Periodicals of Engineering and Natural Sciences ISSN 2303-4521
Vol. 9, No. 3, July 2021, pp.22-28

Performance of microstrip patch antenna for single and array element with and without EBG

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ABSTRACT

In this paper, a compact single patch antenna and microstrip array antenna with EBG structures at 6 GHzhave been compained. A surface wave effect is often considered undesirable, since it increased the side lobes, and decreased the antenna gain and effeciency. This problem can be solved by utilizing EBG to suppress of such waves. Above the antenna substrate, the mushroom-like EBG were proposed. The side lobes have been improved from −6.8 dB to −16.5 dB, and better directivity was achieved from 5.77 dBi to 10 dBi and the efficiency improved from (80%) to 95% by using EBG with rectangular antenna. Additionally, the array antenna radiation pattern with EBG was improved to −23.5 dB, and the directivity and effeciency have been improved to 14.3 dBi and to 91.5 respctively. These antenna structures have a great eventuality for use in C band application.

Keywords: Mushroom-like EBG, Rectangular and array antenna, Antenna performance, Enhanced a microstrip antenna gain, EBG

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1. Introduction

The type of microstrip patch antenna show several features, for instance the low cost, easy to fabricate, and suitable to combine with RF devices [1]. To increas the gain and directivity of single microstrip patch, antenna arrays can be used and provide diversity reception [2]. The phenomenon of the surface waves excitation is considered undesired, where the current is lost in the substrate. Therefore, antenna efficiency, gain, and directivity will be decreased. Many techniques were used to avoide the surface waves effects. Such as, adding dielectric layers over the radiating elements [3] or optimizing the shape of radiating elements [4]. A low effective dielectric constant has been achieved by drilling an air gap under the radiating elements [5]. A compact design is obtained on high dielectric constant [6]. Consequently, by increasing the substrate thickness, the reduction problem in the band width can be solved [7]. The mushroom-like EBG is one of the most important technologies of electromagnetic band-gap (EBG) [8], has been applied to avoid the bad impacts of surface waves. However, The stopband characteristics of such construction is applied to improve the antenna performance by suppressing the surface wave, and design the low profile antenna by the property of in-phase reflection[9-13]. The EBG structure has been used to enhance the radiation pattern of antenna [14-17]. The mutual coupling and side lobe levels were diminished [18,19]. The author in [19] used uniplanar EBG structure to implement a 2×2 antenna array to reduce the mutual coupling, thereby lowering the side lobe. In [20] three various 2D-EBG shapes have been designed, in the whole antenna ground plane for decreasing the back lobe and increasing the gain. Moreover, the mushroom-like EBG was appiled in antenna array to enhance the side lobe and gain [21]. Most of literatures that were done by applying the EBGs as superstrate over the antenna, which resulted in bulky antenna size. Another works also achieved to reduce the mutual coupling in MIMO antenna, or placing the EBG in the antenna ground plane by using multi layers. However, the facilities of EBG in the same substrate to enhance antenna array not much found. The EBG structure operation mechanism can be explain by the LC filter model. The electromagnetic waves are TE and TM modes, on the surface of dielectric substrate the TE mode is happened in case of the surface impedance is capacitive. While TM mode is achieved when the impedance is inductive. The uniplanar EBG (without pin vias) can extinguish the surface waves in TE modes. The mushroom like EBGs have the ablity for suppressing surfaces wave in both modes (TE and TM) [22]. Thus, the cell of EBGs has been applied. In this work, mushroom like EBG has been used for lowering the back radiation of rectangular antenna and four radiating elements in the antenna array, using just one feed point. Both of the compact antennas (single and array) are applied with high dielectric constant, simple desig, and good performance have been accomplished.

2. Enhanced the performance of antenna using EBG

Mushroom like EBG structures are periodically loded in two dimensions. This structure contains four elements named as, ground plane, metallic patche, dielectric substrate, and connecting vias. By connecting vias, we can get the band stop advantage, at the resonant frequency of antenna. In this case the impedance is very high-rise, which leads to suppress surface waves [22-27]. Using the transmission line methode to calculate the mushroom-like EBG dimensions [28-33]. The width of the EBG element is 3 mm; via radius is 1 mm, and the 0.33 mm is the space between the EBGs. Rogers substrate (RT/Duroid 6010) with hickness of 2.74 mm has been used. The rectangular antenna with a probe feed was bounded by the mushroom like EBG structure. The sizes of the rectangular antenna is 6.4 mm × 7.5 mm. Rogers substrate (RT/Duroid 6010) hickness is 2.74 mm, with a dielectric constant (10.2). The dimensions of the EBG cell is 3 mm. The antenna are surrounded by four columns of EBG unit cell from the upper and down sides, and two columns of the same EBG cells in the both sides of right and left as shown in Figure 1.

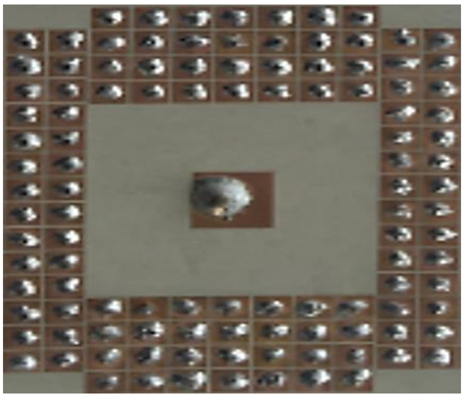


Figure 1. Antenna and mushroom like EBG

The simulated of S-11 for the antenna and mushroom-like EEG at 6 GHz comes with good resulte (−31 dB). The side lobes have been improved from −6.8 dB to −16.5 dB. Additionally, better directivity was achieved by using EBG from 5.77 dBi to 10 dBi as shown. The measured value of S-11 is less than −26.5 dB at 6.05 GHz as shown in Figure 2. In the main lobe, the measured directivity is 10.22 dBi. Good agreement was achieved among the simulated and measured results as shown in Figure 3.

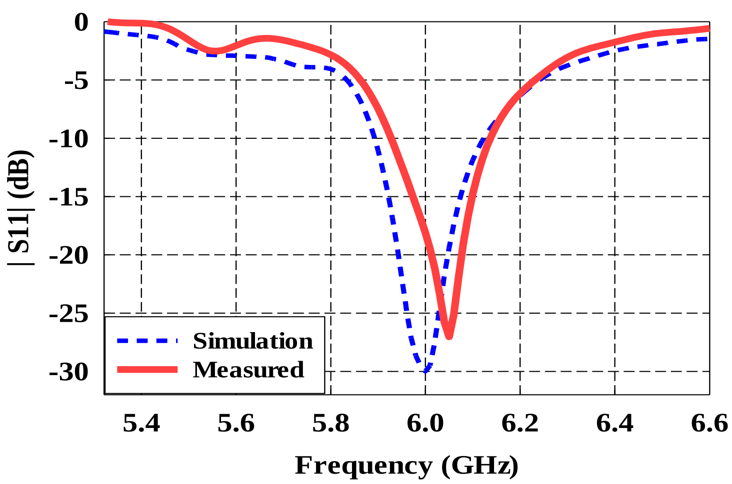


Figure 2. Simulated and measured S11 of antenna by using EBG

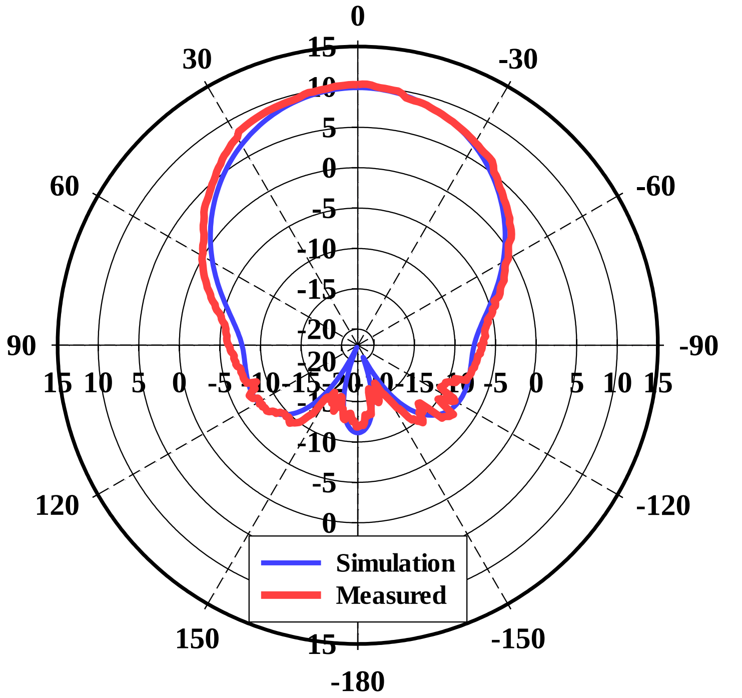
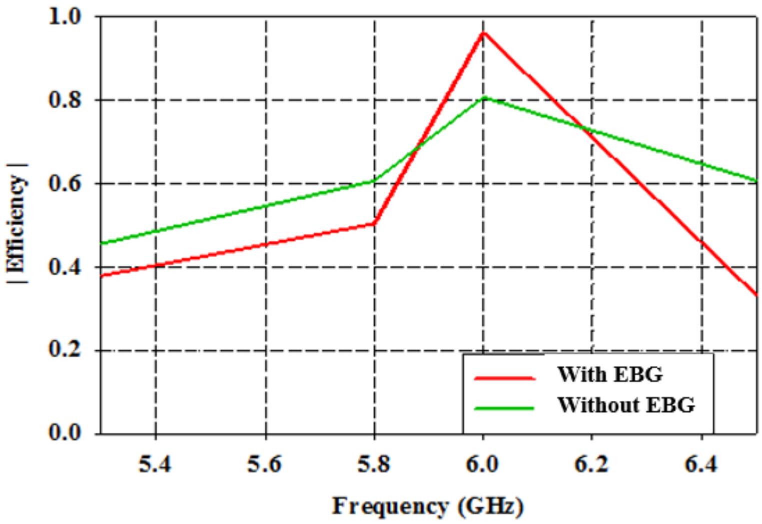


Figure 3. Simulated and measured antenna normalize maximum directivity

In summery, the efficiency comparision of these antennas are presents in Figure 4. The antenna without EBG has efficiency (80%), and after applying the EBG the efficiency improved to 95%.



(a) (b)

Figure 4. Enhanced antenna Efficiency by using EBG

3. Using EBG to enhance the performance of antenna array

Array antenna was proposed to operate in 6 GHz. The substrate thickness is 2.74 mm. To reduce the antenna size, the dielectric constant (ϵ_r) is 10.2. Morever, the dimension of radiating elements are 7 mm × 11 mm. The distance between the centre of rectangular antenna is 25.8 mm. Then, the four patchs were individually connected using transmission line (70 Ω) impedance. Another transmission line with 50 Ω has been used to connecte the elements together. The adjustments of insert distance (Id) and the insert gap (Ig) are 2.1mm and 0.7 mm respectively, to improve the return loss and impedance. As shown in Figure 5 the pin vias are used to connect the antenna ground plane to the square patche of EBGs. The space between the mushroom-like EBG patchs (g) is 0.3 mm and the EBG size is 3mm.

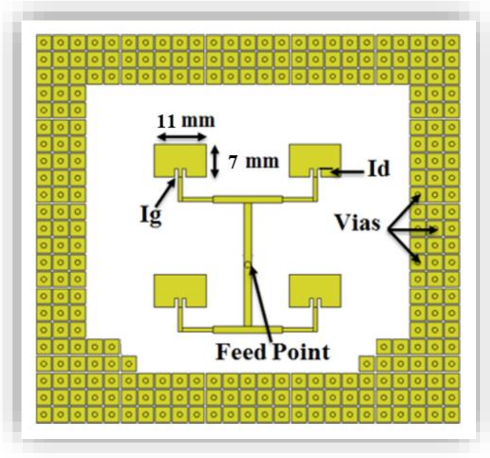


Figure 5. Mushroom like EBG structures and array antenna

The simulated S-parameters (S-11) were performed to explane the antenna performance. At 6 GHz the S11 of antenna array is less than −32 dB. While, the S-11 is −23 dB without using mushroom like EBG as exposed in Figure 6. Largest back radiation was found in the antenna without EBG. The good radiation properties for the mushroom-like EBG structure is presented. The reference antenna back lobe is −17.78 dB. The pattern of array antenna with EBG demonstrates a useful lessening in the side lobe around −23.5 dB. The directivity in the main lobe direction (14.3 dBi) is the better contrasted to the array antenna wich not including EBG (11.56 dBi) as exhibited in Figure 7.

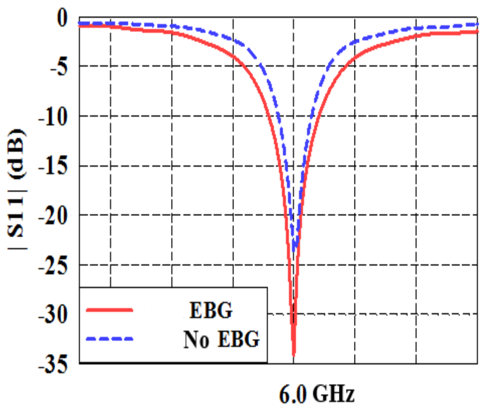


Figure 6. S_{11} of the array antenna with EBG and without

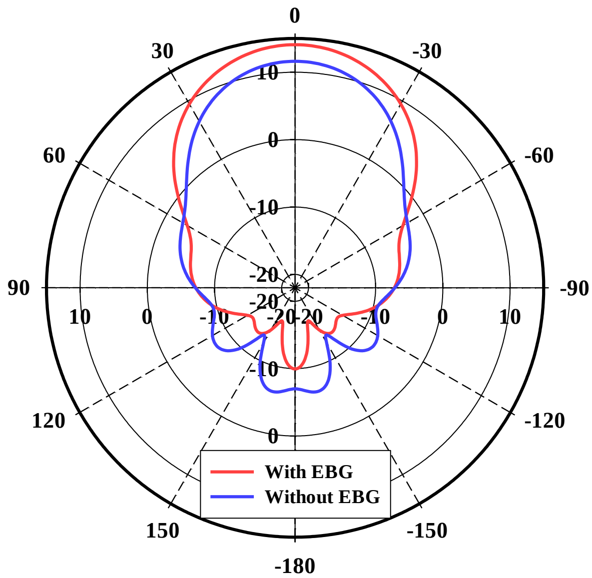


Figure 7. Array antenna directiviy with EBG and without it

Reference antenna array has efficiency equal to 84%. The efficiency has been enhanced to 91.5% just in case of utilising EBG as shown in Figure 8.

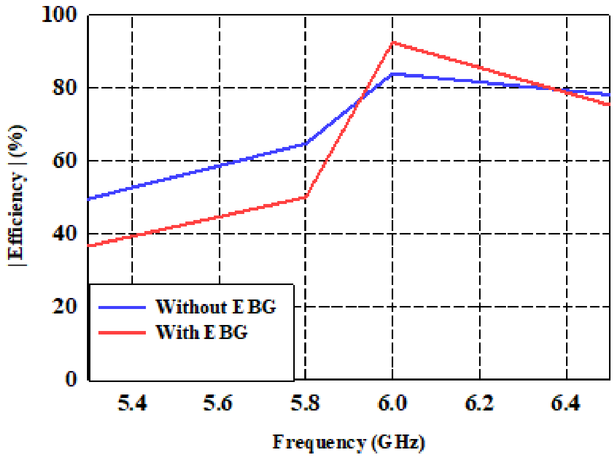


Figure 8. Efficiency enhancement by using mushroom like-EBG

4. Conclusion

In this work, a compact rectangular patch antenna and 2×2 microstrip antenna array with EBG structures have been blended for enhancing the antenna performance such as efficiency, directivity, and side lobe reduction. A surface wave effect is often considered undesirable, since it increased the side lobes, and decreased the antenna bandwidth. This badly-behaved can be solve by utilizing EBG to suppress of such waves. Above the antenna substrate, the mushroom-like EBG were proposed. The side lobes have been improved from −6.8 dB to −16.5 dB, and better directivity was achieved from 5.77 dBi to 10 dBi and the efficiency improved from (80%) to 95% by using EBG with rectangular antenna. Additionally, the array antenna radiation pattern with EBG was improved to −23.5 dB, the directivity of 14.3 dBi, and the efficiency also improved to 91.5.These antenna structures have a great eventuality for use in satellite application.

References

[1] S. Shandal, Y. S. Mezaal, M. Kadim, M. Mosleh, "New Compact Wideband Microstrip Antenna for Wireless Applications", Advanced Electromagnetics", vol.7, no.4, pp. 85–92, 2018.

[2] M. R. Sarker, M. M. Islam, M. T. Alam, and M. Hossam-E-Haider, "Side lobe level reduction in antenna array using weighting function," in 2014 International Conference on Electrical Engineering and Information & Communication Technology, 2014, pp. 1-5: IEEE.

[3] N. Alexopoulos, and D. Jackson, "Fundamental superstrate (cover) effects on printed circuit antennas," IEEE Transactions on antennas and propagation, vol. 32, no. 8, pp. 807-816, 1984.

[4] D. Jackson, J. Williams, A. K. Bhattacharyya, R. L. Smith, S. J. Buchheit, and S. Long, "Microstrip patch designs that do not excite surface waves," IEEE Transactions on antennas and propagation, vol. 41, no. 8, pp. 1026-1037, 1993.

[5] J. S. Kasim, M. S. M. Isa, Z. Zakaria, M. I. Hussein, and M. K. Mohsen, "Review on fixed-frequency beam steering for leaky wave antenna," TELKOMNIKA (Telecommunication Comput. Electron. Control., vol. 17, no.6, pp. 2895-2902.,2019.

[6] D. Weile, "Electromagnetic band gap structures in antenna engineering [reviews and abstracts]," IEEE Antennas and Propagation Magazine, vol. 55, no. 6, pp. 152-153, 2013.

[7] H. Rong, Q. Wang, S. Chen, Y. Cao, and H. Tian, "Wide stopband miniaturized "I"-typed EBG with DGS," Microwave and Optical Technology Letters, vol. 60, no. 1, pp. 44-50, 2018.

[8] M. Abdulhameed, M. M. Isa, I. Ibrahim, M. Zin, Z. Zakaria, M. K. Mohsin, and M. Alrifaie, "Review of radiation pattern control characteristics for the microstrip antenna based on electromagnetic band gap (EBG)," Journal of Telecommunication, Electronic and Computer Engineering (JTEC), vol. 10, no. 3, pp. 129-140, 2018.

[9] M. T. Islam and M. Alam, "Compact EBG structure for alleviating mutual coupling between patch antenna array elements," Progress in Electromagnetics Research, vol. 137, pp. 425-438, 2013.

[10] M. Abdulhameed, M. M. Isa, Z. Zakaria, and M. J. T. Mohsin, "Controlling the Radiation Pattern of Patch Antenna Using Switchable EBG," Telkomnika, vol. 16, no. 5, pp. 2014-2022, 2018.

[11] B. Zong, G. Wang, C. Zhou, and Y. Wang, "Compact low-profile dual-band patch antenna using novel TL-MTM structures," IEEE Antennas Wireless Propagation Letters, vol. 14, pp. 567-570, 2014.

[12] M. Abdulhameed, M. M. Isa, Z. Zakaria, M. K. Mohsin, and M. L. Attiah, "Mushroom-Like EBG to Improve Patch Antenna Performance For C-Band Satellite Application," International Journal of Electrical Computer Engineering, vol. 8, no. 5, p. 3875, 2018.

[13] M. Abdulhameed, M. M. Isa, I. Ibrahim, M. K. Mohsin, S. Hashim, and M. L. Attiah, "Improvement of microstrip antenna performance on thick and high permittivity substrate with electromagnetic band gap," Jour Adv Res Dyn Control Syst, vol. 10, no. 4, pp. 661-9, 2018.

[14] M. K. Mohsen, M. Isa, A. Isa, M. Abdulhameed, M. L. Attiah, and A. M. Dinar, "Enhancement of boresight radiation for leaky wave antenna array," Telkomnika, vol. 17, no. 5, pp. 2179-2185, 2019.

[15] A. M. Dinar, A. M. Zain, F. Salehuddin, M. K. Mohsen, M. L. Attiah, and M. Abdulhameed, "Performance analysis of high-k materials as stern layer in ion-sensitive field effect transistor using commercial TCAD," Telkomnika, vol. 17, no. 6, pp. 2867-2876, 2019.

[16] A. M. Dinar, A. M. Zain, F. Salehuddin, M. Abdulhameed, M. K. Mohsen, and M. L. Attiah, "Impact of Gouy-Chapman-Stern model on conventional ISFET sensitivity and stability," TELKOMNIKA, vol. 17, no. 6, pp. 2842-2850, 2019.

[17] M. K. Abdulhameed, M. s. B. Isa, Z. Zakaria, I. M. Ibrahim, M. K. Mohsen, M. L. Attiah, and A. M. Dinar, "Enhanced performance of compact 2× 2 antenna array with electromagnetic band-gap," Microwave Optical Technology Letters, vol. 62, no. 2, pp. 875-886, 2020..

[18] N. Jin, A. Yu, and X. Zhang, "An enhanced 2× 2 antenna array based on a dumbbell EBG structure," Microwave Optical Technology Letters, vol. 39, no. 5, pp. 395-399, 2003.

[19] T. Jiao, T. Jiang, Y. Li, and X. Mao, "A low mutual coupling MIMO antenna array with periodic crossing electromagnetic band gap," in 2017 Progress in Electromagnetics Research Symposium-Fall (PIERS-FALL), 2017, pp. 279-283: IEEE.

[20] D. M. N. Elsheakh, M. F. Iskander, E. A. Abdallah, H. A. Elsadek, and H. Elhenawy, "Microstrip array antenna with new 2D-electromagnetic band gap structure shapes to reduce harmonics and mutual coupling," Progress In Electromagnetics Research, vol. 12, pp. 203-213, 2010.

[21] M. K. Abdulhameed, M. Isa, I. Ibrahim, Z. Zakaria, M. K. Mohsen, M. L. Attiah, and A. M. Dinar, "Side lobe reduction in array antenna by using novel design of EBG," International Journal of Electrical Computer Engineering, vol. 10, no. 1, 2020.

[22] A. J. A. Al-gburi, I.-M. Ibrahim, M. Abdulhameed, Z. Zakaria, M. Zeain, H. H. Keriee, N. A. Nayyef, H. Alwareth, and A. D. Khaleel, "A compact UWB FSS single layer with stopband properties for shielding applications," Przegląd Elektrotechniczny, no. 2, pp. 165-168, 2021.

[23] M. Abdulhameed, M. M. Isa, Z. Zakaria, I. Ibrahim, and M. K. Mohsen, "Radiation pattern control of microstrip antenna in elevation and azimuth planes using EBG and pin diode," International Journal of Electrical Computer Engineering, vol. 9, no. 1, p. 332, 2019.

[24] M. Abdulhameed, Z. Zakaria, I. M. Ibrahim, M. K. Mohsen, M. L. Attiah, and A. M. Dinar, "Radiation control of microstrip patch antenna by using electromagnetic band gap," *AEU-International Journal of Electronics Communications*, vol. 110, p. 152835, 2019.

[25] F. Abdul, E. Abdul, R. H. Abbas, F. Abdul, and E. Abdul, "An analytic study for the effect of antenna height on line-of-sight VHF / UHF communications coverage distance applied to Baghdad city," *Periodicals of Engineering and Natural Sciences (PEN)*, vol. 7, no. 4, pp. 1965–1976, 2019.

[26] F. Abayaje, S. A. Hashem, H. S. Obaid, Y. S. Mezaal, and S. K. Khaleel, "A miniaturization of the UWB monopole antenna for wireless baseband transmission," *Periodicals of Engineering and Natural Sciences (PEN*, vol. 8, no. 1, pp. 256–262, 2020.

[27] A. M. Aaref, "Artificial intelligence using Nelder-Mead algorithm- based design and performance optimization of microstrip patch antenna," *Periodicals of Engineering and Natural Sciences (PEN),* vol. 9, no. 2, pp. 332–340, 2021.

[28] M. K. Mohsen, M. S. M. Isa, A. A. M. Isa, M. K. Abdulhameed, and M. L. Attiah, "Achieving fixed-frequency beam scanning with a microstrip leaky-wave antenna using double-gap capacitor technique," *IEEE Antennas Wireless Propagation Letters*, vol. 18, no. 7, pp. 1502-1506, 2019.

[29] M. K. Mohsen, M. S. M. Isa, A. A. M. Isa, Z. Zakaria, and M. K. Abdulhameed, "Control Radiation Pattern

for Half Width Microstrip Leaky Wave Antenna by using PIN Diodes," *Int. J. Electr. Comput. Eng.*, vol. 8, no. 5, pp. 2959–2966, 2018.

[30] M. K. Mohsen, M. Isa, Z. Zakaria, A. Isa, M. Abdulhameed, M. L. Attiah, and A. M. Dinar, "Electronically controlled radiation pattern leaky wave antenna array for (C band) application," *Telkomnika,* vol. 17, no. 2, pp. 573-579, 2019.

[31] M. K. Mohsen, M. M. Isa, A. Isa, M. Zin, S. Saat, Z. Zakaria, I. Ibrahim, M. Abu, A. Ahmad, and M. Abdulhameed, "The fundamental of leaky wave antenna," *Journal of Telecommunication, Electronic Computer Engineering,* vol. 10, no. 1, pp. 119-127, 2018.

[32] M. K. Mohsen, M. S. M. Isa, A. A. M. Isa, M. K. Abdulhameed, M. L. Attiah, and A. M. Dinar, "Enhancement Bandwidth of Half Width-Microstrip Leaky Wave Antenna Using Circular Slots," *Progress in Electromagnetics Research,* vol. 94, no. June, pp. 59–74, 2019.

[33] J. S. Kasim, M. Isa, Z. Zakaria, M. Hussein, and M. K. Mohsen, "Radiation beam scanning for leaky wave antenna by using slots," *Telkomnika,* vol. 18, no. 3, pp. 1237-1242, 2020.