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DESIGN AND SIMULATION OF 1X4 PATCH ANTENNA ARRAY FOR RECTENNA

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ABSTRACT

One of the methods to achieve wireless power reception is using electromagnetic radiation with rectenna. Rectenna is a combination of an antenna and rectifier. The antenna is used to receive RF/Microwave signal and the rectifier is used to convert the received RF/Microwave signal into DC signal. A 1X4 rectangular patch antenna array is proposed for receiving microwave signal for wireless power reception application. In this work, the antenna array is designed on a 0.254 mm thick Rogers 5880 substrate at 10 GHz frequency and the simulation is carried-out using ADS software. The corporate feed 1:4 power divider network is used to feed the signal from source to individual antenna element. The inter-element spacing of the array is 0.75λ.The antenna parameters such as return loss, gain, directivity, efficiency, polarization, half power beam width and 3D radiation pattern are obtained for single patch and 1X4 patch antenna array.

KEYWORDS: Patch Antenna, 1X4 Patch Antenna Array, Rectenna, Gain, HPBW.

1. INTRODUCTION

Nowadays, Wireless Power Reception (WPR) and Energy Harvesting (EH) are an emerging area of research due to enormous developments in wireless communication. WPR and EH are achieved using a rectenna which is a device to convert RF/Microwave power into DC power. A rectenna is a combination of an antenna and rectifier. Antenna is used to receive RF/Microwave signal and rectifier is used to convert the received RF/Microwave signal into DC signal. Lot of research is being done on the feasibility of powering mobile devices through the harvesting of RF/Microwave signal [1]- [6]. Figure of Merit (FoM) of the rectenna depends on the output DC power, the weight and size of the rectenna. Better value of FoM is achieved when the output power of the rectenna is high and size of the rectenna is low. The output power increases when the size of the antenna array increases. So, there is a tradeoff between output power and size of the rectenna. From antenna theory, the gain of the antenna is directly proportional to the received antenna power. So in this work, the comparison of gain and area of the antenna are carried out for the antenna array. A 1X4 rectangular patch antenna array is designed and simulated at 10 GHZ frequency for constructing X-band planar, low profile rectenna. The design parameters of single patch and 1X4 array are optimized using software. The antenna parameters such as return loss, gain, directivity, efficiency, polarization, half power beam width and 3D radiation pattern are obtained using the electromagnetic simulator software for antenna and array.

2. DESIGN AND SIMULATION

Table 1 Design Specification

Frequency	10 GHz
Substrate	Rogers 5880
Dielectric constant	2.2
Loss tangent	0.0004
Substrate height	0.254 mm
Conductor thickness	17 µm

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A 1X4 rectangular microtrip patch antenna array consists of four rectangular microstrip patch antenna. The design specifications of the antenna array are shown in Table.1. The antenna array is designed at 10 GHz frequency on a 0.254 mm thick Rogers 5880 substrate with a dielectric constant of 2.2.and loss tangent of 0.0004. The design and simulation of the antenna array is carried out using ADS software. Initially, a single patch is designed on the above mentioned substrate at 10 GHz frequency. The design section of single microstrip antenna consists of patch, quarter wave transformer and feedline. The length (L) and width(W) of the patch are calculated using equations (1) and (2). Quarter wave transformer is used to match the impedances of the antenna and feedline. The impedance of the quarter wave transformer (Z_1) is calculated using equation (3). A 50 Ω surface mount adapter connector is used to connect the feedline to the coaxial cable. The signal is fed from feedline to the patch through a matching network which is a quarter wave transformer. The impedance of the transmission lines are synthesized into physical parameters using line calculator option in the software. The geometry of the designed rectangular patch antenna is shown in Figure 1.

$$L = 0.49\frac{\lambda}{\sqrt{\varepsilon_r}} \quad (1)$$

$$W = \sqrt{\frac{90\frac{\varepsilon_r^2}{\varepsilon_r - 1}}{Z_A}}\, L \quad (2)$$

$$Z_1 = \sqrt{Z_o R_{in}} \quad (3)$$

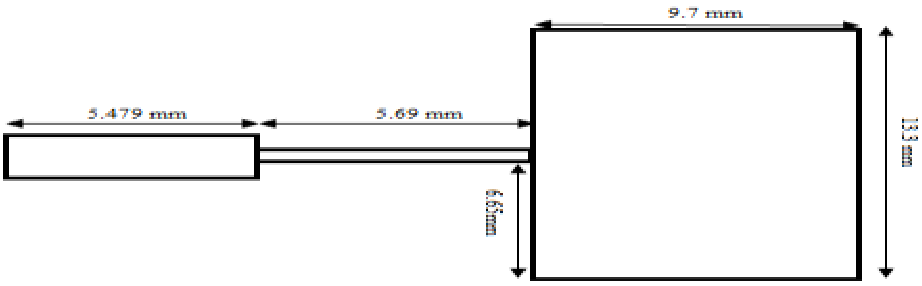

Figure 1 Geometry of Rectangular Patch Antenna

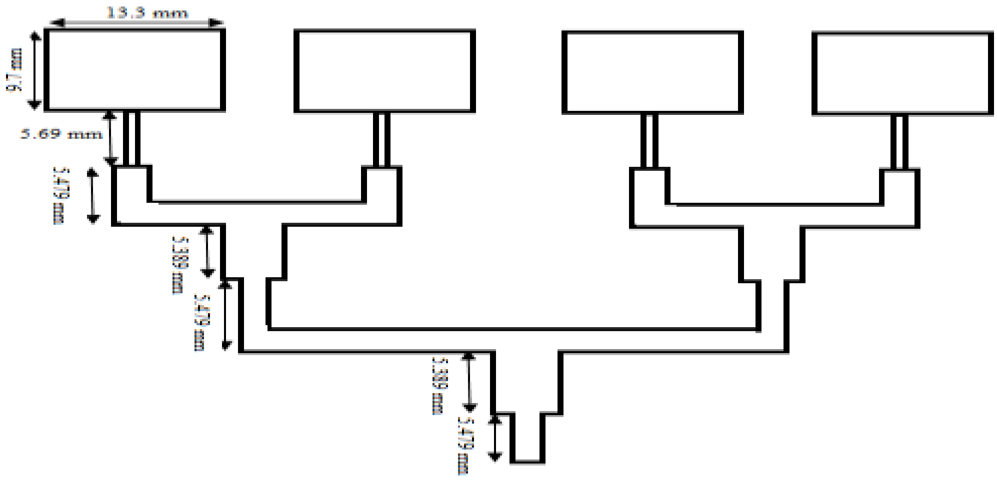

Figure 2 Geometry of 1X4 Rectangular Patch Antenna Array

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After designing single patch, 1X4 patch array is designed on the same substrate at 10 GHz frequency. The inter-element spacing of the array is 0.75λ. In this design, antenna elements are fed by 1:4 corporate feed power divider network. The corporate feed has a single input port and multiple feed lines in parallel which is terminated by patch antennas. The power is divided equally at each junction because the line distributions are symmetric. The impedance of the matching section is calculated using equation (3). The impedance of the transformer and feedline of the array are synthesized into physical dimensions using line calculator option in the software. The geometry of the designed 1X4 rectangular patch antenna array is shown in Figure 2.

3. RESULTS AND DISCUSSION

The return loss of a rectangular patch antenna is measured in the frequency range 9.5 GHz to 10.5 GHz which is shown in Figure 3. The return loss of −32 dB is obtained at 10 GHz designed frequency. The gain of 7.07 dB, directivity of 7.82 dB and efficiency of 84% are obtained for the designed antenna at 10 GHz frequency. The Co and Cross polarization of E-field are 7 dB and −34 dB respectively. Similarly, the Co and Cross polarization of H-field are 7 dB and -32 dB respectively. From the polarization level, it is observed that the antenna is linearly polarized. The 3-D radiation pattern of the patch antenna is plotted in Figure 4. There is no side lobe and beamwidth of the radiation pattern is wide in nature. The HPBW of the patch antenna is 73.95°.

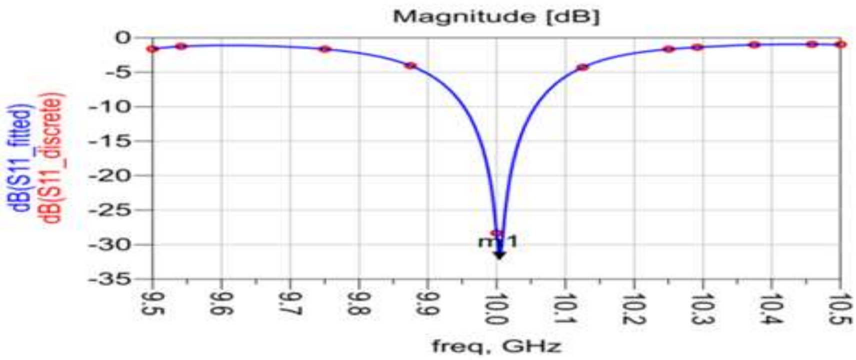

Figure 3 Return Loss of Patch Antenna

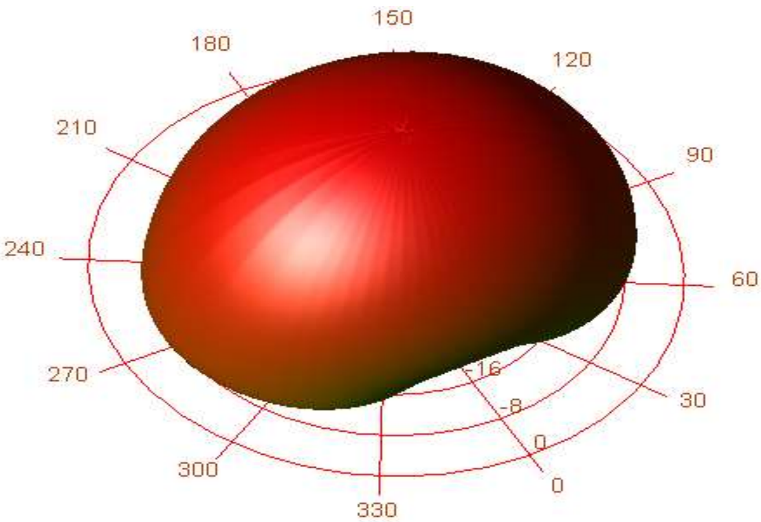

Figure 4 Radiation Pattern of Patch Antenna

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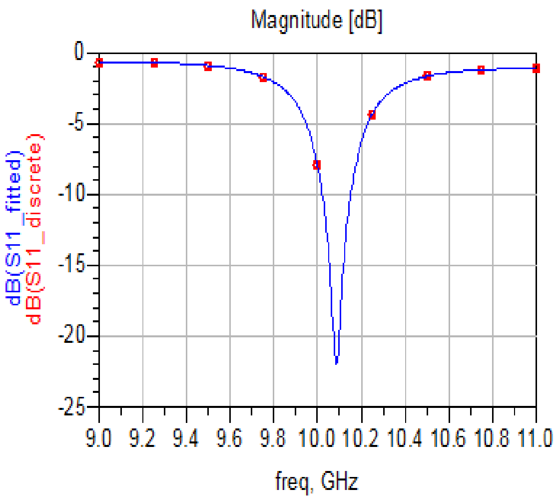

Figure 5 Return loss of 1X4 Patch Antenna Array

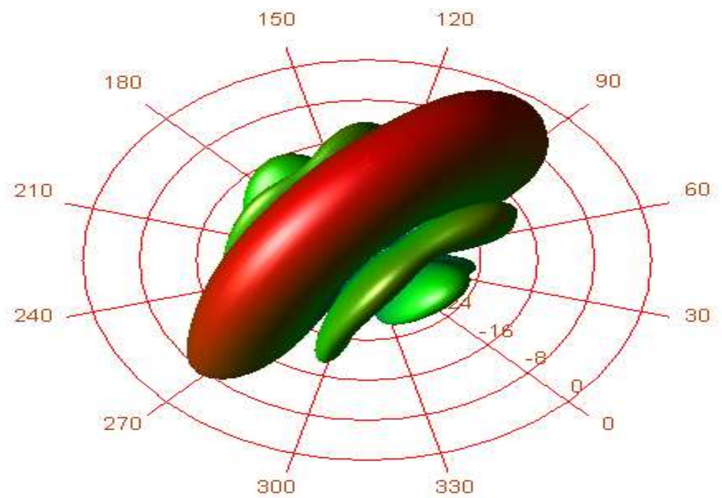

Figure 6 Radiation Pattern of 1X4 Patch Antenna Array

The return loss of a 1X4 rectangular patch antenna is measured in the frequency range 9 GHz to 11 GHz frequency which is shown in Figure 5. The return loss of –8 dB and –22 dB are obtained at 10 GHz and 10.1 GHz frequencies respectively. There is a shift in the frequency which is rectified by tuning the dimension of the patch. The gain of 11.39 dB, directivity of 12.76 dB and efficiency of 73% are obtained for the designed antenna at 10 GHz frequency. When compared to single patch, the efficiency of the array is decreased. This is because of usage of more number of transmission lines in the array which create loss. The Co and Cross polarization of E-field are 11 dB and –23 dB respectively. Similarly, the Co and Cross polarization of H-field are 11 dB and -14 dB respectively. From the polarization level, it is observed that the antenna is linearly polarized. The 3-D radiation pattern of the 1X4 patch antenna array is plotted in Figure 6. There are side lobes in the radiation pattern. The HPBW of the antenna array is 17.13°. From the simulation results, it is observed that the gain and beam width of the antenna array is increased and decreased respectively for the increase in elements in the array. The comparison of gain, HPBW and area are shown in Table.2. So the simulated antenna and array have satisfied the theoretical concept.

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Table 2 Comparison of Gain, HPBW and Area

Antenna	**Gain dB**	**HPBW Degree**	**Area mm^2**
Single	7.07	73.95	506
1X4	11.39	17.13	2025

4. CONCLUSION

Rectangular patch antenna and 1X4 patch antenna arrays are designed at 10 GHz frequency on a 0.254 mm thick Rogers substrate. The design and simulation of antenna and array are carried out using ADS software. The corporate feed 1:4 power divider network is used to feed the signal from source to individual antenna element. The antenna parameters such as return loss, gain, directivity, efficiency, HPBW, Co and cross polarization of E and H planes are obtained. Three dimensional radiation patterns of the antenna and array are plotted. The gain of the antenna is increased by increasing the number of antenna elements. The beam width of the antenna is decreased by increasing the number of antenna elements. The designed array may be suitable for constructing X-band planar, low profile rectenna and these rectenna is used for wireless power reception application. The array is designed using microstrip feed technique. So the proposed antenna array can be easily implemented by using standard fabrication techniques.

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