International Journal of Latest Research in Engineering and Technology (IJLRET)
ISSN: 2454-5031
www.ijlret.com || Volume 03 - Issue 09 || September 2017 || PP. 102-107

Improvisation of the Efficiency of Circular Micro strip Patch Antennas using Slots and Substrate Thickness Variation

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Abstract: Wearable antennas are commercially widely utilized due to its remarkable contribution towards navigation and federal safety innovation, along with its portability and efficiency advantages. Circular micro strip patch antennas, although beneficial in terms of flexibility and good radiation control, are also known for their bandwidth deficiencies, which require a longer period of transient analysis. Additionally, this tends to produce greater return losses. Hence, this paper leans towards improvising the efficiency of the Circular Micro strip patch antenna, operating at 2.4 GHz frequency, on a high-pressure fiberglass laminate (G-10) lossy substrate. This is addressed through the introduction of a circular centre slot, and the variation of the levels of the substrate's thickness. Optimum results suggest a -24 dB return loss for the slotted Circular Micro strip Patch Antenna, while a -15.9 dB return loss is achieved with a regular, non-slotted Circular Patch Antenna. Simulation and results were gathered through CST Microwave Studio.

Keywords: Wearable Antenna, Circular Micro strip Antenna, 2.4 GHz, G-10 Substrate

I. INTRODUCTION

Antennas are one of the fundamental parts of the electrical system, given their importantpart in converting electronic signals into electromagnetic waves [1]. Although a significant variation of shapes and sizes exist for antennas, the importance of wearable antennas has been eminent due to the increasing popularity of wireless, compact devices in the past few years, aiming to provide an easier, more efficient lifestyle [2]. Portability aside, wearable antennas also providesbenefitsin the field of safety and navigation, with great flexibility and lower production costs [2,3].

Micro strip Patch antennas are wearable antennas which are usually made up of three parts, inclusive of the ground, a dielectric substrate, and the patch. Although these antennas are available in various shapes [1], circular antennas are found to be one of the most usual types of patch antennas, due to its tremendous flexibility [4], which in turn, also provides an excellent radiation control [4]. Easy implementation is also guaranteed, as antenna designers only need to adjust the radius of the circular patch antenna whilst trying to find the optimum design [4,5].However, this particular shape of patch antenna is also exposed to bandwidth deficiencies, which causes a longer transient analysis period and implementation time, and also leads to higher return loss (S11) readings [6].

To account for its deficiencies, this research aims to centralize on improving the efficiency of the Circular micro strip patch antenna through the introduction of a circular centre slot, and the variation of the thickness of the substrate. An operating frequency of 2.4 GHz is used due to its advantages in terms of suitability for wider ranges, and its ability to pass through obstacles such as walls [7]. A high-pressure fiberglass laminate (G-10), with a dielectric constant of 4.8, is then utilized as the main substrate. However, the patch itself is simulated as a perfect electric conductor (PEC) material on CST Microwave Studio. The feeding method used is coaxial probing, wherein the radio frequency power is directly fed into the patch through the probe feed [8].

Comparison criteria include gathering simulation results from the measurement of the performance of both the substrate thickness varied antenna and the slotted circular patch antennas, against the regular circular patch antenna in terms of the return loss (S11-dB), VSWR, and the radiation pattern. However, it is important to mention that this paper intends its focus on improvising the efficiency of the Circular patch antenna in terms of transient analysis time and return loss reading for WLAN applications operating at 2.4 GHz. Hence, multiband applications remains to be out of the scope of this research.

II. PROPOSED METHODOLOGY

2.1 Calculation of the Design Parameters

Designing a Circular Patch Antenna starts with the calculation of the required design parameters, which would be utilized to simulate the antenna. Table 1 displays the series of formulas required for giving an initial approximation of the design parameters needed for simulating a Circular Micro strip patch antenna at a specified operating frequency [9-11].

Table 1: Design Parameter Formulas for Circular Micro strip Patch Antenna [11]

Parameter	**Symbol**	**Formula**
Extension Length	thickness	$\frac{\Delta L}{h} = 0.412\frac{\left(\varepsilon_{reff}+0.3\right)\left(\frac{W}{h}+0.264\right)}{\left(\varepsilon_{reff}-0.258\right)\left(\frac{W}{h}+0.8\right)}$
Radius	R	$a = \frac{F}{\left[1+\frac{2h}{\pi\varepsilon_r F}\left[l_n\left[\frac{\pi F}{2h}\right]+1.7726\right]\right]^{1/2}}$
Constant F	F	$F = \frac{8.791\times 10^9}{f_r\sqrt{\varepsilon_r}}$
Effective Radius	Re	$a_e = \frac{1.8412 v_o}{2\pi f_r\sqrt{\varepsilon_r}}$

The figure below shows the corresponding locations of the design parameters into the antenna. Note that a square substrate is used, which explains an equal length and width of the substrate [11].

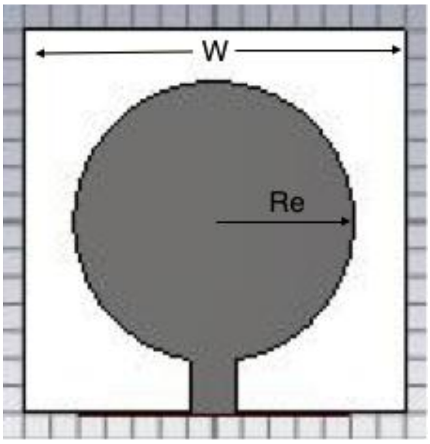

Figure 1: Circular Micro Strip Patch Antenna [11]

Once simulated, the results gathered will then be optimized and fine-tuned through the variation of the main parameter, the radius, through a trial and error fine-tuning method. The completion of these series of steps would result in an optimized antenna design, whose return loss is found exactly at the specified operating frequency.

2.2 Improvisation of Circular Micro strip Patch Antenna Efficiency

Following an initially optimized non-slotted Circular Patch Antenna, improvisation of the efficiency of the Circular Microstrip patch antenna is aimed. From this, two separate steps will be taken in parallel. On one hand, the thickness of the substrate will be varied at ranges around the calculated thickness value [12], while on the other hand; a circular slot will be introduced in the centre of the circular patch antenna [13-14]. These steps are taken in order to account for the bandwidth deficiencies of the original Circular patch antenna [6, 12-14]. However, since both variations would create disparities in the initial readings, these have to be re-optimized through a trial and error method until the return loss is again found at the specified operating frequency. The algorithm is summarized in the flowchart shown in Figure 2.

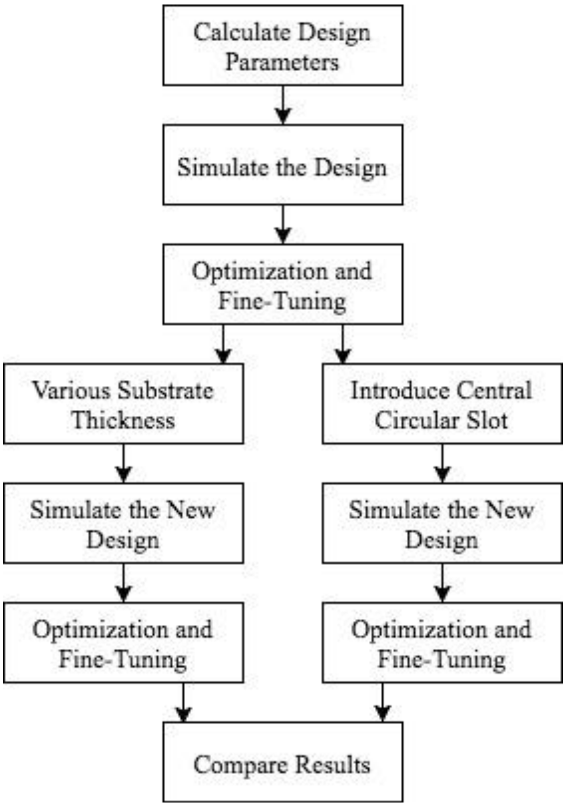

Figure 2: Circular Antenna Efficiency Improvisation Flowchart

III. RESULTS

3.1 Regular Circular Micro strip Patch Antenna Results

Following the traditional process of designing an antenna as discussed in Section 2, Table 2 summarizes the calculated design parameter values and its optimized version, which had been extracted subsequent to simulating the calculated values, which had resulted from a trial and error fine-tuning method. Throughout the experimental results, an operating frequency of 2.4 GHz is specified.

Table 2: Calculated versus Optimized Design Parameter Values

Parameter	**Symbol**	**Calculated Value (mm)**	**Optimized Value (mm)**
Extension Length	thickness	0.74	0.72
Ground Plane Width	Wg	60	70
Ground Plane Length	Lg	60	70
Effective Radius	Re	19.24	29.82
Feed Length	Lp	12.82	13.25
Feed Width	Wp	8.33	8.75
Substrate Thickness	S_t	2	2.82

Simulation of the optimized design parameters, all of which had been achieved through CST Microwave studio software [15], had resulted in a main lobe magnitude of the radiation pattern of 3.81 dBi at 29 degrees main lobe direction, and a return loss (S11) result of -15.9 dB at an operating frequency of 2.4 GHz. These results, along with the Voltage Standing Wave Ratio (VSWR) graph, can be observed graphically in the following figures.

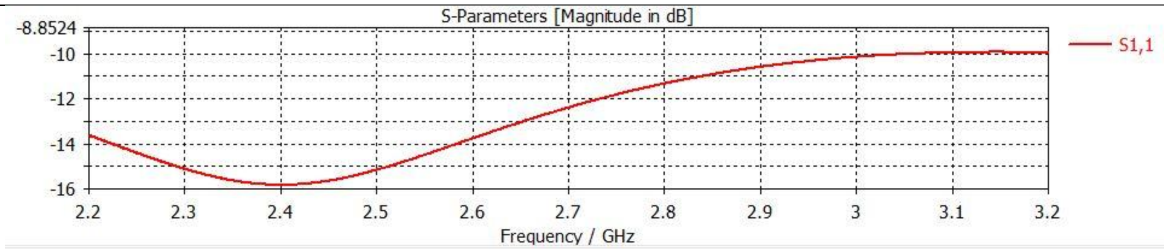

Figure 3: Return Loss Graph of Regular Non-slotted Circular Patch Antenna

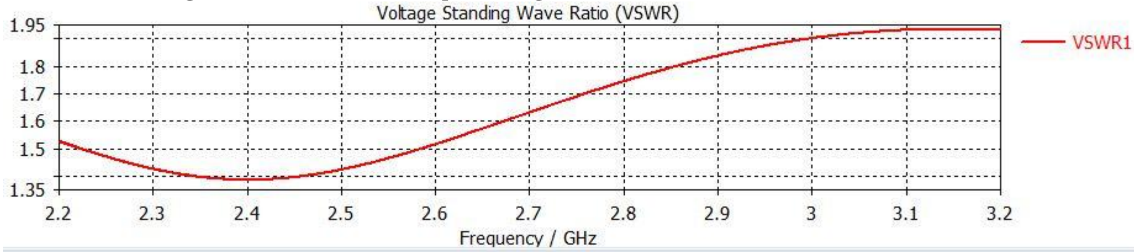

Figure 4: VSWR Graph of Regular Non-slotted Circular Patch Antenna

Figure 5: 2D Radiation Pattern of Regular Non-slotted Circular Patch Antenna

3.2 Slotted Circular Micro strip Patch Antenna Results

Once the results for the optimized, regular non-slotted Circular Micro strip Patch antenna had been acquired, a circular slot at the center of the circular patch antenna is introduced. The radius of the introduced slot is varied until the return loss is found at the same operating frequency as the specified 2.4 GHz. However, aside from the radius of the slot introduced, the rest of the design parameters remain the same as the optimized design parameters utilized for the regular, non-slotted circular patch antenna.

For the optimized values specified in Table 2, the radius of the central circular slot that would give the return loss at the exact specified value of the operating frequency is found to be 17.95 mm. The slotted circular antenna is given in Figure 6.

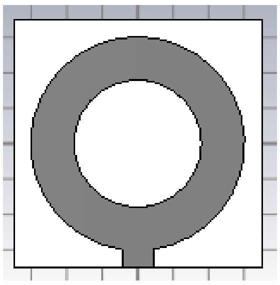

Figure 6: Slotted Circular Patch Antenna

Introducing the central circular slothelped increase the return loss (S11) value from the previous -15.9 dB value into a -24 dB return loss found at the same operating frequency of 2.4 GHz. Accordingly, the main lobe magnitude of the radiation pattern had increased to 4.47 dBi at 33 degrees direction, compared to the previous value of 3.81 dBi. Such improvements can be visualized from the following figures below.

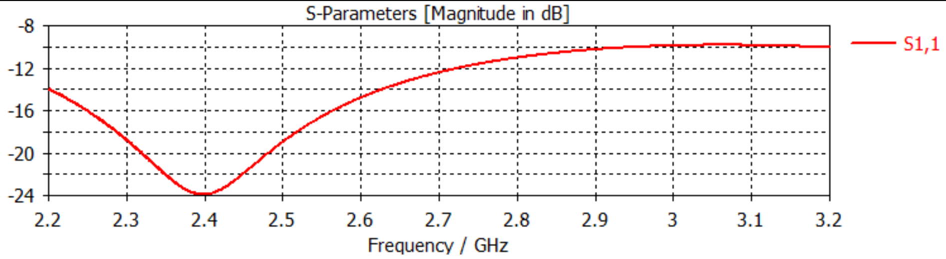

Figure 7: Return Loss Graph of Slotted Circular Patch Antenna

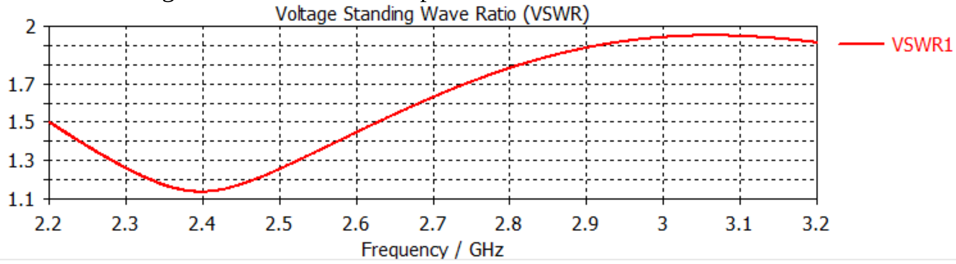

Figure 8: VSWR Graph of Slotted Circular Patch Antenna

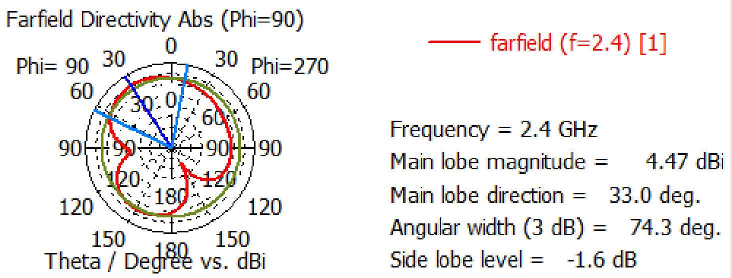

Figure 9: 2D Radiation Pattern of Slotted Circular Patch Antenna

3.3 Substrate Thickness Variation Results

In parallel to adding a central circular slot subsequent to obtaining the optimized non-slotted Circular Micro strip patch antenna, the effects of varying the substrate thickness on the return loss (S11) characteristic is also investigated. As previously mentioned in Table 2, the substrate thickness for the optimized non-slotted Circular patch antenna is found to be 2.82 mm. Hence, the effects of both higher and lower thickness levels were examined, as summarized in Table 3.

Table 3: Effect of Substrate Thickness on the S11 and Operating Frequency

Substrate Thickness (mm)	S11 return loss	Operating Frequency
2.52	-16 dB	2.43 GHz
2.82	-15.9 dB	2.4 GHz
3.25	-14.8 dB	2.38 GHz
3.45	-15.2 dB	2.37 GHz
3.7	-16 dB	2.35 GHz

As observed, a minimal difference is observed with the return loss (S11) value whilst varying the substrate thickness. However, it can be observed that the operating frequency wherein the return loss value is found shifts lower with a thicker substrate. Accordingly, it slightly shifts to a higher operating frequency when using a thinner substrate. Hence, it can be deduced that the variation of the substrate thickness has a slight negligible effect on the S11 return loss, but is inversely proportional to the corresponding operating frequency. Therefore, substrate thickness variation can be a useful parameter when fine-tuning an antenna design to fit a specific operating frequency.

IV. CONCLUSION

In conclusion, it has been extrapolated that innovation directed towards improvisation of the performance of the Micro strip patch antennas remains advantageous for the society due to its benefits in terms of public safety and navigation [1,2], as well as the sudden rise in popularity of compact, wearable devices [1-3].Despite the flexibility and good radiation control advantages of the Circular Micro strip patch antenna, it is also characterized by bandwidth deficiencies leading to a longer transient analysis period and higher return losses [4-6]. Hence, improvement of the return loss and overall efficiency is aimed through the introduction of a central circular antenna slot [13-14]. Additionally, the effects of varying the substrate thickness are also investigated [12]. A coaxial probe fed Circular Micro strip patch antenna with an operating frequency of 2.4 GHz, and uses high pressure fiberglass laminate (G-10) as a substrate, is the subject to the investigation.

After gathering the results via CST Microwave studio [15], and the design parameter formulas [9-11], an optimum performance level of -15.9 dB return loss and 3.88 dBi main lobe magnitude for the radiation pattern were achieved through a regular, non-slotted Circular Micro patch strip antenna with a G-10 substrate. However, adding the circular central slot had helped improve the return loss level to -24 dB, and the main lobe magnitude for the radiation pattern to around 4.47 dBi. This is strengthened by the fact that adding a slot in the middle of the antenna increases the range of reach or that specific antenna [13]. However, after investigating on the variation of the substrate thickness, it has been deduced that although it negligibly affects the return loss level, it shifts the frequency in an inverse relationship. Hence, its usability lies within fine-tuning an antenna design to find its optimum form.

Nonetheless, further innovation and future work will be extended towards investigating the effects of other shapes of antenna slots, and determining the optimum shape that would yield the best results. Additionally, improvisation on the efficiency of multiband antennas can also be explored.

References

[1]. M.Ayyapan, B.Manoj, S.Rodrigues, "Low Return Loss Circular Microstrip Patch Antenna at 5.8 GHz for Wide-band Applications", *International Conference on Electrical, Electronics, and Optimization Techniques (ICEEOT)*, 2016, pp. 3023-3026.

[2]. J.M. Rathod , "Comparative study of microstrip patch antenna for wireless communication application", *International Journal of Innovation, Management and Technology*, vol.1, no.2, 2010, pp. 194-197.

[3]. N. H. M. Rais, P. J. Soh, F. Malek, S. Ahmad, N. B. M. Hashim and P. S. Hall, "A review of wearable antenna," *2009 Loughborough Antennas & Propagation Conference*, Loughborough, 2009, pp. 225-228.

[4]. M.T. Huque, M. Chowdhury, M.K. Hosain, M.S. Alam,"Performance and Analysis of corporate feed rectangular patch element and circular patch element 4x2 microstrip array antennas", *International Journal of Advanced Computer Science & Applications*, 2011, vol.2, no.7.

[5]. C.A. Balanis, "Antenna theory: Analysis and design", 2005, vol. 1.

[6]. A.H.A. Yawer, A.A.A. Mohammed, "Bandwidth Enhancement of Circular Microstrip Antennas", *ARPN, Journal of Engineering and Applied Sciences*, 2010, vol. 5, no.1, pp. 6-14.

[7]. M. Klein, "What's the Difference between 2.4 and 5 GHz Wi-fi", How-To Geek, LLC, 2017.

[8]. A. Majumder, "Rectangular Microstrip Patch Antenna using Coaxial Probe Feeding technique to Operate in S-band", *International Journal of Engineering Trends and technology*, 2013, vol. 4, issue 4, pp. 1206-1210.

[9]. A.M. Ramly, N.A. Malek, S.Y. Mohamad, M.A. Sukor, "Design of a Circular Patch Antenna for 3D Printing*", 2016 International Conference on Computer and Communication Engineering*, IEEE, 2016, pp. 406-408

[10]. M. Ayyappan, B. Manoj, S. Rodrigues, "Low Return Loss Circular Microstrip Patch Antenna at 5.8 GHz for Wide-band Applications", *International Conference on Electrical, Electronics, and Optimization Techniques (ICEEOT)*, 2016, IEEE, pp. 3023-3026

[11]. A. Copiaco, M.F. Malek, N. Abdulaziz, O. Al Khatib, "A Comparison between the Rectangular and the Circular Microstrip Patch Antennas operating at 2.4 GHz", *The International Conference on Electrical and Computing Technologies and Applications (ICECTA),* Submitted for Publication, 2017.

[12]. H.W. Cho, T.Y. Kim, and B.G. Kim, "Effect of Substrate Thickness on the Radiation Characteristics of Inductor-loaded Patch Antenna", *International Symposium on Antennas and Propagation (ISAP)*, 2010.

[13]. M. Ayyappan, B. Manoj, S. Rodrigues, "Low Return Loss Circular Microstrip Patch Antenna at 5.8 GHz for Wide-band Applications", *International Conference on Electrical, Electronics, and Optimization Techniques (ICEEOT)*, 2016, IEEE, pp. 3023-3026

[14]. M. Karmugil, K. Anusudha, "Design of Circular Microstrip Patch Antenna for Ultra Wide Band Applications", *International Conference on Control, Instrumentation, Communication, and Computational Technologies (ICCICCT)*, 2016, IEEE, pp. 304-308

[15]. CST Microwave Studio (2017), Computer Simulation Technology, Accessible at: https://www.cst.com/products/cstmws