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Optimization of Directivity and Gain Performances on Circular Patch Antenna Design for 2.4 GHz Applications

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Abstract: ***In this paper, simulation and optimization analysis on circular patch antenna for 2.4GHz is presented. The performance that been specifically focused in this analysis is the improvement of the directivity and gain of the circular patch antenna design. Basically, the objective of this analysis is to compare the circular patch antenna of a single form with 1x2 antenna array formation. These antennas are designed with the proximity feeding technique. From the previous literature and findings, the optimization works of array arrangement have been proven will improve the directivity and gain performances. In this study, the array arrangement with proximity feeding technique of optimization work to improve the directivity and gain of a circular patch antenna has been explored. Comparison of a single and array of micro strip circular patch with proximity feeding technique as the FR-4 is the substrates with permittivity equal to 3.95 is presented. Based on the results, 1x2 array arrangements enhance the directivity and gain output compared to a single form circular patch antenna design. The directivity performance improves 28% and gain has been improved by 47% after optimization. The findings show that the array elements with proximity feeding technique design offer to improve and enhance the directivity and gain performances of an antenna.***

Keywords: ***Antenna array, gain, optimization.***

I. INTRODUCTION

Today, there are several optimization methods that have been studied by many researchers in order to improve and enhance the performances in micro strip patch antenna design. There are several points of performance enhancement of fundamental parameters of an antenna that studies and analyzed by researchers. For the micro strip patch antenna that suffers from limited gain characteristics, narrow bandwidth, and low in gain. According to [1], l these weak points in micro strip patch antenna has been improved by several methods which are fix with various shapes, halfway substrate expulsion method, utilizing Meta material spread, and exhibit arrangement procedure.

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Directivity is one of the parameters that focused on to be optimized. According to Balanis [2], directivity is the proportion of the radiation force in a provided guidance from the antenna to the radiation power found the middle value of overall headings. Directivity parameter is paired with the total antenna efficiency and gain. the gain of the antenna is firmly identified with the directivity while the total antenna effectiveness is utilized to consider losses at the receiver and inside the structure of the antenna.

According to the previous study and findings from researchers in the fields, regarding the optimization of directivity performance, referring to [3], this paper discussed the directivity enhancement techniques. As it stated that the directivity can be expanded by utilizing the micros trip antenna cluster structure yet this again build the size. Therefore the directivity of the micro strip antenna is expanded by somewhat growing the components of the fixed antenna and multilayer structure with verified dielectric. Another research study regarding the high directivity of the micro strip patch antenna. In this journal [4], a different Double Negative (DNG) been implemented to enhance the performance of a micro strip patch antenna. The outcomes indicate that this method has enhanced performance as far as directivity, gain, and radiation efficiency of the antenna. The directivity is improved from 6.878dBi to 7.184dBi. The efficiency of an antenna is amplified from 72% to 80.42%. The gain of the antenna is also enhanced from 5.454dB to 6.237dB. Next, in [5], this paper was examined on the directivity of micro strip fix antenna with twofold layer superstrate. Two dielectric superstrate layers, each a quarter wavelength in thickness and isolated by an air opening, are presented over the micro strip fix, isolated by another air distance. The parameters of these layers are utilized as key controllers of the directivity improvement. Gain enhancement has been discussed in [1] as they investigated the improvement of addition utilizing exhibit design and utilizing rectangular shape micro strip fix antenna.

The objectives of the study are to design a single circular shape patch antenna and 1x2 arrays circular shape patch antenna, simulates the design with CST software tools at the operational frequency of 2.4GHz and analyze the directivity and gain performance of both design. The effectiveness of the array configuration technique is the main focus of this analysis. The other performance-related such as return loss S_{11}, VSWR, Radiation efficiency and total efficiency of these antennas also been discussed.

II. RESEARCH METHODOLOGY

1. Identification of Project Requirement.

1.1 Proposed Antenna Design

In designing a micro strip patch antenna, four parts need to take into accounts which are the patch, the matching line or feeding line, the substrate and the grounding plane. For the patch, the proposed design is the circular shape. As discussed in [6-7], for this shape, the only one parameter which is the radius of the patch needs to be calculated. By hypothesis, the range of the radiation plane will influence the resonant frequency of the antenna structure. For the substrate, this is an important step in designing an antenna. Substrates need to be selected according to several requirements. Availability of the materials, application, Losses and most important point is the cost [8]. Thus, flame-resistance (FR4) substrate fulfills all the listed requirements. In this specific design, since the feeding technique that been use is the proximity feeds, this design required two layers of the FR4 substrates been sandwiched together with the feeding in between and grounding plane at the back.

1.2 Feeding Method

This paper is the continuity study from previous experiments that been discussed in [6] and [7]. In [6], the analysis on five feeding technique on the circular patch antenna has been discussed. From the findings, the proximity feeding technique shows the best performance among another feeding method. Thus, in this analysis, proximity feeding technique has been chosen to be implemented in both designs.

1.3 Array Configuration Technique

As mention earlier, the array configuration efficiently affects in designing high directivity, and high gains antenna. The high gain antenna is the requirement in designing an antenna for applications used in military and communications. High-directivity radio wires are utilized in changeless establishments, for example, satellite TV, remote back-haul, and so forth as they have to transmit and get data over long separates, in a specific course. [9].

2. Related Formula and Calculation

The higher the directivity, the more centered in the bar emanated by an antenna. A higher directivity likewise implies that the channel will travel further. An antenna that transmitted similarly well every which way would be omnidirectional and have a directivity of 1 (0 dB).

$$\text{Antenna Gain} = \text{Directivity} \times \text{Antenna Efficiency} \quad (1)$$

According to the Balanis [2], the gain is the product of directivity and efficiency. Where effectiveness represents the losses on the antennas, for example, producing deficiencies, surface covering losses, dielectric, obstruction, VSWR, or some other factor. In an antenna’s exhibit, a lot of numerous indistinguishable antennas which work all together radio wire, the directivity of the whole cluster are the multiplicative aggregate of the individual antenna's directivity work with a numerical explanation known as the display factor A F, which regularly relies upon the area, the period, and the excitation of every antenna component. The general directivity capacity is given by

$$D_{array}(\theta, \phi) = A\,F \times D(\theta, \phi) \quad (2)$$

Where, D (θ, ϕ) is the directivity of a solitary component. This single component term is in some cases referred to as the component design [10].

Design of Antennas

In this research, two types of design are presented. The first design is a single circular patch antenna with proximity feeding. The size of the antenna and all the parameters related are shown in Fig. 1.

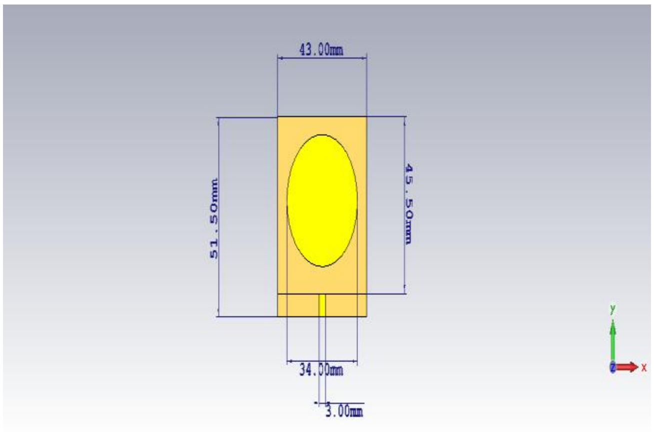

Fig. 1 Parameters of single circular patch design with proximity feeding

As Fig. 2, it shows the second design for this analysis which is the 1x2 array circular patch antenna with proximity feeding technique. All the parameter related as in Fig. 2. The configuration of both designs is a circular radiation patch as copper is the material placed on top of the FR4 substrate. This design requires two layers of substrates which are sandwiched together and the feeding line layered in between. Grounding plane is position at the back of the second substrate.

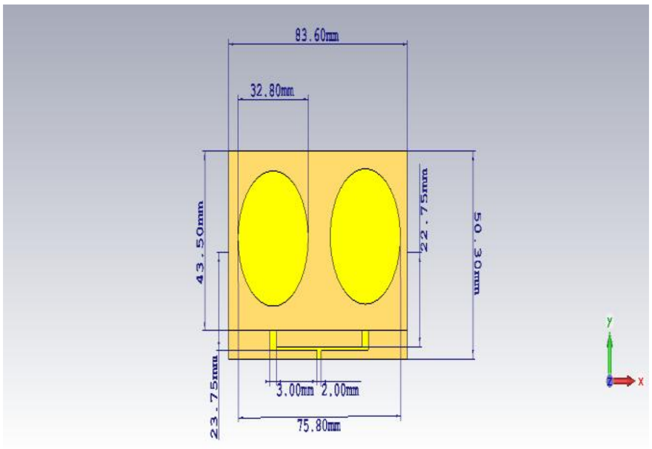

Fig. 2 1x 2 array circular patches with proximity feeding

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Table. 1 Parameters of the Antennas

Factors	Type	
	Single	1x2 Array
Parch radius, a	17	16.4
Substrate Width, W	43	83.6
Substrate Length, L_1	45.5	45.5
Substrate Length, L_2	51	51
Feed Width, Wf	3	3
Feed length, Lf	25.75	23.75

III. RESULTS AND DISCUSSIONS

Results

The results for a single circular patch antenna with proximity feeding shows in Fig. 3 to Fig. 7 respectively.

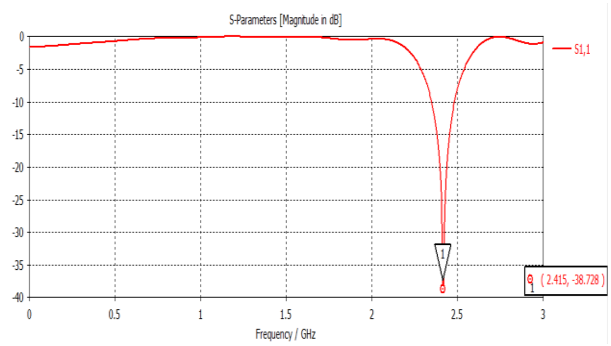


Fig. 3 Return loss S_{11} result of single element antenna

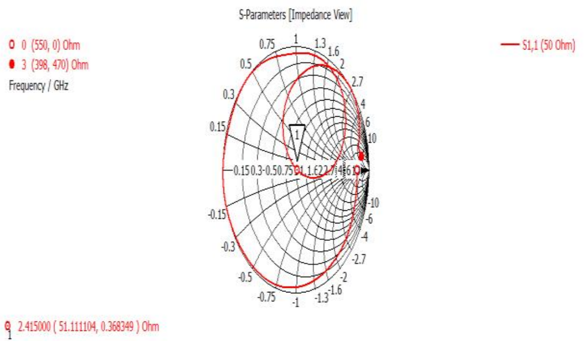
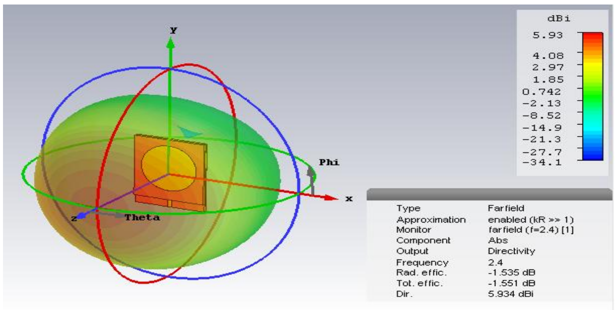


Fig. 4 Z Smith chart for S_{11} result of single element antenna



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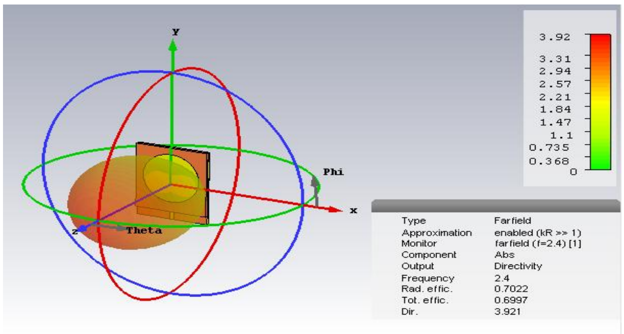
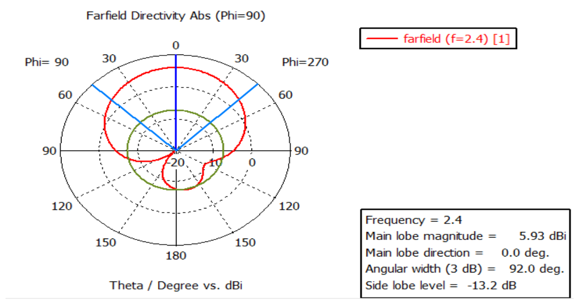


(b)

Fig. 5 (a) Farfield for directivity result of single element antenna (b) Farfield for directivity results in a linear scaling of a single element antenna



(a)

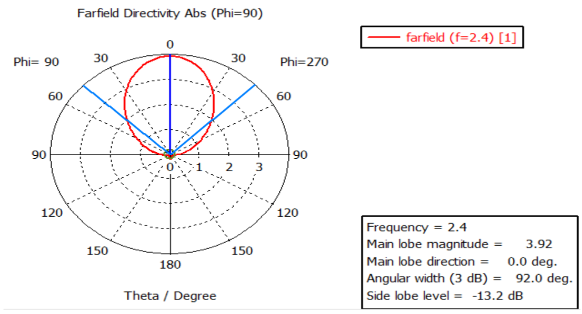


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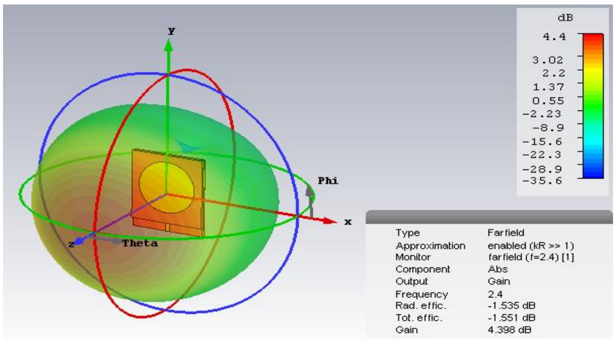
Fig. 6 (a) Farfields for directivity results in the polar form of a single element antenna (b) Farfields for directivity results in linear scaling in polar form of a single element antenna



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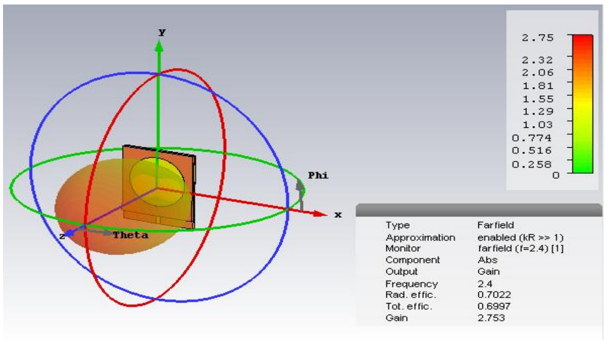


(b)

Fig. 7 (a) Farfields for the gain result of single element antenna (b) Farfields for gain result in a linear scaling of a single element antenna

The results for the 1x2 array circular patch antenna with proximity feeding shows in Fig. 8 to Fig. 12 respectively.

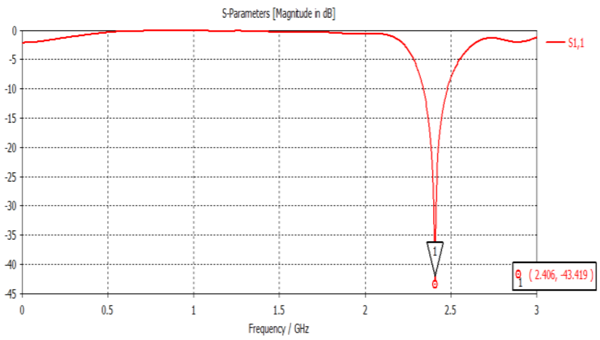


Fig. 8 Return loss S_{11} result for the 1x2 array element

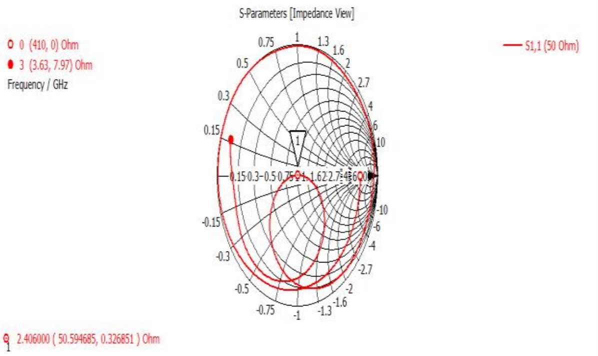
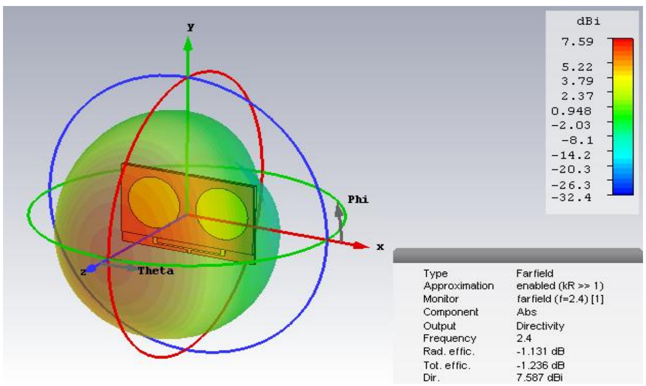


Fig. 9 Return loss in Z Smith chart for the 1x2 array element



(a)

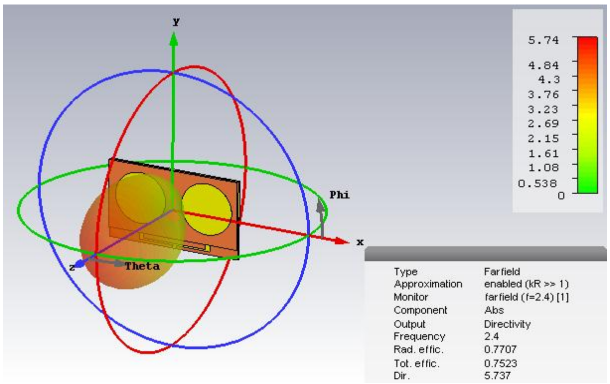


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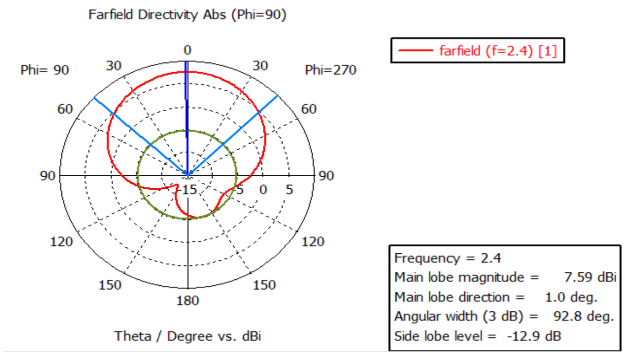
Fig. 10 (a) Farfields for directivity result for the 1x2 array element (b) Fig. 14: Farfields for directivity in linear scaling for the 1x2 array element



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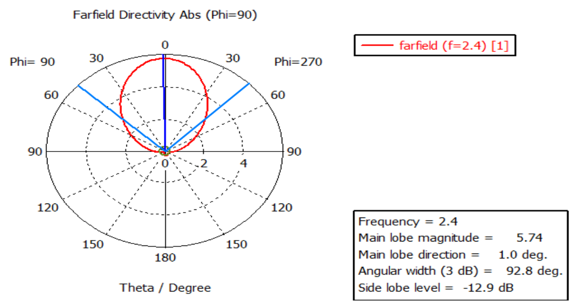
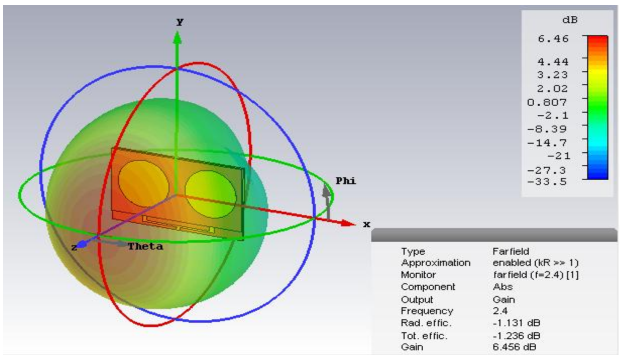


(b)

Fig. 11 (a) Directivity's result in polar form for the 1x2 array element (b) Directivity's result in linear scaling for the 1x2 array element



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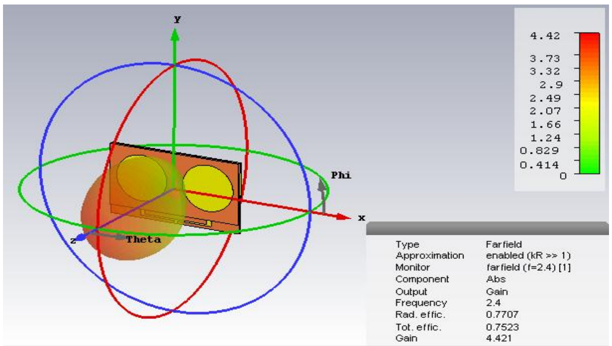


(b)

Fig. 12 (a) Farfields for gain result in linear scaling in polar form of 1x2 array element antennas (b) Farfields for gain result in linear scaling in polar form of 1x2 array element antenna

IV. DISCUSSION

Fig. 13 shows the comparison of return loss performance for both designs. As the radius patch is reduced from 17mm to 16.4mm, the resonance frequency affected which resulting it's to be nearer to the operating frequency at 2.4GHz. A single antenna design gives -38.728dB at 2.415GHz.

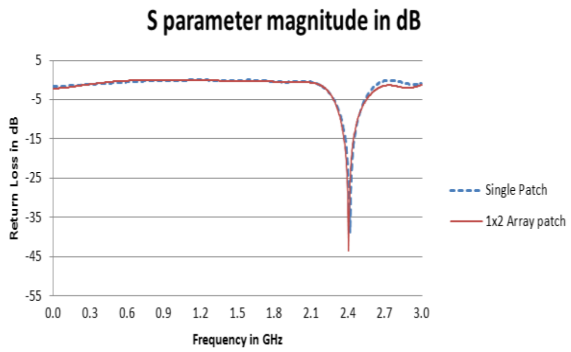
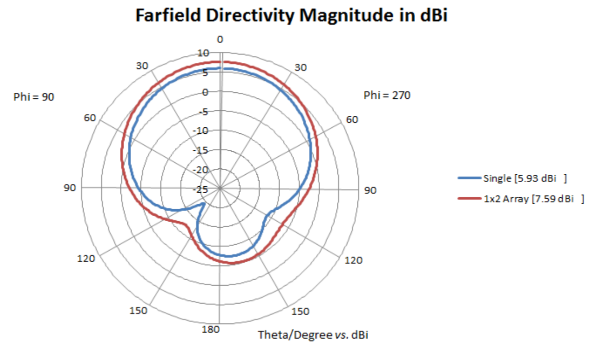


Fig. 13 Comparison of S_{11} performance between the single antenna and 1x2 array antenna designs

On the other hands, for 1x2 arrays, the return loss performance gives -43.419dB at 2.406GHz. For directivity and gain performances of both designs, Fig. 14 shows the comparison of the performances.



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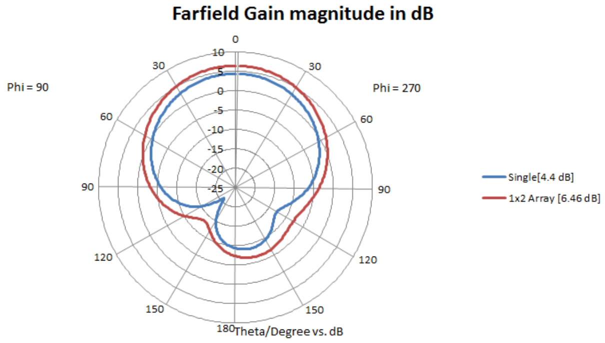

(b)

Fig. 14 Comparison of performances between the single antenna and 1x2 array antenna design in polar form (a) Performance of Directivity magnitude in dBi. (b) Performance of Gain magnitude in dB

The performance values of the antennas obtained from the simulation analysis were shown in Table 2. The results tabulated the directivity and gain value for each type of antenna design. Others performances such as VSWR, radiation efficiency, total efficiency, and impedance matching also includes and tabulates in Table 2. The percentages of improvement between both designs were calculated and recorded in Table 2.The antennas were designed and analyzed using CST microwave studio software.

Table. 2 Simulation analysis results

Variable parameters performances	Element types		% of improvement
	Single	1x2 array	
Directivity (dBi)	5.93	7.59	*28*
Gain (dB)	4.4	6.46	*47*
Centred Frequency (GHz)	2.415	2.406	*0.4*
Return loss S_{11} (dB)	-38.728	-43.419	*12*
Radiation Efficiency (%)	70.22	77.07	*10*
Total Efficiency (%)	69.97	75.23	*8*
VSWR	1.0234	1.0136	*1*
Impedance matching (Ω)	51.11 + j0.37	50.59 + j0.33	

In table 2, it is been approved that all the parameters result related to the analysis are improved and optimized. The change of radius also gives much impact on the return loss s11 performances. The enhancement of directivity, efficiency, and gain performance are more affected by the array configuration technique.

The directivity performance of 1x2 array antennas design improves 28% compared to single antenna design. On the other hands, gain performance
improves almost 47% with array configuration design. A single circular patch antenna and 1x2 arrays circular patch antenna, the z smith chart shows the results very close to 50Ω of impedance matching which is 51.11 + j0.37 and 50.59 + j0.33 respectively.
The real part of the impedance coordinating exceptionally near to 50Ω and this proves that maximum transferred of power to the radiated patch antenna. On the other hands, for the imaginary part of the impedance, the values show from z smith chart is near to zero. An antenna with genuine info impedance (zero imaginary part) is said to be resonant. [11]. this proves that both antennas are working as expected.

V. CONCLUSIONS

This study is helpful in enhancing the directivity and gains of a circular patch antenna with proximity feeding where the objective is to optimize the performances have been achieved. Based on the results, the performances of directivity and gains has been optimized and improved by using array configuration approach. The results also show that:

- By using array configuration, the radiation patch circular's radius, *a* is reduced from 17mm to 16.4mm. 1x2 array elements design manage to reduce the size of patch compare to single elements around 3.5%.
- Even the patch size is reduced since the array configuration is the identical multiplication of patch antenna elements, the total size of the antenna will be increased up to 50% from the single element. For this particular design, a single circular patch antenna has 43mm x 51.5mm in size, meanwhile for 1x2 circular patch arrays antennas is 83.6mmx50.3mm in size.
- Overall, all the results of performances related in this analysis are affected by the array configuration of the optimization method.

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