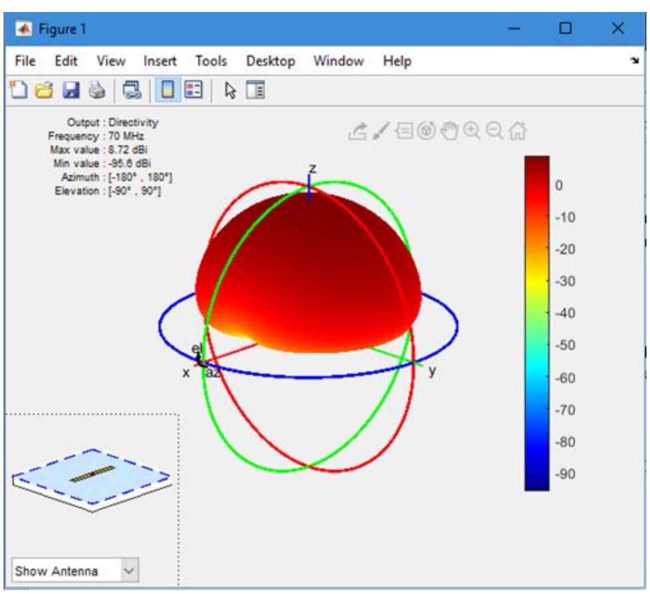

Figure 2: Results B

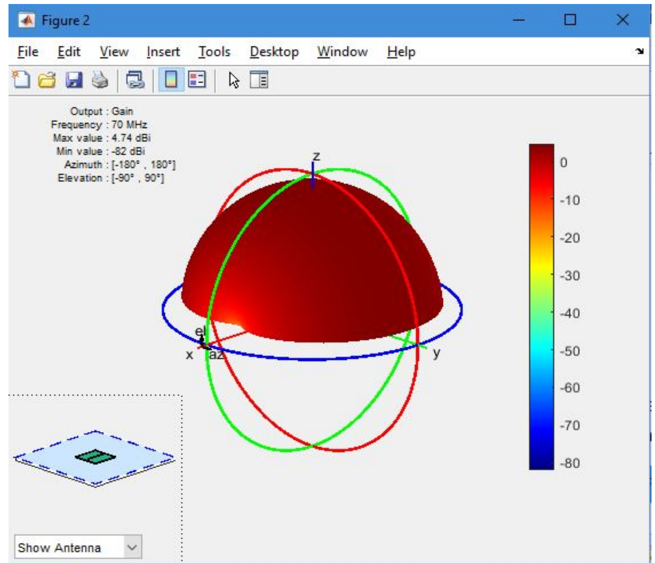

Figure 3: Results C

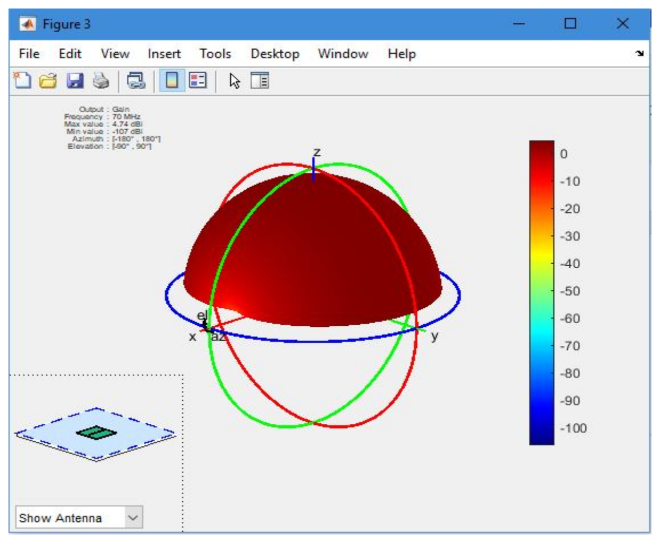

Figure 4: Results D

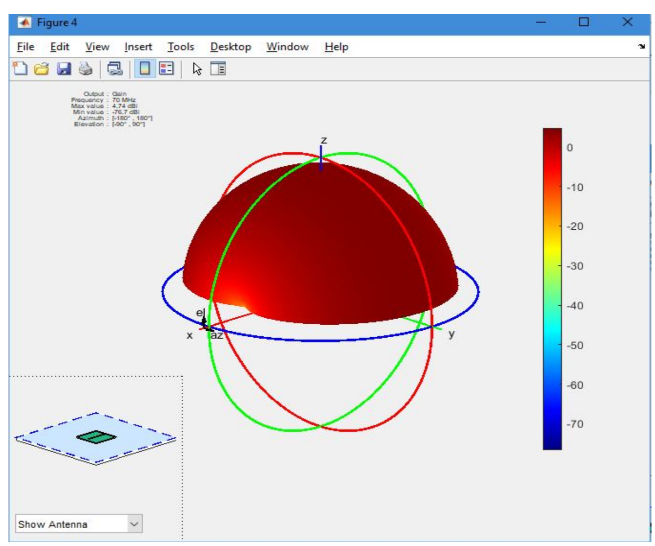

Figure 5: Results E

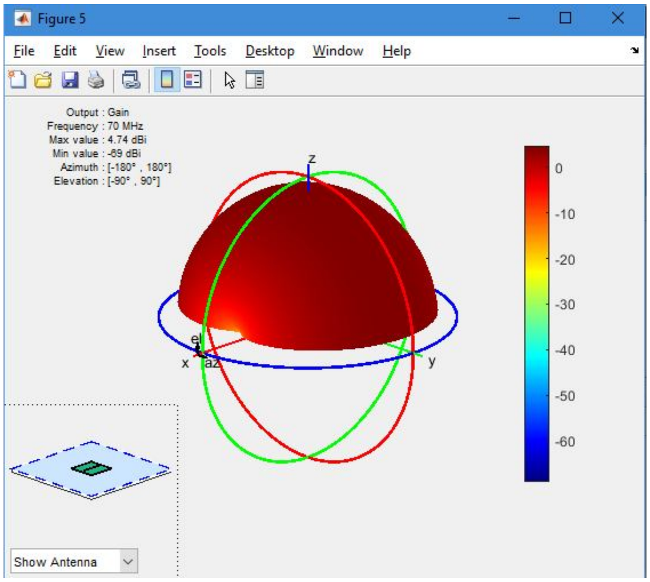

Figure 6: Results F

10. ANALYSIS OF DATA

After pairing the obtained directivity values with the corresponding dielectric constants, the researchers found that the directivity of the horizontally mounted dipole antenna increased as the dielectric constant of the material decreased [37]. It was found that, among the five selected dielectric materials, air returned the highest directivity of 8.7201 for the horizontally mounted dipole antenna. Characteristically, the air has the lowest dielectric constant of KAir = 1.00059 at 1 atm. The material with the second-highest obtained directivity was foam, with directivity of 4.7431. This material has the second-lowest dielectric constant of KFoam = 1.03. The next highest obtained directivity was obtained from Teflon, with directivity of 4.7425. The dielectric constant of Teflon is the third-lowest among the five, being KTeflon = 2.1. The material with the fourth-highest directivity was polystyrene, with directivity of 4.7422. The dielectric constant of this material is KPolystyrene = 2.55. Finally, the material with the fifth-highest directivity (i.e. the lowest directivity) was fused quartz, with directivity of 4.7415. It has a dielectric constant of KFused Quartz = 3.78.

A notable observation on the changes between the directivities of the materials with respect to the type of dielectric material it is mounted on is that the variation between the two variables does not occur linearly. Between air and foam, there is a change of 0.02941 between their dielectric constants, and a change of 3.9776 between their dipole antenna directivities. This is the greatest change of directivity between all pairs.

For all non-air dielectrics (i.e. solid dielectrics), the directivity was within the 4.74 range - much less than that of air. From this observation, the researchers recommend exploring further dielectric materials of different phases, such as water, methane gas, etc for future experiments. Also, the researchers recommend looking into other factors affecting dielectrics, such as their loss tangent, to be included in future experiments.

11. CONCLUSION

In conclusion, the directivity of a dipole antenna was affected by which dielectric substrate was used on the dipole antenna simulation. With the use of a matrix laboratory, the dipole antenna simulated was able to display the expected antenna radiation pattern. While also displaying the magnitude concentration of the radiation. As suspected the radiation of electromagnetic waves while having no substrate or air was used as a dielectric substrate would prove to have the greatest amount of directivity. This was due to how the antenna was not blocked by any dielectric substrate, while also having no constraints since no geometric object would block the path of propagation. On the other hand, foam, Teflon, polystyrene and fused quartz while having similar directivity magnitudes; respectively in decreasing order had a slight difference in the directivity magnitude. This suggests two things, first with the use of a substrate the directivity of the antenna decreases almost half in comparison to having no dielectric substrate at all. This offers an advantage since the antenna propagation would have a better area effect rather than focused on a specific area, although depending on the use case this could also be a disadvantage. The decrease in directivity would lessen the reach of the signal towards a specific area; although not ideal would still be a valuable use case for a dipole antenna. And second, the use of a dielectric substrate would also affect different aspects of the antenna hence in terms of directivity, the choice when choosing a dielectric substrate in a circuit, would depend on other factors like price and durability of the dielectric substance. In turn the circuitry would have more flexibility in design since different dielectric substrates contain different characteristics like how malleable or brittle the respective dielectric would be. Leaving this decision to the designer allows a better grasp on the circuitry and how the antenna would be applied in the technology. The database configurations of the system followed the studies of [38,39,40,41,42]. The program configurations follows the studies of [43,44,45].

12. RECOMMENDATION

For future references, the researchers highly recommend increasing the number of dielectric substrates that would be researching on. The study only took into account 5 different dielectric substrates: Air, Teflon, Foam, Polystyrene, and Fused Quartz. There are other substrates that could be taken into consideration for the study such as FR4, Plexiglas, E glass, RO4725JXR, RO4730JXR, etc. Studying the different properties of these substances could help future researchers apply these substrates on different antenna applications. Additionally, future researchers could also take into consideration the properties of an antenna that could be used for different purposes. These properties include the Antenna Gain, the Aperture, the Bandwidth, Polarization, Effective Length or the Polar Diagram. All of which have different purposes that could be studied even further. By seeing which substrates work on which properties of antennas, new conclusions could be made. Furthermore, a different antenna could be researched on. For this study, a dipole antenna was used. A different antenna may result in a different conclusion for a specific property or substrate. Also, by changing the polarization of the antenna to vertical or by changing the length of the antenna, the transmission of the signal may be changed as well. By doing so, the maximum and minimum values may be altered and so would the azimuthal and elevational angles. Additionally, other parameters that were not displayed by the researchers could be studied on such as the return loss, the voltage standing wave ratio (VSWR), the bandwidth, antenna efficiency, and the radiating efficiency. The MATLAB code that was made could also be improved to provide a better image that could illustrate the antenna radiation more efficiently. Correlation graphs could also be made, for example, the frequency versus the VSMR. By comparing several of the properties stated before, a relationship between some of these could further antenna efficiency studies.

REFERENCES

[1] A.S.M. Alqadami and M.F. Jamlos, "Effect of a Flexible Polymer Dielectric and Magneto-Dielectric Composite Substrates in Antenna Array." Antennas and Propagation. Vol. 2, pp. 744 – 745, 2016.

[2] P. Yen, J.A. Paul, and T. Itoh, "Millimeter-Wave Planar Slot Antennas with Dielectric Feed." International Microwave Symposium Digest. Vol. 1, pp. 114–116, 1981.

[3] P. Tilanthe and P. C. Sharma, "An Equilateral Triangular Patch Antenna with T - Shaped Notch for Enhanced Gain." Wireless Communication and Sensor Networks. Vol. 4, pp. 179-180, 2008. https://doi.org/10.1109/WCSN.2008.4772706

[4] V. Thakur and D. Chaudhary, "Performance Improvement of Microstrip Patch Antenna using Substrate with Lower Relative Permittivity." International Journal of Computer Applications. Vol. 102, No. 6, pp. 23–25, 2014. https://doi.org/10.5120/17820-8756

[5] L. Orlando, "Object Dimension vs Antenna Frequency." Ground Penetrating Radar, GPR. Vol. 2, pp. 55, 2010. https://doi.org/10.1109/ICGPR.2010.5550258

[6] J. Qiu, "Design of the Small Microstrip Antenna Based on the WLAN/UWB Wireless Communication System." Advances in Intelligent Systems and Computing. Vol. 928, pp. 74-79, 2019. https://doi.org/10.1007/978-3-030-15235-2_12

[7] J. Yu, L. Yu, and C. Wang, "Design of Wireless Sensor Network Node based on CC2430." Advances in Intelligent Systems and Computing. Vol. 928, pp. 74-79, 2019. https://doi.org/10.1007/978-3-030-15235-2_86

[8] D. Shashi Kumar and S. Suganthi, "Gain and Bandwidth Enhancement by Optimizing Four Elements Corporate-Fed Microstrip Array for 2.4ghz Applications." Electrical Engineering. Vol. 546, pp. 215-222, 2019. https://doi.org/10.1007/978-981-13-6159-3_23

[9] R. Yadav and R. Mishra, "Microstrip Patch Antenna Array for UWB Application." Electrical Engineering. Vol. 546, pp. 357-363, 2019.

[10] Y. Zheng, L. Rosa, T. Thai, S.H. Ng, S. Juodkazis, and U. Bach, "Phase Controlled SERS Enhancement." Scientific Reports. Vol.9, 2019.

[11] T. Mutaf, G. Çalışkan, C. Meydan, S.S. Öncel, and M. Elibol, "Biogenic Nanoparticle Synthesis Using Marine Alga Schizochytrium Sp." IFMB, Vol. 73, pp. 213-218, 2019. https://doi.org/10.1007/978-3-030-17971-7_33

[12] D. G. Pahinkar, L. Boteler, D. Ibitayo, S. Narumanchi, P. Paret, D. DeVoto, and S. Graham, "Liquid-Cooled Aluminum Silicon Carbide Heat Sinks for Reliable Power Electronics Packages." Journal of Electronic Packaging, Transactions of the ASME. Vol. 141, Vol. 4, 2019.

[13] M. Lu, "Enhanced Sintered Silver for Sic Wide Bandgap Power Electronics Integrated Package Module." Journal of Electronic Packaging, Transactions of the ASME. Vol.141, No. 3, 2019.

[14] M. Hossain, I. Faruque, M. Ahmed, M. Alam, and M. Islam, "Polarization-Insensitive Infrared-Visible Perfect Metamaterial Absorber and Permittivity Sensor." Results in Physics. Vol. 14, pp. 102-429, 2019.

[15] X. Zhao, G. Duan, A. Li, C. Chen, and X. Zhang, "Integrating Microsystems with Metamaterials Towards Meta-devices." Microsystems and Nanoengineering. Vol. 5, 2019.

[16] S. Son, K. Lee, and W. Park, "Application and Analysis of Direct Sampling Method in Real-World Microwave Imaging." Applied Mathematics Letters. Vol. 96, pp. 47-53, 2019. https://doi.org/10.1016/j.aml.2019.04.016

[17] J. H. Park, V. Kumar, and N. E. Cho, "A Class Involving Derivatives of Ratio of the Analytic Functions." Journal of Computational Analysis and Applications. Vol. 28, No. 3, pp. 463-474, 2019.

[18] A. Torisaka, D. Hayashi, S. Kawasaki, N. Nishii, Y. Terada, S. Yokoyama, and H. Sakamoto, "Development of Shape Monitoring System Using SMA Dipole Antenna on a Deployable Membrane Structure." Acta Astronautica. Vol. 160, pp. 147-154, 2019.

[19] M. Berardengo, G. E. P. Della Porta, S. Manzoni, and M. Vanali, "Adaptive Multi-Modal Tuned Mass Dampers Based on Shape Memory Alloys: Design And Validation." Conference Proceedings of the Society for Experimental Mechanics Series. Vol. 6, pp. 151-156, 2019.

[20] N. I. Avdievich, G. Solomakha, L. Ruhm, K. Scheffler, and A. Henning, "Evaluation of Short Folded Dipole Antennas as Receive Elements of Ultra-High-Field Human Head Array." Magnetic Resonance in Medicine. Vol. 82, No. 2, pp. 811-824, 2019. https://doi.org/10.1002/mrm.27754

[21] N. I. Avdievich, G. Solomakha, L. Ruhm, K. Scheffler, and A. Henning, "Double-Row 18-Loop

Transceive–32-Loop Receive Tight-Fit Array Provides for Whole-Brain Coverage, High Transmit Performance, and SNR Improvement Near the Brain Center At 9.4T." Magnetic Resonance in Medicine. Vol. 81, No. 5, pp. 3392-3405, 2019.

[22] M. Wang, B. Xu, Y. Li, Y. Luo, H. Zou, and G. Yang, "Multiband Multiple-Input Multiple-Output Antenna with High Isolation for Future 5G Smartphone Applications." International Journal of RF and Microwave Computer-Aided Engineering. Vol. 29, No. 7, 2019.

[23] D.D.N. Abinoja and L.Y. Materum, "BIC-based optimization of the identification of multipath propagation clusters in MIMO wireless systems," ISAP 2016 - International Symposium on Antennas and Propagation. pp. 428-429, 2016.

[24] G. Jin, M. Li, W. Wang, L. Li, and S. Liao, "Planar Beam-Switching Dipole Antenna." IET Microwaves, Antennas and Propagation. Vol. 13, No. 7, pp. 997-1002, 2019.

[25] B. Yu, J. Li, and S. Shen, "Directional Control of Narrow Band Thermal Emission from Nanoantennas." Journal of Photonics for Energy. Vol. 9, No. 3, 2019.

[26] S. Mikki, S. Clauzier, and Y. Antar, "A Correlation Theory of Antenna Directivity with Applications to Superdirective Arrays." Antennas and Wireless Propagation Letters. Vol. 18, No. 5, pp. 811-815, 2019.

[27] D. Sarkar, S. Mikki, and Y. Antar, "Eigenspace Structure Estimation for Dual-Polarized Massive MIMO Systems using an IDM-CGF Technique." Antennas and Wireless Propagation Letters. Vol. 18, No. 4, pp. 781-785, 2019.

[28] S. Sara and E. Abdenacer, "Novel Dual-Band Dipole Antenna Integrated with EBG Electronic Bandgap Structures Dedicated to Mobile Communications." Wireless Technologies Embedded and Intelligent Systems. Vol. 7, pp. 287-291, 2019.

[29] S. Chen, L. Shi, and J. Xun, "New EBG of CSRR with Lumped Capacitors Applied to Oscillator Harmonics Suppression." International Journal of RF and Microwave Computer-Aided Engineering. Vol. 29, No. 7, pp 21-27, 2019.

[30] S. Lee, G. Shin, S. Radha, J. Choi, and I. Yoon, "Low-Profile, Electrically Small Planar Huygens Source Antenna with an Endfire Radiation Characteristic." Antennas and Wireless Propagation Letters. Vol. 18, No. 3, pp. 412-416, 2019.

[31] J. Zeng and K. Luk, "Single-Layered Broadband Magnetoelectric Dipole Antenna for New 5G Applications." Antennas and Wireless Propagation Letters. Vol. 18, No. 5, pp. 911-915, 2019.

[32] F.O. Alkurt and M. Karaaslan, "Pattern Reconfigurable Metasurface to Improve Characteristics of Low Profile Antenna Parameters." International Journal of RF and Microwave Computer-Aided Engineering. Vol. 21, pp. 790, 2019.

[33] A.E. Dulay, R. Sze, A. Tan, Y.-H. Huang, R. Yap, and L. Materum, "FPGA implementation of an indoor broadband power line channel emulator," IEEE International Conference on Information and Communications with Samsung LTE and 5G Special Workshop. pp. 218-223, 2017.
https://doi.org/10.1109/INFOC.2017.8001678

[34] J. Yan, E. Shamonina, and C.J. Stevens, "Planar Directivty of a Dipole array." Artificial Materials for Novel Wave Phenomena, METAMATERIALS. Vol. 1, pp. 445-447, 2018.

[35] A. Radkovskaya, S. Kiriushechkina, A. Vakulenko, C.J. Stevens, and E. Shamonina, "Superdirectivity from Arrays of Strongly Coupled Meta-atoms." Journal of Applied Physics. Vol. 10, pp. 124, 2018.

[36] H.G. Oltman, "Electromagnetically Coupled Microstrip Dipole Antenna Elements." Antennas and Propagation. Vol. 3, pp. 274 – 279, 2017.

[37] J. Wilson, "Dielectric Constants." Sensor Technology Handbook. Vol. 5, pp. 615 – 616, 2005.

[38] A. Africa, and C. Uy, "Development of a cost-efficient waste bin management system with mobile monitoring and tracking." International Journal of Advanced Trends in Computer Science and Engineering (IJATCSE). Vol. 8, No. 2, pp. 319-327, 2019.
https://doi.org/10.30534/ijatcse/2019/35822019

[39] A. Africa, C. Alcantara, M. Lagula, A. Latina Jr. and C. Te, "Mobile phone graphical user interface (GUI) for appliance remote control: An SMS-Based electronic appliance monitoring and control system." International Journal of Advanced Trends in Computer Science and Engineering (IJATCSE). Vol. 8, No. 3, pp. 487-494, 2019.
https://doi.org/10.30534/ijatcse/2019/23832019

[40] J. Sashi Banu, J. Sastry, B. Devi and V. Prakash, "Career Guidance through TIC-TAC-TOE Game." International Journal of Emerging Trends in Engineering Research (IJETER). Vol. 7, No. 6, pp. 25-31, 2019.
https://doi.org/10.30534/ijeter/2019/01762019

[41] E. Panganiban, "Microcontroller-based Wearable Blood Pressure Monitoring Device with GPS and SMS Feature through Mobile App." International Journal of Emerging Trends in Engineering Research (IJETER). Vol. 7, No. 6, pp. 32-35, 2019.

[42] A. Africa, "A Mathematical Fuzzy Logic Control Systems Model Using Rough Set Theory for Robot Applications." Journal of Telecommunication, Electronic and Computer Engineering. Vol. 9, No. 2-8, pp. 7-11, 2017.
https://doi.org/10.30534/ijeter/2019/02762019

[43] A. Africa, "A Rough Set Based Solar Powered Flood Water Purification System with a Fuzzy Logic Model." ARPN Journal of Engineering and Applied Sciences. Vol. 12, No. 3, pp.638-647, 2017.

[44] A. Africa and J. Velasco, "Development of a Urine Strip Analyzer using Artificial Neural Network using an Android Phone." ARPN Journal of Engineering and Applied Sciences. Vol. 12, No. 6, pp. 1706-1712, 2017.

[45] A. Africa, S. Bautista, F. Lardizabal, J. Patron, and A. Santos, "Minimizing Passenger Congestion in Train Stations through Radio Frequency Identification (RFID) coupled with Database Monitoring System." ARPN Journal of Engineering and Applied Sciences. Vol. 12, No. 9, pp. 2863-2869, 2017.