High Gain Semi-circular Patch Antenna Array Resonating in WLAN Band for Wireless Power Transmission

Chandrika Bhatnagar[1], Ved Prakash[2], Sonal Dahiya[2]

[1]M.Tech Scholar, Amity University Haryana, Gurgaon, India
[2]Assistant Professor, Amity University Haryana, Gurgaon, India

---

Abstract - *The paper presents a 1×3 semicircular patch antenna array with enhanced gain for WLAN applications. A bilayer circular patch antenna with U and half U shaped slots is optimized for high gain and then incorporated in a 1×3 array. The bilayer patch antenna has a gain around 6.50dB. When incorporated in the array the gain is enhanced to around 7dB. The coaxial feed is used to excite the antenna. HFSS is used for the simulation.*

***Keywords**: Antenna, Antenna array, WPT- Wireless Power Transmission, HFSS-High Frequency Structure Simulator*

1. INTRODUCTION

With the world getting more and more dependent on electronic gadgets, wireless technology is gaining the spotlight. It has become a necessity for the researchers to look for alternatives to wires. The technology called Wireless Power Transmission has been in the limelight since long but has gained more importance than ever because of these new trends.

Antennas play a significant role in WPT technology. Antennas can be optimized to get a better gain performance. Higher the directivity higher the coverage area [1]. An array of antennas can help achieve even higher coverage area. Microstrip patch antennas are very useful for short-range power transmission. They are low in cost, are mechanically rugged, light weight, have low profile and are easy to fabricate. These attributes make them quite popular and appropriate for many applications such as aircraft, spacecraft, satellite applications and commercial applications like mobile radio and wireless communication [2]. Patch antennas have some limitations too viz. low efficiency, low power, high Q (sometimes in excess of 100), poor polarization purity, poor scan performance, spurious feed radiation and very narrow frequency bandwidth [2]. The bandwidth of patch antenna can be enhanced by increasing the thickness of the substrate and by stacking. Stacking also leads to dual band characteristics [3,4]. The U slot enhances the bandwidth and makes the patch compact [5].

It has been found that introduction of reactive elements like stubs, shorting pins and slots in the patch antenna introduces dual band characteristics in the antenna [6].

In the proposed design the aforementioned techniques namely stacking and increasing substrate thickness have been practiced to have a broader bandwidth. Parametric study has been done by modifying the radius of the semicircular patch and the coaxial feed point. It has been observed that modifying the radius modifies the resonant frequency. The feed point location affects the antenna gain and return loss. When the feed point was shifted closer to the centre of the patch, the return loss came out to be higher. Same observation was made when the feed point was shifted farther from the centre of the patch. A particular location on the x-axis resulted in the best return loss vs frequency plot. Various designs were produced to obtain a higher gain antenna and increased bandwidth in comparison with an ordinary patch antenna.

2. ANTENNA DESIGN

The patch antenna design presented in this paper in intended for a high gain and a high bandwidth. Various methods have been studied to achieve the aforementioned characteristics. Two techniques namely stacking and cutting out slots have been used in the designs.

2.1. Bilayer Circular Patch Antenna Design

The proposed design consists of two layers of substrate of same material of different thicknesses. The material chosen for the substrate is Rogers RT/duroid (tm) which has a permittivity, ε_r, of 2.2 and a loss tangent of 0.0009. The first layer of substrate sits on the ground and has a uniform thickness of 6mm [7]. The semicircular patch sits on the grounded substrate with half-U shaped slots cut through it. The second layer of substrate has a thickness of 5mm [7]. The circular patch which makes the second patch is installed with U shaped slots and is seated on the second layer of the substrate. Coaxial feeding technique has been preferred as it has less spurious radiations [8]. The dimensions of the slot and the feed location has been shown in Figure 1. The figure also shows the top view of the proposed design. The feed location is shown by the coordinates x_o, y_o. The side view of the design is shown in Figure 2. Table I shows the design parameters.

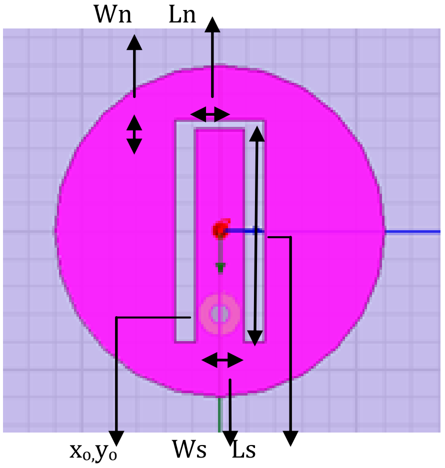

Figure 1: Dimensions of slot

Table I: Design parameters of bilayer circular patch antenna

Patch radius	9mm
Feed location(x,y,z)	6,0,0
Slot length (Ls)	16mm
Slot width (Ws)	1.5mm
Notch length (Ln)	1.5mm
Notch width (Wn)	0.65mm
Thickness of grounded substrate	6mm
Thichness of second layer of substrate	5mm

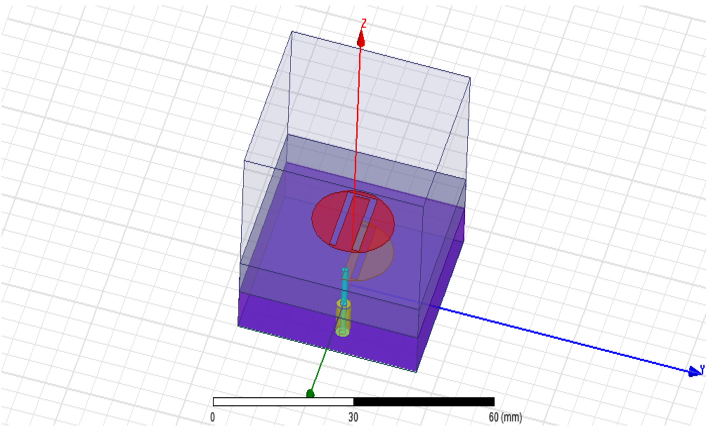

Figure 2: Side view of the design

2.2. Discussion

The feed pints were shifted and the best results were found at the feed point x_o,y_o,z_o=6,0,0. The return loss value, that came out to be -14.3696dB, was observed to be the most acceptable when the feed was provided at this location. This also suggests that there is fine matching at the frequency below -10dB region. The antenna is found to resonate at the frequency 5.6600GHz. The bandwidth of the antenna comes out to be high i.e around 190MHz. The return loss vs frequency plot is shown in Figure 3. An increase in the patch radius resulted in a decrease in the resonant frequency. The patch with a radius equal to 9mm gave the best results in terms of gain and return loss. The gain of the proposed design comes out to be around 7dB. The radiation pattern is shown in Figure 4.

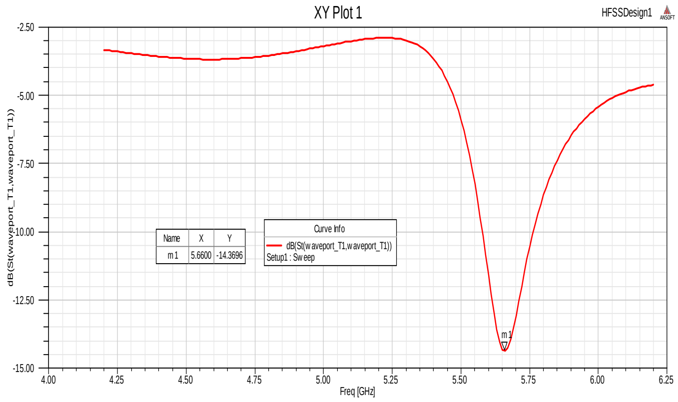

Figure 3: Return loss vs frequency plot

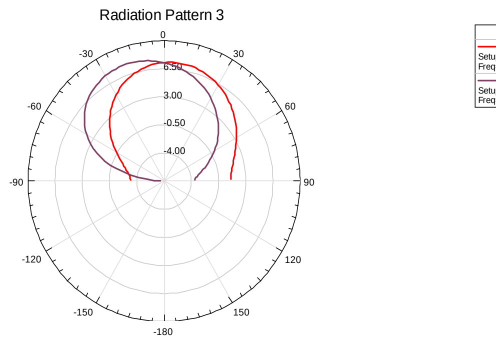

Figure 4: Radiation pattern of the proposed design

2.3. The Semicircular Patch Antenna Array

This design was incorporated in a 1×3 array in which three semicircular patches were embedded on the grounded substrate with a distance of 6mm between the patches. The substrate material was chosen as Rogers RT/duroid 5880 (tm). The distance between the patches was 6mm. The feed was provided to the patch at the centre. A half U shaped slot was cut through the semicircular patch. The dimensions of the patch and the slots are given in Table II. The design of the array is shown in Figure 5.

Table II. Dimensions for 1×3 circular patch antenna array design

Patch radius	9 mm
Feed location (x,y,z)	6,0,0
Length of the slot	16 mm
Width of the slot	1.5 mm
Length of the notch	1.5 mm
Width of the notch	0.65 mm
Thickness of grounded substrate	6 mm

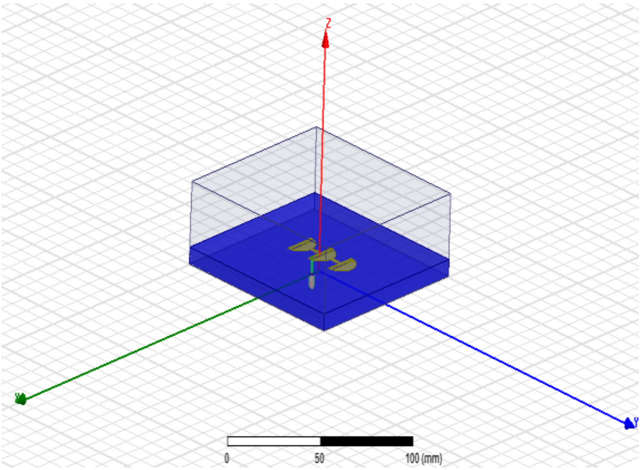

Figure 5: Side view of the design

2.4. Discussion

The semicircular patch antenna array design is based on the design of the bilayer patch antenna with U and half U shaped slots as the antenna design gave a high gain. The array shows good return loss vs frequency characteristics and this suggests that there is good matching at the frequency point below -10dB. The S_{11} characteristics show that the return loss is -20.7676dB at the frequency 4.900GHz. The bandwidth of the array is higher which is desirable for WLAN applications. The return loss vs frequency plot also suggests that the array is a dual band antenna. The return loss vs frequency plot for the array is shown in Figure 9. The antenna shows dual band characteristics as the plot shows a good matching at frequency point 6.300GHz also below -10dB. A value of gain slightly above 7.50 dB in the direction of -30 to 0 degrees and that of 7.20 dB in the direction of 0 degrees is observed for the array design. Figure 10 shows the radiation pattern for the design. There's an increment in the gain of the array as compared to the bilayer patch design discussed above. The
The array contains semicircular patches with half U shaped slots which also results in the reduction in the antenna size.

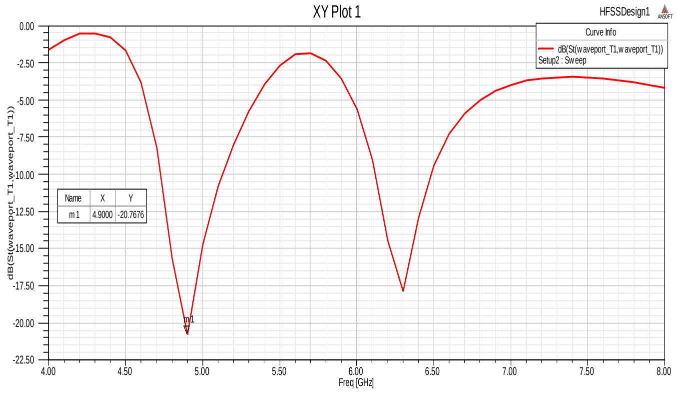

Figure 9: Return loss vs frequency plot for the array

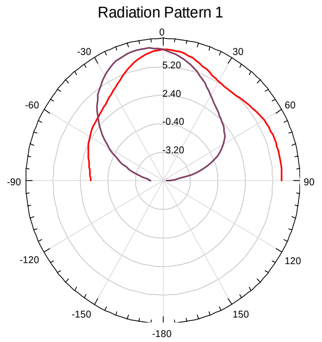

Figure 10: Radiation pattern for the array

3. COMPARISION OF SIMULATION RESULTS

The results show that the semicircular patch antenna array has a gain slightly higher than the bilayer circular patch antenna itself. The array also gives a better matching at 4.9GHz below -10 dB as the return loss value is lower i.e -20.7676 dB. The bandwidth of the array comes out to be high i.e. approximately 400MHz. Also the array is a dual band antenna as it gives good matching below -10dB at two different frequencies. Table 3 shows the comparison of results of the bilayer circular patch antenna design and the semicircular patch antenna array.

Table 3: Comparison of results

Parameter	Bilayer Circular Patch Antenna	Semicircular Patch Antenna Array
Gain	~7dB	>7dB
Return Loss	-14.3696dB	-20.7676dB
Bandwidth	~190MHz	~400MHz

The table suggests that the model, incorporated in an array, can result in higher gain in WLAN band. When a comparison is made between the two designs, it is found that the array can help achieve higher directivity and hence coverage area for wireless transmission of power.

4. CONCLUSION AND FUTURE SCOPE

The bilayer circular patch antenna shows a high gain of around 7dB which shows that the antenna has a higher coverage area. When incorporated in the 1×3 array the gain is slightly increased. The bandwidth of the semicircular patch antenna array is higher. The array can be used to achieve a higher range of transmission of power. As gain is directly related with coverage distance, more radiating elements can be incorporated in the array to have higher gain and hence coverage distance. A series of such arrays can further increase this range. This design is very useful WLAN applications.

ACKNOWLEDGEMENT

I am indebted to my guides Mr Ved Prakash and Ms Sonal Dahiya for their assistance and kind help. And a special note of thanks to Ms. Shalini Shah, assistant professor at Amity University Noida, for her support in this work.

REFERENCES

[1] Pramod Dhande, “Antenna and its applications”, pp 66-78, DRDO Science Spectrum, March 2009
[2] C.A. Balanis, “Antenna Theory-analysis and design”, Third Edition, pp-769-775, A JOHN WILEY & SONS, INC., PUBLICATION, 2005
[3] Sappan, A., “A new broadband stacked two layered microstrip antenna,” IEEE Trans. Antennas Propag. Soc. Int. Symp. Dig., Vol. 22, 251–254, 1984.
[4] Chen, C. H., A. N. Tulintseff, and R. M. Sorbello, “Broadband two layer microstrip antenna,” IEEE Trans. Antennas Propag. Soc. Int. Symp. Dig., 270–273, 1984.
[5] Arvind Kumar and Mithilesh Kumar, “Gain Enhancement in A Novel Square Microstrip Patch Antenna Using Metallic Rings”,IEEE International Conference, 2014
[6] D. D Krishna, M Gopikrishna, C. K. Aanandan, P. Mohanan and K. Vasudevan, “Compact dual- band slot loaded circular microstrip antenna with a superstrate, ”Progress in Electromagnetic Research, Vol. 83, pp. 245-255, 2008.
[7] Amel Boufrioua, “Bilayer microstrip patch antenna loaded with U and half U-shaped slots”, IEEE, 978-1-4799-3824-7/14 2014
[8] J. J. Bahl and P. Bhartia, “Microstrip antennas,” Edited by M. A Dedham, Artech House, 1980.